EVERYDAY
DECEMBER 1997

# PRACTICAL ELECTRONICS

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£2.65

FREE INSIDE!
GIANT PULL-OUT DATA CHART
FORMULAE & NOTES

## ACTIVE MICROPHONE
A simple circuit to increase sensitivity

## MINI ORGAN
An unusual, inexpensive analogue design

## SAFE & SOUND
Alarm deterrent for PIR security lights

## TEACH-IN '98
Part 2: Capacitors and Inductors

Index for Volume 26

THE No.1 MAGAZINE FOR ELECTRONICS TECHNOLOGY & COMPUTER PROJECTS

Special Feature
## ALTERNATIVE and FUTURE TECHNOLOGIES

## WIND GENERATORS 380 WATT

1 14 metre dia blades, carbon matrix blades, 3 year warranty, 12vdc output, 24v version available, control electronics included, brushless neodymium cubic curve alternator, only two moving parts, maintenance free, simple roof top installation, start up speed 7mph, max output (30mph) 380w £499 ref AIR1

## PLANS

**PORTABLE X RAY MACHINE PLANS** Easy to construct plans on a simple and cheap way to build a home X-ray machine! Effective device, X-ray sealed assemblies can be used for expenmental purposes Not a toy or for minors! £6/set Ref F/XP1

**TELEKINETIC ENHANCER PLANS** Mystify and amaze your friends by creating motion with no known apparent means or cause Uses no electrical or mechanical connections, no special gimmicks yet produces positive motion and effect Excellent for science projects, magic shows, party demonstrations or serious research & development of this strange and amazing phychic phenomenon £4/set Ref F/TKE1

**ELECTRONIC HYPNOSIS PLANS & DATA** This data shows several ways to put subjects under your control Included is a full volume reference text and several construction plans that when assembled can produce highly effective stimuli This material must be used cautiously It is for use as entertainment at parties etc only, by those experienced in its use £15/set Ref F/EH2

**GRAVITY GENERATOR PLANS** This unique plan demonstrates a simple electrical phenomena that produces an anti-gravity effect You can actually build a small mock spaceship out of simple materials and without any visible means- cause it to levitate £10/set Ref F/GRA1

**WORLDS SMALLEST TESLA COIL/LIGHTENING DISPLAY GLOBE PLANS** Produces up to 750,000 volts of discharge, experiment with extraordinary HV effects 'Plasma in a jar' St Elmo's fire, Corona, excellent science project or conversation piece £5/set Ref F/BTC1/LG5

**COPPER VAPOUR LASER PLANS** Produces 100mw of visible green light High coherency and spectral quality similar to Argon laser but easier and less costly to build yet far more efficient This particular design was developed at the Atomic Energy Commision of NEGEV in Israel £10/set Ref F/CVL1

**VOICE SCRAMBLER PLANS** Minature solid state system turns speech sound into indecipherable noise that cannot be understood without a second matching unit Use on telephone to prevent third party listening and bugging £6/set Ref F/VS9

**PULSED TV JOKER PLANS** Little hand held device utilises pulse techniques that will completely disrupt TV picture and sound! works on FM too! DISCRETION ADVISED £8/set Ref F/TJ5

**BODYHEAT TELESCOPE PLANS** Highly directional long range device uses recent technology to detect the presence of living bodies, warm and hot spots, heat leaks etc Intended for security, law enforcement, research and development, etc Excellent security device or very interesting science project £8/set Ref F/BHT1

**BURNING, CUTTING CO2 LASER PLANS** Projects an invisible beam of heat capable of burning and melting materials over a considerable distance This laser is one of the most efficient, converting 10% input power into useful output Not only is this device a workhorse in welding, cutting and heat processing materials but it is also a likely candidate as an effective directed energy beam weapon against missiles, aircraft, ground-to-ground, etc Particle beams may very well utilize a laser of this type to blast a channel in the atmosphere for a high energy stream of neutrons or other particles The device is easily applicable to burning and etching wood, cutting, plastics, textiles etc £12/set Ref F/LC7

**DYNAMO FLASHLIGHT** Interesting concept, no batteries needed just squeeze the trigger for instant light apparently even works under water in an emergency although we haven't tried it yet! £6 99 ref SC152

**ULTRASONIC BLASTER PLANS** Laboratory source of sonic shock waves Blow holes in metal, produce 'cold' steam, atomize liquides Many cleaning uses for PC boards, jewllery, coins, small parts etc £6/set Ref F/ULB1

**ANTI DOG FORCE FIELD PLANS** Highly effective circuit produces time variable pulses of accoustical energy that dogs cannot tolerate £6/set Ref F/DOG2

**LASER BOUNCE LISTENER SYSTEM PLANS** Allows you to hear sounds from a premises without gaining access £12/set Ref F/LLIST1

**PHASOR BLAST WAVE PISTOL SERIES PLANS** Handheld, has large transducer and battery capacity with external controls £6/set Ref F/PSP4

**INFINITY TRANSMITTER PLANS** Telephone line grabber/room monitor The ultimate in home/office security and safety! simple to use! Call your home or office phone, push a secret tone on your telephone to access either A) On premises sound and voices or B) Existing conversation with break-in capability for emergency messages £7 Ref F/TELEGRAB

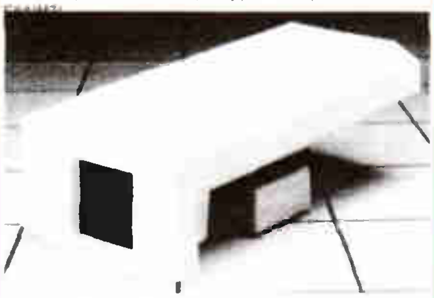
**BUG DETECTOR PLANS** Is that someone getting the goods on you? Easy to construct device locates any hidden source of radio energy! Sniffs out and finds bugs and other sources of bothersome interference Detects low high and UHF frequencies £5/set Ref F/BD1

**ELECTROMAGNETIC GUN PLANS** Projects a metal object a considerable distance-requires adult supervision £5 ref F/EML2

**ELECTRIC MAN PLANS, SHOCK PEOPLE WITH THE TOUCH OF YOUR HAND!** £5/set Ref F/EMA1

**PARABOLIC DISH MICROPHONE PLANS** Listen to distant sounds and voices, open windows, sound sources in 'hard to get' or hostile premises Uses satellite technology to gather distant sounds and focus them to our ultra sensitive electronics Plans also show an optional wireless link system £8/set ref F/PM5

**2 FOR 1 MULTIFUNCTIONAL HIGH FREQUENCY AND HIGH DC VOLTAGE, SOLID STATE TESLA COIL AND VARIABLE 100,000 VDC OUTPUT GENERATOR PLANS** Operates on 9-12vdc, many possible experiments £10 Ref



## COLOUR CCTV VIDEO CAMERAS,

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**Pal, 1v P-P, composite, 75ohm, 1/3" CCD, 4mm F2.8, 500x582, 12vdc, mounting bracket, auto shutter, 100x50x180mm, 3 months warranty, 1 off price £119 ref XEF150, 10 or more £99 ea 100+ £89**


## SUPERWIDEBAND RADAR DETECTOR 360 deg COVERAGE

Detects both radar and laser, X K superwide KA bands LED signal strength display Audio and visual alerts, Alert priority Rear and front facing optical waveguides, Triplecheck verification, city mode, tutorial mode, dark mode, aux jack, volume control These may be illegal to use in certain countries
1 1"x2 7"x4 6"

**Superband £149 ref RD2**

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## HELIOS PNB-2 RUSSIAN BORDER GUARD OBSERVATION BINOCULARS £1799

Intended for the medium to long range observation of air and ground targets and the determina tion of their angular co-ordinates These giant binoculars are a tribute Russian optical ingenuity, with a performance that simply has to be seen to be believed A large exit pupil diameter of 7 33mm provides exceptional light passing power, which when combined with its high
magnification of x15 allows the user to view over vast distances with delightfully bright crisp, high resolution images Robust and able in construction incorporating an uncomplicated yet thoughtfully designed mechanical layout ensuring ease of operation and quick precise targeting These binoculars have a wide variety of applications and are suitable for use by coastguards, law enforcement organizations, cus toms, farmers etc
Specifications
x15 magnification, 110mm objective, 6 deg angle of view, Field at 100m=105m focusing 10m-inf, fully coated precision ground optics, orange and neutral filters, rubber lens caps, rapid tergetting hand grips, padded headrest, screw in silica gel cartridges, wooden tripod, operating temperatures -40 c to +50 c , weight 25kg, (15kg without tripod) supplied in wooden carrying case
Border guard binoculars £1799 ref PNB2

## TZS4 INFRARED NIGHT SIGHT

One of our top most selling night sights is this Russian TZS4 This sight enable you to see in very low light levels, or with the aid of the built in infra red illuminator- in total darkness In 1/4 moonlight you would spot a man at 150m, in total darkness at 75m Magnification 2 3x, 240x66x190mm,0 9kg, focusing range 1 5m-infinity, M42 camera mount included, runs on 2xAA batteries, 100mm focal length, 8 deg illuminator divergence, 50hrs continuous (no illuminator) 10hrs with, carryingcase and strap

**TZS4 Nightsight £199 ref BAR61**

ISSN 0262 3617
PROJECTS . . . THEORY . . . NEWS . . .
COMMENT . . . POPULAR FEATURES . . .

VOL. 26 No. 12 DECEMBER 1997

# EVERYDAY PRACTICAL ELECTRONICS

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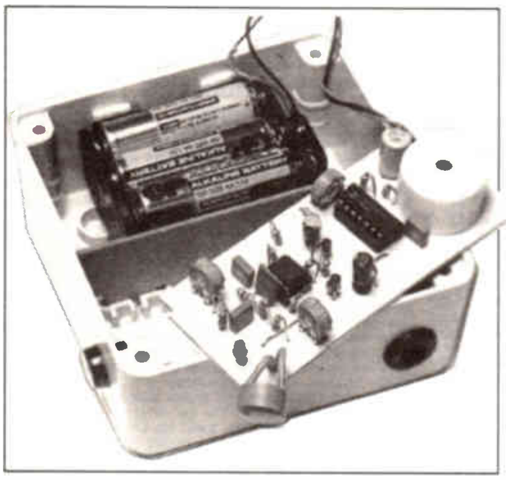
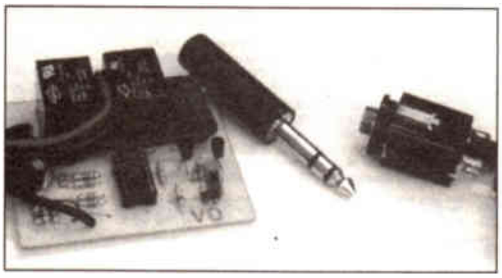
**The No. 1 Magazine for Electronics Technology and Computer Projects**





*Our January '98 issue will be published on Friday, 5 December 1997. See page 811 for details.*

## Projects and Circuits



## Series and Features



## Regulars and Services

FREE

# NEXT MONTH

# GIANT PIC DATA CHART

*Another free data chart. Next month we cover PICs with pinouts, family short form data, instruction set, block diagram, source addresses, etc.*

## VIRTUAL SCOPE

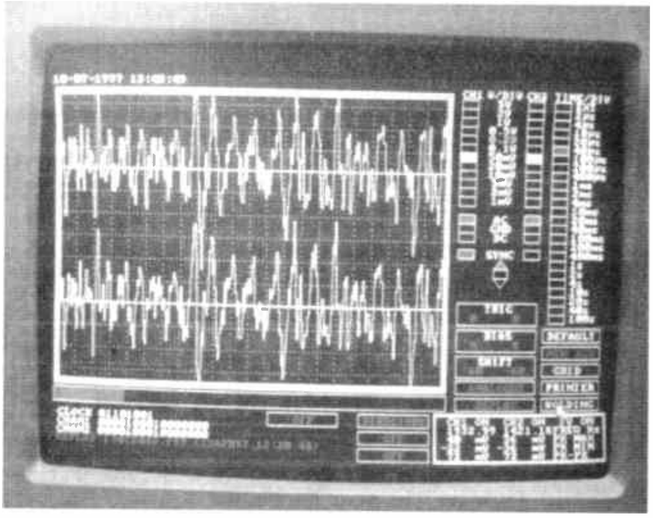
*Dramatically improve your workshop facilities with this highly versatile PC-controlled dual-trace oscilloscope simulator.*

*Two 8-bit analogue channels; two 8-bit digital channels; runs at 10MHz; masses of functions and facilities too numerous to list; everything controlled via the screen and mouse – NO controls on the interface! Outputs data to screen, disk and printer – permanent records of your waveforms!*

*Basic computer requirements: PC-compatible from '386 to Pentium upwards; min. 100Kb free memory; MS-DOS 3.1 or later; EGA, VGA or better colour screen; a PS/2 2-button mouse driver; QuickBASIC or QBasic installed; parallel printer port; runs entirely under DOS (Windows not needed).*

*Try before you buy – a 3·5-inch demo disk of the software will be available!*

***It's impressive – don't miss it!***



## SIMPLE MW RADIO

*Most beginners to electronics build a radio. Here's your chance to achieve that magical result – sound out of nowhere!*

*The cost of ready-made radio sets is so low these days that at first there seems to be little point in building your own. On the other hand, a simple broadcast receiver has traditionally been a popular starting point for the electronics hobbyist, and it remains an interesting and useful project for beginners.*

*This very simple circuit is a tuned radio frequency (t.r.f.) type which is based on a single integrated circuit that is designed specifically for this function. Although only a handful of components are used, the level of performance is quite good, and a number of stations can be received at good volume.*

## DISCO LIGHTS FLASHER

*A brilliant way to liven up the party! No disco would be complete without at least one set of flashing lights. The commercial variety, although rich in special effects, tend to be very expensive. Even hiring them for one evening can prove prohibitively costly. This circuit is a much cheaper and simpler alternative which will make it ideal for parties at home and similar situations.*

*The circuit is designed to flash five mains bulbs in various ways: The first mode is "random" whereby the lamps flash in any order. The second is "sequential" where they operate in a fixed pattern. The third is "automatic" and here the bulbs alternate between periods of random and sequential operation. You can also set the rate at which the bulbs operate and the timing of random and sequential operation when "automatic" is selected.*

# NO ONE DOES IT BETTER

## PLUS ALTERNATIVE AND FUTURE TECHNOLOGIES – 2

## PLUS ALL THE REGULAR FEATURES

**EVERYDAY PRACTICAL ELECTRONICS**

**DON'T MISS AN ISSUE – PLACE YOUR ORDER NOW!**

**JANUARY ISSUE ON SALE FRIDAY, DECEMBER 5**

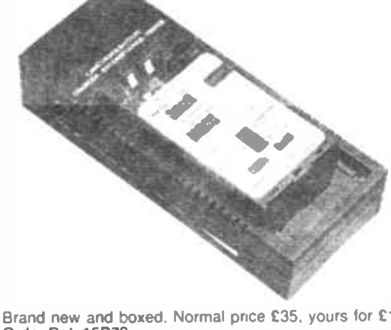
## £1 BARGAIN PACKS – List 4

One item only per pack unless otherwise stated. See last month for Nos 1, 2 and 3 and next month for No 5.

**1N-HANDLE MAINS ON/OFF SWITCHES,** sometimes known as pistol grip switches, pack of 2, Order Ref: 839.
**5A DOUBLE-POLE CHANGEOVER TOGGLE SWITCHES,** ideal reversing DC motors, etc., pack of 2, Order Ref: 841.
**3M 2-CORE CURLY LEAD,** 5A, Order Ref: 846
**1M 3-CORE CURLY LEAD,** 13A, Order Ref: 847
**AC SHADED-POLE MAINS MOTOR** with base fixing plate. Order Ref: 848.
**4" PLASTIC DIAL,** fits flatted ¼" spindle, transparent so dial can be underneath, pack of 2, Order Ref. 851.
**2,500μF 12V CAPACITORS,** pack of 5, Order Ref. 853.
**DELAY SWITCH** on B7G base, Order Ref: 854.
**3 CHANGEOVER RELAY, 6V AC** or 3V DC, 3 changeover contacts, Order Ref: 859.
**NORMALLY ON, V3 MICROSWITCH,** pack of 4, Order Ref: 862.
**HIVAC NUMICATOR TUBE,** Hivac ref XN3, Order Ref: 865.
**DITTO** but reference XN11, Order Ref: 866.
**SUB MIN NORMALLY OFF MICROSWITCH,** pack of 4, Order Ref: 867.
**SUB MIN CHANGEOVER MICROSWITCH,** pack of 3, Order Ref: 868.
**EX-GPO TELEPHONE DIAL,** rotary type, Order Ref: 904.
**QUARTZ LINEAR HEATING TUBES, 360W** but **110V** so would have to be joined in series, pack of 2, Order Ref: 907.
**2" ROUND LOUDSPEAKERS,** 50 ohm coil, pack of 2, Order Ref: 908.
**EDGE TYPE PUSH SWITCHES, BCD** system, pack of 2, Order Ref: 915.
**10M 4-CORE FLEX,** suitable for telephone extension, Order Ref: 918.
**OLD TYPE KETTLE ELEMENT,** 2-pin plug, Order Ref: 925.
**6V 24W HEADLAMP BULB,** normal BC plug in cap, Order Ref: 928.
**40 LAMP UNIT** to make a figure or letter display, Order Ref: 930.
**10K HORIZONTAL PRESET RESISTORS,** pack of 10, Order Ref: 931.
**1M 64-WAY RIBBON CABLE,** Order Ref: 932.
**MAINS PSU,** 15V 320mA AC, Order Ref: 934.
**15V+15V 1.5VA POTTED PCB MAINS TRANSFORMER,** Order Ref: 937.
**16 OHM 3" SPEAKERS,** pack of 2, Order Ref: 962.
**MAINS RELAY** with 15A changeover contacts, Order Ref: 965.
**IN-LINE FUSEHOLDERS,** take 20mm fuse, just cut the flex and insert, pack of 4, Order Ref: 969
**OBLONG PANEL MOUNTING NEONS,** pack of 4, Order Ref: 970.
**COPPER CLAD PANELS,** size 7" x 4", pack of 2, Order Ref: 973.
**STANDARD SIZED AUDIO PLUG** adapted to take two 3mm plugs, Order Ref: 974.
**3.5MM JACK PLUGS,** pack of 10, Order Ref: 975
**DRILL CONTROL CASE,** ready punched and with control logos, Order Ref: 979.
**8μF 350V ELECTROLYTICS,** pack of 2, Order Ref: 987.
**SCREW-IN NEON BULBS,** pack of 4, Order Ref: 990.
**VERY SMALL SLIDE SWITCH,** pack of 4, Order Ref 992.
**50μF+50μF 350V WORKING ELECTROLYTICS,** pack of 2, Order Ref: 994.
**8700μF 7V WORKING ELECTROLYTIC,** Order Ref: 996
**1 MEG PRESET POTS,** pack of 4, Order Ref: 998
**WHITE PROJECT BOX,** 78mm x 115mm x 35mm, Order Ref 1006.
**SLIDELOCK 15A FUSES,** panel mounting, pack of 3, Order Ref: 1011.
**6V SOLENOIDS,** good length pull, pack of 2, Order Ref: 1012.
**RELAY WITH 3 SETS OF CHANGEOVER 8A CONTACTS,** 24V AC or 12V DC, 3 sets 8A changeover contacts, Order Ref: 1016.
**WHITE TOGGLE SWITCH,** push-in spring retain type, pack of 4, Order Ref: 1019.
**2M MAINS LEADS,** 2-core, black outer, pack of 4, Order Ref. 1020.
**2M MAINS LEADS,** 3-core, black outer, pack of 3, Order Ref 1021.
**FERRITE SLAB AERIAL** with coils, pack of 2, Order Ref. 1027.
**12V DC POLARISED RELAY,** 2 changeover contacts, Order Ref. 1032.
**12in. x 12in. PAXOLIN PANEL,** medium thickness, Order Ref: 1033.
**TUNING CAPS,** solid DIA, for LW and MW, pack of 2, Order Ref: 37.
**TRIMMER CAPS,** screw down type, 10 assorted, Order Ref: 38.
**IF TRANSFORMERS,** 465kHz, pack of 4, Order Ref: 40
**SOCKETS** for stripboard, make your own IC holders, pack of 10, Order Ref: 54
**6½" 4 OHM SPEAKER,** Order Ref. 137
**100K STEREO POTS,** pack of 4, Order Ref: 143.
**FUSE HOLDERS,** chassis mounting for 20mm fuses, pack of 5, Order Ref: 144.
**SOCKET COVERS,** child protectors for twin 13A sockets, pack of 4, Order Ref: 149.
**DITTO** but for single 13A sockets, pack of 4, Order Ref 150.
**POT CORES,** circular, ferrite, 54mm x 18mm, pack of 2 pairs, Order Ref: 156.
**AIR SPACED TUNER,** 20pF with ¼" spindle, Order Ref: 182.
**METAL BOX,** slightly sloping, 8x3x4, 1 only, Order Ref 209.
**TELEPHONE LEADS,** 5-core curly reinforced telephone leads, pack of 2, Order Ref: 213.
**STEREO PRE-AMP,** Mullard 9001, 1 only, Order Ref: 216.
**PUSH-ON TAGS** for ¼" spades, pack of 100, Order Ref: 217.
**DITTO** but right-angled, pack of 100, Order Ref: 218.

## CAMCHARGER

### CAMCORDER BATTERY QUICK CHARGER (WITH RECONDITIONER & TESTER)



Brand new and boxed. Normal price £35, yours for **£15,** Order Ref: 15P73.

## TOROIDAL MAINS TRANSFORMERS

All with 220/240V primary winding. 0-30V+0-30V at 120VA, would give you 30V at 4A or 60V at 2A, price **£8**, Order 8PE2. Order Ref: 8PG2. 0-110V + 0-110V at 120VA would give you 110V at just over 8A or 220V at 1/2A, price **£8,** Order Ref: 8PG3. 0-35V + 0-35V at 150VA would give you 35V at 4A or 70V at 2A. Price **£8**, Oder Ref: 8PG9. 0-35V + 0-35V at 220VA would give you 35V at 6½A or 70V at 3¼A, price **£9,** Order Ref: 9PG4. 0-110V + 0-110V at 220VA would give you 110V at 2A or 220V at 1A, price **£10**, Order Ref: 10PG5. 0-45V + 0-45V at 500VA would give you 45V at 11A or 90V at 5½A, price **£20,** Order Ref: 20PG7. 0-110 + 0-110V at 500VA would give you 110V at 5A or 220V at nearly 3A, price **£25,** Order Ref: 25PG7.

**SUPER WOOFERS.** A 10" 4ohm with a power rating of 250W music and normal 150W. Normal selling price for this is **£55** + VAT, you can buy at **£29** including VAT and carriage. Order Ref: 29P7. The second one is a 8" 4ohm, 200W music, 100W normal. Again by Challenger, price **£18,** Order Ref: 18P9.

Deduct 10% from these prices if you order in pairs or can collect. These are all brand new in maker's packing.

**SOLDERING IRON.**
Super mains powered with long life ceramic element, heavy duty 40W for that extra special job. Complete with plated wire stand and 245mm leads, **£3,** Order Ref: 3P221.

## YOU SAVE £40

**THE JAP MADE 12V 12A-SEALED BATTERY** from regular suppliers costs £50, you can have one from us for only **£10** including VAT if you collect or **£12** if we have to send. Being sealed it can be used in any position and is maintenance free. All in tip top condition and fully guaranteed, Order Ref: 12P32. Or if you want a smaller one we have 12V 2.3AH, regular price £14, yours for only **£3.50,** Order Ref 3.5P11.


**FLASHING BEACON.** Uses an XENON tube and has amber-coloured dome with separate bracket, 12V operated. Price only **£5,** Order Ref: 5P.267.
**HIGH RESOLUTION MONITOR.** 9" by Philips, in metal frame for easy mounting. Brand new, offered at less than the price of the tube alone, **£15,** Order Ref: 15P1.
**15W 8" SPEAKER AND 3" TWEETER.** Amstrad, made for their high quality music centre, **£4** per pair, Order Ref: 4P57.
**INSULATION TESTER WITH MULTIMETER.** Internally generates voltages which enables you to read insulation directly in megohms. The multimeter has four ranges, AC/DC Volts, 3 ranges milliamps, 3 ranges resistance and 5 amp range. These instruments are ex-British Telecom but in very good condition, tested and guaranteed OK, probably cost at least **£50,** yours for only **£7.50** with leads, carrying case **£2** extra, Order Ref: 7.5P4.
We have some of the above testers but slightly faulty, not working on all ranges, should be repairable, we supply, diagram, **£3,** Order Ref: 3P176.
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**LCD 3½" DIGIT PANEL METER.** This is a multi-range voltmeter/ammeter using the A-D converter chip 7106 to provide five ranges each of volts and amps. Supplied with full data sheet. Special snip price of **£12,** Order Ref: 12P19.
**MINI BLOW HEATER.** 1kW, ideal for under desk or airing cupboard, etc. Needs only a simple mounting frame, **£5,** Order Ref: 5P23
**MEDICINE CUPBOARD ALARM.** Will warn when cupboard door is opened. Light makes the bell ring. Neatly cased, requires only a battery, **£3,** Order Ref: 3P155.
**DON'T LET IT OVERFLOW.** Be it bath, sink, cellar, sump, etc., this device will tell you when the water has risen to the pre-set level. Adjustable, neatly cased for wall mounting, **£3,** Order Ref: 3P156.
**DIGITAL THERMOMETER.** Suitable for outdoors or indoors, has an extra wide temperature range −50° to +70°C, complete with heavy duty battery which should last several years. Its sensor can be outside, but with the read-out inside, **£4,** Order Ref: 4P104.

# SMART HIGH QUALITY ELECTRONIC KITS

All kits are complete with PCB and other components in a blister pack. If you want more information about them, we have copies of the illustrated Smart catalogue available price **£1**.

| Cat. No. | Description | Price £ |
|---|---|---|
| 1003 | 5 watt electronic siren | 2.53 |
| 1005 | Touch switch | 2.87 |
| 1008 | SF function generator | 6.90 |
| 1010 | 5-input stereo mixer, with monitor output | 19.31 |
| 1016 | Loudspeaker protection unit | 3.22 |
| 1017 | Linear CB 30W amp | 4.70 |
| 1020 | 0-5 min. time switch | 4.70 |
| 1023 | Dynamic headphone preamp | 2.50 |
| 1025 | 7 watt hi-fi power amplifier | 2.53 |
| 1026 | Running lights | 4.60 |
| 1027 | NiCad battery charger | 3.91 |
| 1030 | Light dimmer | 2.53 |
| 1032 | Stereo tone control | 3.55 |
| 1035 | Space sound effects | 2.30 |
| 1039 | Stereo VU meter | 4.60 |
| 1042 | AF generator 250Hz-16kHz | 1.70 |
| 1043 | Loudness stereo unit | 3.22 |
| 1047 | Sound switch | 5.29 |
| 1048 | Electronic thermostat | 3.68 |
| 1050 | 3-input hi-fi stereo preamplifier | 12.42 |
| 1052 | 3-input mono mixer | 6.21 |
| 1053 | Electronic metronome | 3.22 |
| 1054 | 4-input instrument mixer | 2.76 |
| 1056 | 8V-20V 8A stabilised power supply | 12.42 |
| 1057 | Cassette head preamplifier | 3.22 |
| 1059 | Telephone amplifier | 4.60 |
| 1060 | +40V 8A power supply | 8.28 |
| 1061 | 12V 1 2A stabilised power supply | 3.36 |
| 1062 | 5V 0-5A stabilised supply for TTL | 2.30 |
| 1063 | 12V 2A power supply | 2.30 |
| 1064 | +12V 0.5A stabilised supply | 3.22 |
| 1067 | Stereo VU meter with leads | 9.20 |
| 1068 | 18V 0-5A stabilised power supply | 2.53 |
| 1070 | Hi-Fi preamplifier | 7.47 |
| 1085 | D.C. converter: 12V to 6V or 7.5V or 9V | 2.53 |
| 1086 | Music-to-light for your car | 4.60 |
| 1089 | L.E.D. flasher/555 tester | 1.61 |
| 1090 | Stress meter | 3.22 |
| 1093 | Windscreen wiper controller | 3.68 |
| 1094 | Home alarm system | 12.42 |
| 1095 | Lead acid battery charger | 3.45 |
| 1100 | 2 × 18 watt integrated amplifier | 18.39 |
| 1101 | Dollar tester | 4.70 |
| 1103 | L.E.D. power meter | 1.84 |
| 1106 | Thermometer with l.e.d.s | 6.90 |
| 1107 | Electronics to help win the pools | 3.68 |
| 1112 | Loudspeaker protection with delay | 4.60 |
| 1113 | 2 × 18 watt power amplifier | 5.98 |
| 1115 | Courtesy light delay | 2.07 |
| 1118 | Time switch, with triac, 0-10 mins | 4.14 |
| 1119 | Telephone line recording device | 5.25 |
| 1123 | Morse code generator | 1.84 |
| 1124 | Electronic bell | 2.76 |
| 1125 | Telephone lock | 2.68 |
| 1126 | Microphone preamplifier | 4.60 |
| 1127 | Microphone tone control | 4.60 |
| 1128a | Power flasher 12V d.c. | 2.53 |
| 1133 | Stereo sound-to-light | 5.26 |

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## J & N FACTORS

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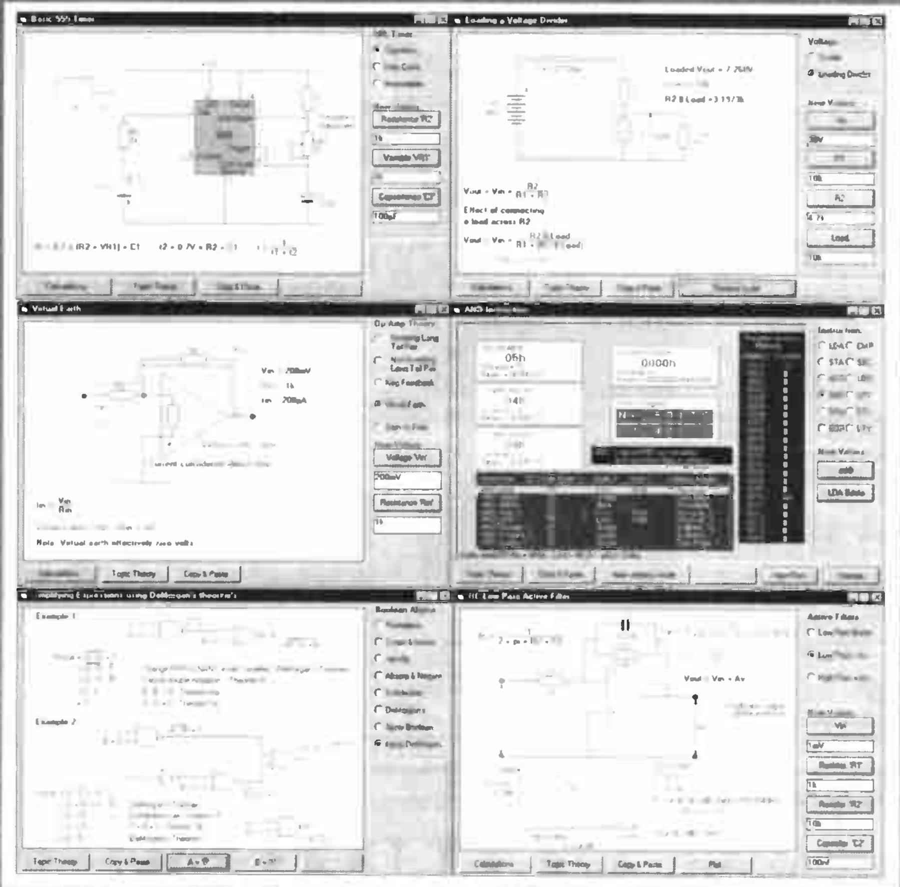

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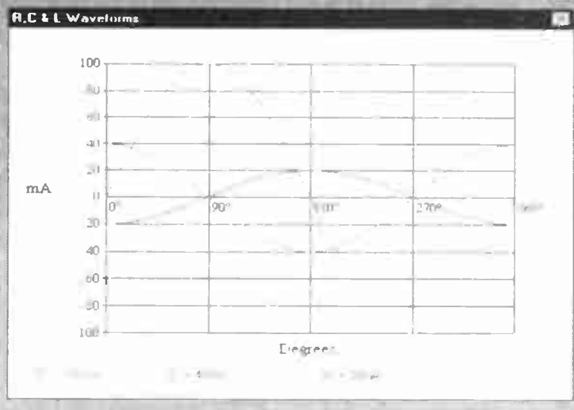


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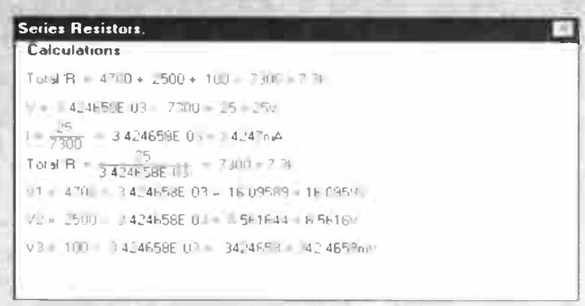


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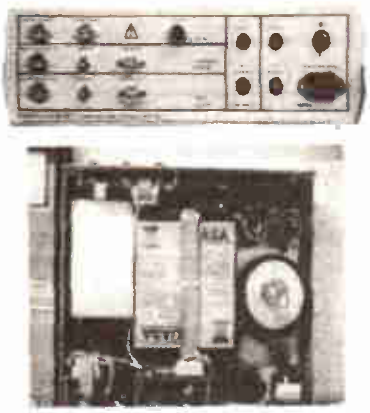

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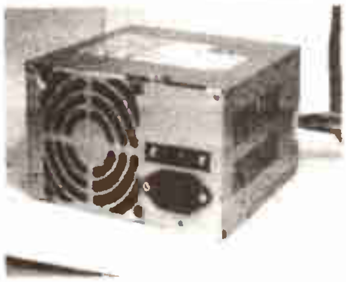

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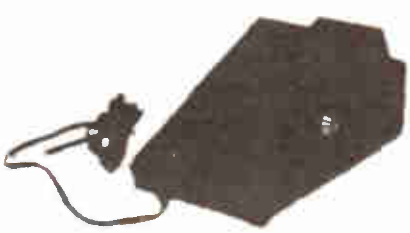

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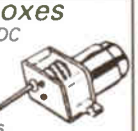

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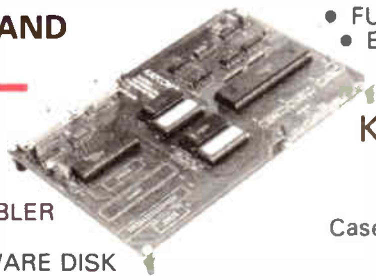

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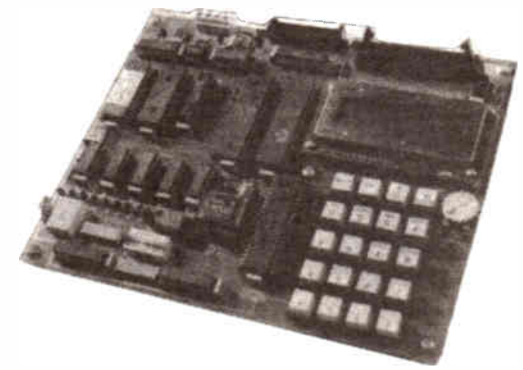

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EVERYDAY PRACTICAL ELECTRONICS

VOL. 26 No. 12 DECEMBER '97

**Editorial Offices:**
EVERYDAY PRACTICAL ELECTRONICS EDITORIAL
ALLEN HOUSE, EAST BOROUGH, WIMBORNE
DORSET BH21 1PF
Phone: Wimborne (01202) 881749
Fax: (01202) 841692. **Due to the cost we cannot reply to overseas orders or queries by Fax.**
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## BOOGIE ON DOWN

It's not often that we publish anything other than our own original material in *EPE*, but this month and next month we have departed from the norm and are republishing a chapter taken from a recently published book. It's Chapter 21 from *Bebop to the Boolean Boogie* by Clive (call me Max) Maxfield.

Every so often a technical book comes along that sets a standard for others to follow; two previous books that come immediately to mind are *Foundations of Wireless and Electronics* by M. G. Scroggie and *The Art of Electronics* by Horowitz and Hill, both of which have run to a number of editions ("Scroggie" was first published in 1936!).

We believe two more technical books are about to line up alongside the all time greats and both of these are Bebop books. We are sure you will discover that the article *Alternative and Future Technologies* is informative and easy to read. Max's style helps things along tremendously and you will find you have absorbed masses of technical information almost without conscious effort.

When you realise that this month's issue contains only half of Chapter 21 and that we have had to add extra pages to the magazine to get it all in (and will probably do the same for Part 2 next month), then you can see how much information is contained in the book.

No doubt some of the technologies described in Chapter 21 will fall by the wayside but they all make fascinating reading and, in many instances, are simply mind boggling. If, like me, you want to read more then we can also supply the book – we have taken the unprecedented step of importing it (and the other Bebop book – read on) ourselves to make it available at an exceptional price in the UK.

## BYTES

Max's other book, *Bebop BYTES Back*, co-written with Alvin Brown, is perhaps even more fascinating. It includes a Free CD-ROM with a Virtual Computer on it – called the Bebopuțer – that allows you to understand the inner workings of a computer, write machine code or assembly code programs and try them out, etc. If you want to understand computers then this is an enjoyable way of doing it.

Time will tell if these books line up with Scroggie and Horowitz and Hill, if they don't I will be surprised. We did not have the good fortune to publish them but we can make sure you benefit from them.

Mike Kenward

### AVAILABILITY

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**Editorial:** Wimborne (01202) 881749
**Advertisement Manager:**
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### COMPONENT SUPPLIES

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# SAFE AND SOUND

TERRY de VAUX-BALBIRNIE

*Foil the villains with our anti-theft bleeper for security lights*

PASSIVE infra-red (PIR) floodlights are available at very low cost from DIY stores and mail order suppliers. For those who are not "in the know", these lights switch on for a certain time when a sensor detects the heat radiated by a person's body. Thus, when someone moves within the detection zone, up to about 10 metres away, the light is activated.

In more expensive models, the operating time may be adjustable using a control on the unit, but in cheaper models it will be fixed at, say, four minutes. A detector responds to the ambient light and disables the circuit during daylight hours.

These lamps are useful because they may be arranged to throw light on the driveway and along the path to the front door. Placed to the side and rear of the house, they may also be used as a deterrent against burglary.

Note that this type of external PIR unit cannot be interfaced with a house alarm system. One reason is because the house owner or friends and family would trigger it. Also, these lights are prone to occasional false operation. This may happen when a cat or dog passes by, and also if moving objects such as branches of trees fall within range.

## NO KIDDING

However, it would be helpful if an intruder *thought* that he had triggered an alarm if he went to the rear of the house. It is well known that deterring burglary can involve just as much "kidology" as real technology.

For example, a dummy alarm box on the side of the house can be almost as effective as the real thing. With the device to be described here, the intruder moving into the PIR detection field at night activates the light which, in turn, triggers the circuit. A buzzer then emits a distinctive bleeping sound.

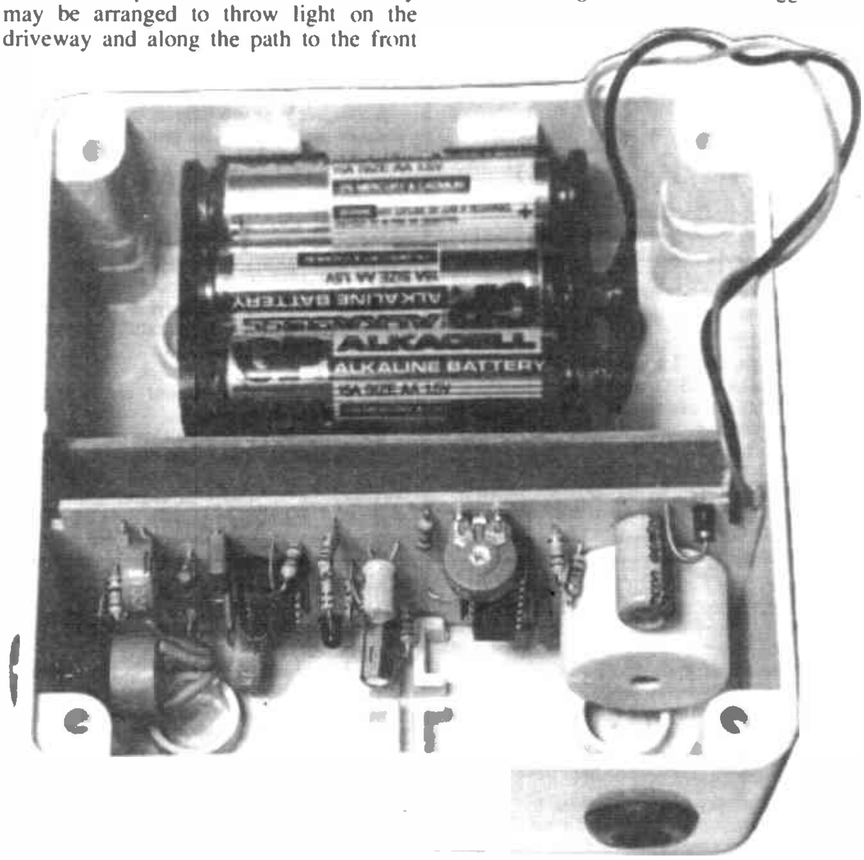
An intruder will not necessarily connect this with the light having come on, and it does not matter if he does. The effect will be confusion and he will probably beat a hasty retreat. The sound is not so loud that it will disturb people in other houses but it will be sufficient to draw the attention of anyone nearby.

The intruder may think that the bleeping indicates that a full-size siren will sound if he remains there. He might even think that the police or a security company have been contacted by an auto-dial telephone system. In either case, he is not likely to wait and find out.

There is a further application for this device, and it may be combined with the first one if required. That is to place a sounder inside the house so that it tells the occupants that the light has been triggered. This idea may be useful because the light itself is not usually visible inside the house when the curtains are drawn.

It could be used to give advance warning that someone was approaching, or as an automatic door "bell". Bear in mind, however, that there is a possibility of false triggering.

*For this reason, the use of an internal buzzer, especially when the PIR lamp is sited to the rear of the house, would not be a good idea where the elderly or infirm are involved since it could cause undue anxiety.*




## LONG LIFE

The unit, together with battery, is built in a small waterproof plastic case. No connections are made to the lamp itself. An ordinary box would be suitable if it could be positioned so that rain water did not fall on it. However, the specified one has a "professional" appearance and is of a type which could well be associated with an alarm.

Power consumption is only about 400µA on standby and the battery pack,

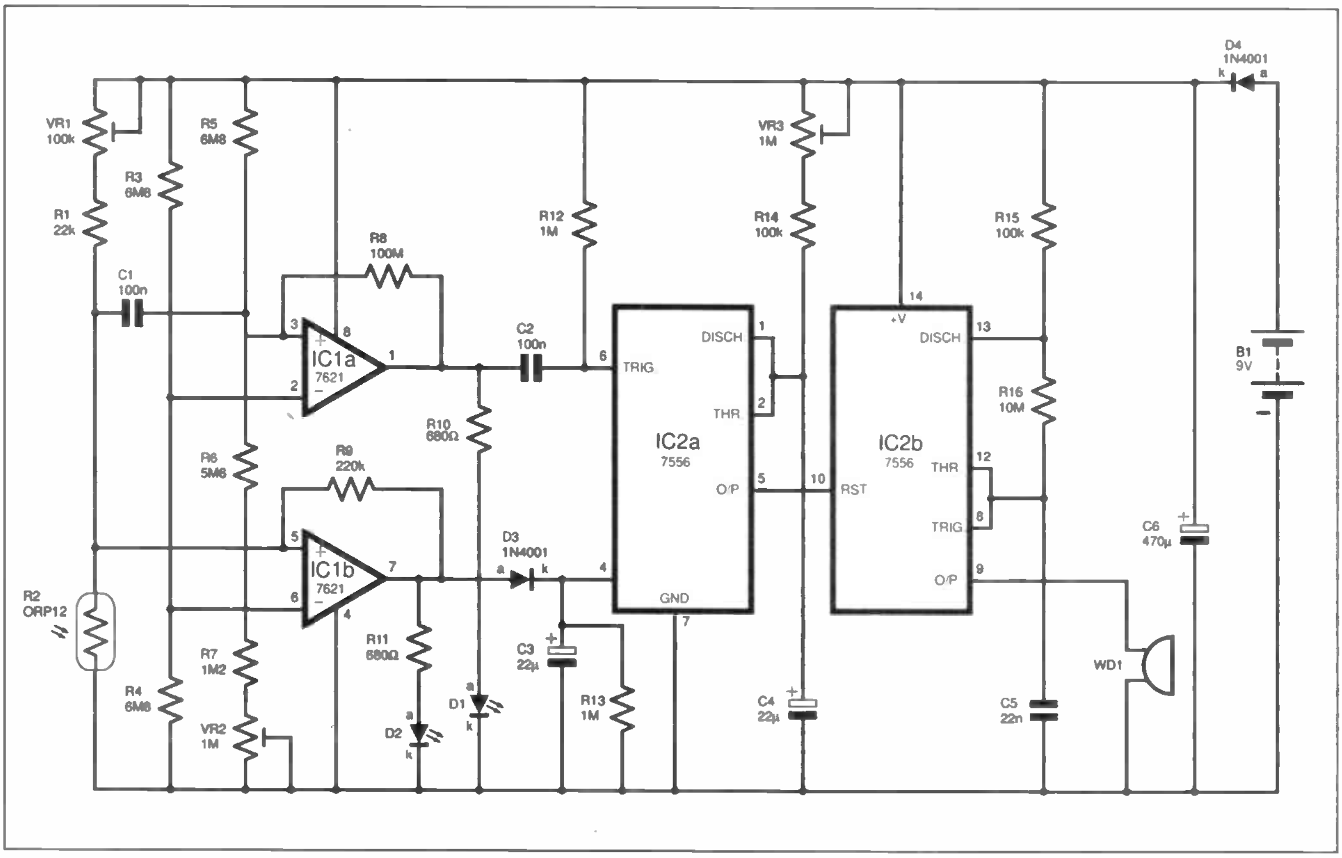



*Fig.1. Complete circuit diagram for the Safe and Sound intruder deterrent.*

consisting of six alkaline AA cells, may be expected to last for several months, even allowing for a certain amount of operation. There seems to be no reason why the user should wish to switch the circuit off so no on-off switch is provided.

The unit can be mounted on an outside wall out of reach of any intruder, but it should be where light from the PIR lamp will reach a sensor on the side. *It should be positioned so that, at night, it receives light from the PIR lamp only.*

The prototype operates at more than 10 metres from the lamp, or at about the same distance that a person must be to trigger it. The unit may, therefore, be placed so that it will sound when the intruder is directly below it. The sound is emitted through a hole on the underside of the box so the buzzer will sound quite loud to someone passing by.

Operation is inhibited above a preset light level. Consequently, the unit will not be triggered by random flashes of light, such as flickering sunlight reaching it through trees during daylight hours.

The operating time may be adjusted between about three and 30 seconds.

## CIRCUIT DESCRIPTION

The Safe and Sound circuit diagram is shown in Fig.1. IC1 is a dual operational amplifier – that is, it contains two independent CMOS op.amps, IC1a and IC1b, in a single package. This component has been specially chosen for its very small quiescent current requirement – 100µA approximately.

IC2 is a dual timer and is another low-current CMOS device requiring about 100µA only. The first timer, IC2a, is configured as a monostable, while the second one, IC2b, is used as an astable.

Both op.amps are used as voltage comparators. The rule about these is as follows: if the voltage at the non-inverting (+) input of either op.amp exceeds that at the inverting (−) one, the corresponding output will be high (near positive supply voltage) otherwise it will remain low (near 0V).

The inverting inputs of both op.amps (pins 2 and 6) are connected to a common potential divider consisting of resistors R3 and R4. Since these have the same value, the voltage at the inverting inputs is one-half that of the supply – that is, about 4·5V.

Considering IC1a, this has its non-inverting input, pin 3, connected to a further potential divider. This is comprised of resistor R5 in the upper arm, and R6 and R7 together with preset potentiometer VR2 in the lower arm.

With VR2 adjusted to minimum resistance, the total resistance in the lower arm will be equal to that in the upper one. The voltage at pin 3 is then the same as that at pin 2. With VR2 increased, the resistance in the lower arm will exceed that in the upper arm and the voltage at pin 3 will be greater that at pin 2.

As a result, IC1a will have its output pin 1 high. Consequently, l.e.d. (light-emitting diode) D1 will be turned on, with its current limited by resistor R10.

## MORE DIVISION

There is another potential divider, formed between resistor R1 and preset VR1 in the upper arm, and light-dependent resistor (l.d.r.) R2 in the lower arm.

As the intensity of light falling on the l.d.r. increases, its resistance falls and so does the voltage at the junction with R1/C1. Slow changes in the light level have no effect because capacitor C1 blocks the gradual voltage variations.

However, C1 passes on any sudden change. Thus, a rapid rise in the illumination of the light-sensitive surface of the l.d.r. results in a fall in its resistance and a sudden drop in the voltage at R1/C1.

This change results in the voltage at IC1a pin 3 falling momentarily below that at pin 2. Consequently, the output at IC1a pin 1 goes low and l.e.d. D1 becomes switched off until the inputs stabilize at their previous states, which takes about one second.

This sudden low transition is passed by capacitor C2 to the monostable, IC2a, at its trigger input pin 6. This causes the output, pin 5, to go high for a preset time, and then revert to low.

The time during which it remains high depends on the values of resistor R14, preset VR3 and capacitor C4. With the values specified, the shortest period (with VR3 set to minimum resistance) is about three seconds. With VR3 adjusted to maximum resistance, it is about 30 seconds, depending on the tolerance of C4.

Note that the trigger input is normally held high (in the absence of a low pulse) via resistor R12, and this prevents false operation. Assume for the moment that pin 4 (reset input) is high so that the monostable is enabled. This will be explained in more detail later.

## RAPID STREAM

With IC2a output pin 5 high, IC2b pin 10 (reset input) is also held high and this enables its astable mode. Its output pin 9 thus generates a stream of pulses and these cause the buzzer, WD1, to emit a series of rapid bleeps.

When the monostable IC2a times out, its pin 5 goes low, and so does IC2b pin 10. Consequently, astable IC2b is now maintained in a reset condition and the buzzer stops sounding.

The astable rate is set by resistors R15, R16 and capacitor C5. There is no adjustment provided because the rate is not thought to be particularly important. With the components specified it will be about 3Hz – that is, it will generate about three pulses per second. A higher rate could be obtained by reducing the value of C5, and vice versa.

## CHANGED BEHAVIOUR

However, the behaviour of the circuit is modified by op.amp IC1b. This has its non-inverting input (pin 5) connected to the l.d.r. via C1. Under daylight conditions, the resistance of the l.d.r. is less than the combined total of VR1 and R1, so that the voltage at pin 5 will be less than that at pin 6.

The op.amp will then have its output pin 7 low. This low state is blocked by diode D3 and has no further effect. The reset input, pin 4, of IC2a is then maintained in a low condition via resistor R13. This disables the monostable so that, in the event of a trigger pulse arriving in the manner described above, the op.amp will not change its output state.

When the light level falls below the threshold set by preset VR1, the resistance of the l.d.r. rises above that of VR1 plus R1 and the voltage at IC1b pin 5 then exceeds that at IC1b pin 6.

The output at IC1b pin 7 then goes high and l.e.d. D2 turns on, with its current limited by resistor R11. This high state is passed though diode D3 to IC2 pin 4, so enabling the monostable and making it capable of being triggered. The exact point at which this happens depends on the setting of preset VR1.

If the PIR floodlight comes on, the light reaching resistor R2 causes IC1b output pin 7 to go low again immediately. Normally, this would disable the monostable and no pulses would be given. The purpose of capacitor C3 is to prevent this effect.

While IC1b pin 7 is high, C3 is kept charged. When it goes low, C3 briefly maintains IC2 pin 4 in a high state, so allowing the monostable to operate. C3 now discharges slowly through resistor R13 and, with the values specified, enables the monostable for about as long as its maximum timed period, as set by VR3, R14 and C4.

Diode D3 prevents C3 from discharging by sinking current back into IC1b output pin 7 when the latter is low. Note that the period during which IC2a pin 4 is kept high is about the same as the maximum monostable timing. It will, therefore, allow the monostable to time-out, no matter how long the period has been set for.

## POSITIVE FEEDBACK

Resistors R8 and R9 apply a little positive feedback to op.amps IC1a and IC1b respectively. This sharpens the switching action at the critical level. Thus, the op.amp outputs will always operate "cleanly" with no dithering at the threshold value which could cause false operation.

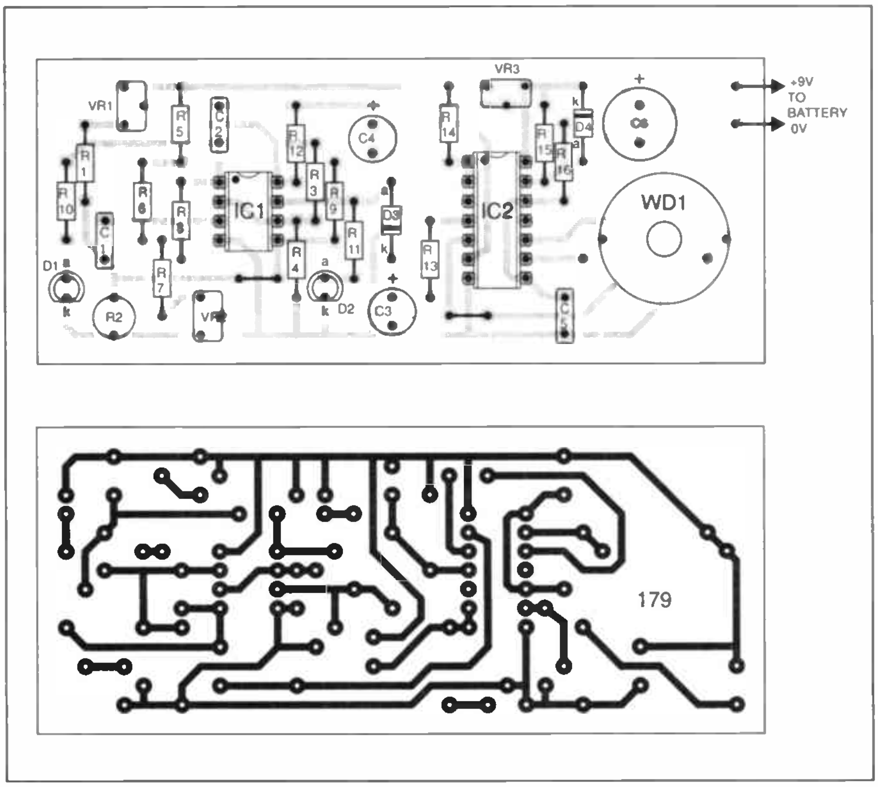



*Fig.2. Printed circuit board component layout and full size underside copper foil master track pattern for the Safe and Sound unit.*

One consequence of this is that the light level will need to rise a little more in the morning to disable operation than was needed at night to enable it.

Diode D4 provides protection in case the battery has been connected with incorrect polarity. It also lowers the supply voltage by its forward voltage drop of approximately 0·7V. This reduces the supply to about 8·3V maximum.

Returning to the l.e.d.s, D1 will normally be on, but will go off momentarily when the l.d.r. experiences a sudden increase in illumination. The other l.e.d., D2, will normally be off but will come on and remain on when the ambient light falls below the preset level.

The l.e.d.s are used purely for testing and setting-up purposes. Since they would draw an unacceptable amount of current if left there, they are disconnected once the circuit has been set up ready for use.

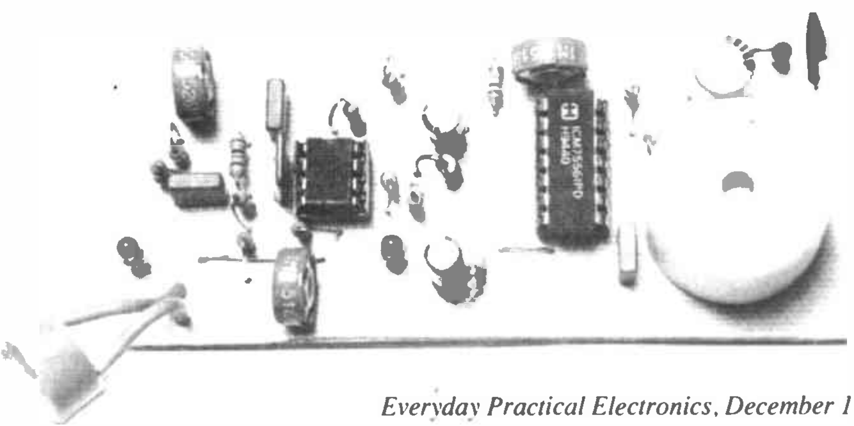
Since the voltages at the op.amp inputs are all set by potential dividers, as the supply voltage falls, all operating points will be reduced in sympathy. Their relative states will therefore remain unchanged. This means that the circuit will continue to operate correctly as the battery ages. However, if the battery voltage falls below about 6V, the buzzer will probably not be loud enough for service and then the battery will need to be replaced.

The quiescent current requirement of the circuit determines the maximum possible battery life. This is related to the current needed for the i.c.s and the continuous current flowing through the potential dividers. The resistors here have very high values and the current drain is small.

The current flowing through the potential divider containing the l.d.r. depends on the preset adjustment of VR1 and the amount of light falling on the l.d.r.

When mounted in the box, the l.d.r. should be placed behind a waterproof red cover. This cuts down the amount of ambient light reaching it and its resistance will, therefore, be higher than would otherwise be the case.

In practice, VR1 will probably be set to maximum resistance so the current flowing through this potential divider will be very small – some 60µA during the day. At night, it will fall even lower since the l.d.r. will now have an exceptionally high resistance.



## CONSTRUCTION

Construction of the Safe and Sound system is based on a single-sided printed circuit board (p.c.b.). Its topside (component view) is shown in Fig.2, together with the underside copper foil master track pattern. This board is available from the *EPE PCB Service*, code 179.

Begin by soldering the two link wires in position. Next add all the resistors. Resistor R8 has an unusually high value, 100MΩ. These are not widely available and, if necessary, two 47MΩ resistors connected in series may be used instead.

Next mount diodes D3 and D4, ensuring their correct polarity. Now mount the capacitors, ensuring correct orientation of the three electrolytic ones, C3, C4 and C6.

Solder the l.e.d.s in position; the slightly shorter lead is (normally) the cathode (k).

Follow with the i.c. sockets and preset potentiometers.

The polarity of the buzzer must be observed or it will not work – the positive lead is clearly marked on the body. Extra pads on the p.c.b. allow for a second buzzer to be used in parallel with the first, mounting it remotely in some other part of the house. If this is done low power buzzers should be used.

Solder the l.d.r. using the full length of its leads. These should be sleeved using pieces of insulation from a spare bit of mains cable. This will enable the device to be moved relative to the circuit panel so that it takes up its correct position behind the plastic cover.

Solder the battery clip wires to the points marked "+9V" (red) and "0V" (black). For testing, it would be wise to place a piece of self-adhesive tape over the hole in the top of the buzzer to reduce the sound output.

Insert the i.c.s into their sockets with the correct orientation. These are both CMOS components and, as such, are liable to damage by static electricity charge. Touch something which is earthed before handling the pins.

## COMPONENTS

**Resistors**

| | |
|---|---|
| R1 | 22k |
| R2 | ORP12 or similar light dependent resistor |
| R3, R4, R5 | 6M8 (3 off) |
| R6 | 5M6 |
| R7 | 1M2 |
| R8 | 100M – see text |
| R9 | 220k |
| R10, R11 | 680Ω (2 off) |
| R12, R13 | 1M (2 off) |
| R14, R15 | 100k (2 off) |
| R16 | 10M |

All 0·25W 5% carbon film, except R2

See SHOP TALK Page

**Potentiometers**

| | |
|---|---|
| VR1 | 100k preset, min. vert. |
| VR2, VR3 | 1M preset, min. vert. (2 off) |

**Capacitors**

| | |
|---|---|
| C1, C2 | 100n polyester, 5mm pin spacing (2 off) |
| C3, C4 | 22µ radial elect. 16V (2 off) |
| C5 | 22n polyester, 5mm pin spacing |
| C6 | 470µ radial elect. 16V |

**Semiconductors**

| | |
|---|---|
| D1, D2 | red l.e.d. (2 off) |
| D3, D4 | 1N4001 rectifier diode (2 off) |
| IC1 | ICL7621 dual op.amp |
| IC2 | ICM7556 dual CMOS timer |

**Miscellaneous**

| | |
|---|---|
| B1 | AA size alkaline cells (6 off) |
| WD1 | piezo buzzer, p.c.b. mounting (see text) |

Printed circuit board, available from the *EPE PCB Service*, code 179; battery holder and connector; panel-mounting neon indicator (see text); rubber grommet; 8-pin d.i.l. socket; 14-pin d.i.l. socket; waterproof plastic case, 100mm × 100mm × 50mm; adhesive fixing pads; solder; connecting wire, etc.

**Approx Cost Guidance Only £17 excl. batt.**

## TESTING

The p.c.b. should now be checked for correct operation before proceeding. First, though, thoroughly check all your soldering and positioning of components.

Adjust VR2's wiper to approximately mid-track position. This provides a medium sensitivity which will probably work well in practice. Adjust VR1 fully anti-clockwise (as viewed from the edge of the p.c.b.). This is probably how it can remain. Adjust VR3 fully clockwise (as viewed from the top edge of the p.c.b.) to give minimum timing.

Connect the battery. Point the l.d.r. at a window or light bulb and cover it with your hand. Quickly remove your hand and note that l.e.d. D1 goes off for about one second.

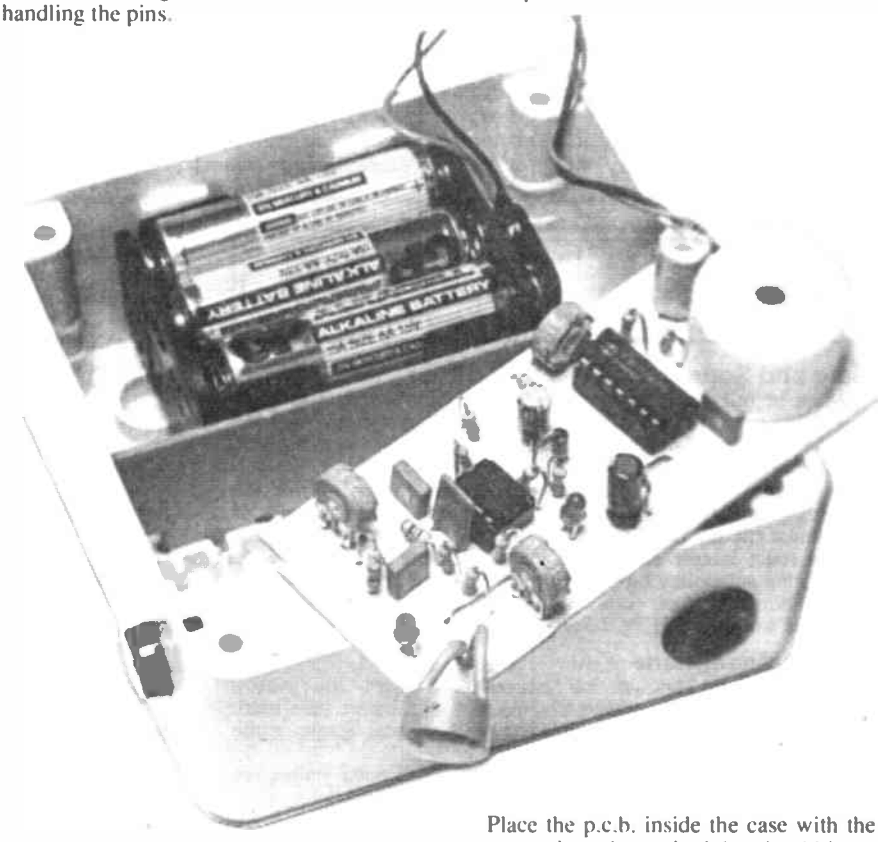
Stick a piece of Blu-Tack or Plasticine over the l.d.r. window so that light is totally excluded. Check that l.e.d. D2 comes on and remains on. Note, however, that it may take several seconds to respond.

When the l.d.r. is now suddenly uncovered, the buzzer will begin bleeping for a few seconds, providing there is sufficient light in the room. Note that it is not good enough to place a finger over the l.d.r. to exclude the light because this will probably still allow sufficient light to reach the sensitive surface and prevent the test from working.

When satisfied that the circuit operates correctly, cut one lead of each l.e.d. and separate the cut ends to prevent them from working. Cut the leads in such a way that they can be repaired again if this proves necessary in the future.

## CASING THE P.C.B.

It is advisable to use the specified waterproof case since this will prevent the ingress of rain water, followed by subsequent corrosion and malfunction of internal parts.



Place the p.c.b. inside the case with the correct orientation – the l.d.r. should be at the side facing the PIR lamp position. The rear edge of the p.c.b. should be engaged with one of the slots on the rear wall of the case.

File the corners of the p.c.b. as necessary to allow sufficient clearance for the lid to fit. Remove the p.c.b. again and drill the hole in the side of the box for light to reach the l.d.r. This must be covered with a translucent material so that it is made waterproof and, at the same time, given a professional appearance.

For the prototype, the lens end of a red mains-type neon indicator was used as the lens. The body was cut through to leave about 4mm of threaded end which was used to secure it through the hole. If it is cut carefully, the neon tube inside may be saved for future use.

The hole should be made a tight fit for the body and a little waterproof adhesive applied around it before tightening the nut. With the circuit panel in place again, bend the l.d.r. leads so that this component takes up a position directly behind the lens.

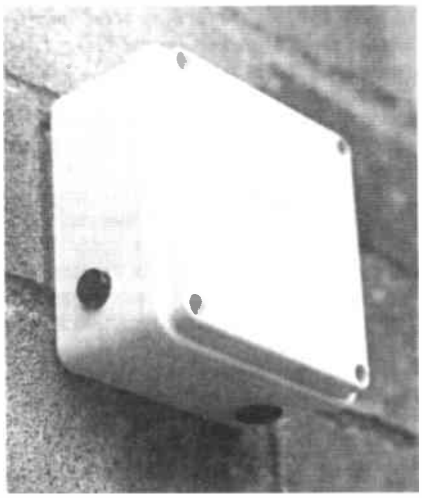
Measure the position of the buzzer, remove the p.c.b. and drill a hole directly below it. This should be of such a size that it will accept a rubber grommet having an 8mm diameter hole. This gives a neat finish and discourages water from creeping inside.

Attach the battery holder using a piece of thick cardboard with protrusions which will engage with slots in the back. Adhesive fixing pads on the side opposite will provide additional support. The p.c.b. may be secured by applying an adhesive fixing pad to the point where it enters the slot on the back of the box.

## GETTING ENGAGED

The unit may be mounted on the wall in the chosen position using two long masonry nails 90mm apart. These should protrude from the wall by about 25mm, so that they engage with the recesses in the rear of the box. This avoids having to drill holes in the case with the possibility of water entering.

If there is any extraneous light at night, such as from the security light on a nearby house, it will be necessary to re-position the unit. Alternatively, try fitting a short



*Securely mounted!*

tube to the end of the sensor to exclude all light apart from that from the PIR lamp.

If the sensitivity needs to be altered, adjust preset VR2 accordingly – clockwise rotation (as viewed from the left-hand side of the p.c.b.) reduces the sensitivity.

If the level of light at which the unit begins to respond needs to be changed, clockwise rotation of VR1's wiper will cause it to operate under lighter conditions. Leaving the setting as it is, the circuit will begin to respond when it is almost dark and the current requirement will then be minimised.

Preset VR3 may now be adjusted for the required timing for the buzzer-on period. Remove the tape from the buzzer!

If a subsidiary buzzer is to be used, make the connection to the p.c.b. via a 2A screw terminal block and two short link wires. The terminal block may be placed in the battery section of the case.

Drill a tight hole for the wires to pass through the case and seal it using a waterproof sealant or tight rubber grommet. The wires which lead to the buzzer may be of any light-duty twin type and may be of any reasonable length. Light-duty loudspeaker wire would be ideal because a stripe on one of the wires indicates the polarity.

The remote buzzer may be mounted in a small plastic box and secured to the wall.

Under damp conditions, a film of moisture could form on the p.c.b. and cause erratic operation, although no such problems were experienced with the prototype unit. However, if it occurs, it could be cured by spraying both sides of the p.c.b. with a very light coating of silicone grease or water-repellant varnish from an aerosol.

# SHOP TALK
## with David Barrington

### Safe and Sound

Most of our component advertisers should be able to offer the ORP12, or its equivalent, light dependent resistor needed for the *Safe and Sound* project. The 100 megohm resistor (R8) was ordered from **Electromail** (☎ ***01536 204555***), code 158-222. Alternatively, two 47M resistors in series will do the job (**Maplin** "high voltage" types, code V47M – these may come in packs of 5+ (latest cat. not received)).

The main buzzer also came from the latter company, code KU56L. If a subsidiary buzzer is also to be used, then both should be low-current types, code KU58N. The printed circuit board is available from the *EPE PCB Service*, code 179.

### Active Microphone

No problems should be encountered with the *Active Microphone*, except perhaps the electret mic. insert (see text). You could try one of **Maplin's** omni-directional range, code FS43W (Sub-min.) or QY62 (Ultra-min.).

Stick to the BC184L transistor, other prefixes have alternative pinouts.

### Car Immobiliser

The main criterion regarding components for the *Car Immobiliser* is in obtaining the correctly rated relays and a suitable 6mm switched jack socket. The designer informs us he obtained his from **Maplin**, relay codes DC80B (12V 1A) and JM67X (12V 10A), and jack socket BW80B. Please heed the warning about wire current ratings.

The Car Immobiliser printed circuit board is available from the *EPE PCB Service*, code 175.

### Mini Organ

If the specified (**Maplin** KC93B) box is used, the loudspeaker for the *Mini Organ* must not exceed 38mm dia. or 17mm depth. The one in the model also came from the above company, code WB04E. The rest of the components should be readily available.

### Teach-In '98 Part 2

Just a few components are needed for *Teach-In '98* Part 2, plus you will also require a digital multimeter, a power supply and a breadboard as recommended in the text.

**Greenweld** are putting together a pack of all the recommended items including the multimeter and p.s.u. These will be offered at a special price, post free if you spend over £10. Contact them on ☎ ***01703 236363***, Fax ***01703 236307*** or by writing to them at 27D Park Road, Southampton, SO15 3UQ.

**Maplin** can also supply all the items. Their order code for these is HB99 and they will include a *free* copy of their new catalogue. Hobbyists will find the catalogue an invaluable source of components, tools, test gear etc., as well as information.

**Squires** have told us that they can supply a set of tools for those following *Teach-In*, they are at The Old Corn Store, Chessels Farm, Hoe Lane, Bognor Regis, West Sussex, PO22 8NW. ***Tel/Fax 01243 587009.***

# New Technology Update

*Battery technology is developing to meet the increasing demands of consumer equipment, particularly in the area of rechargeable alkaline manganese cells – Ian Poole reports*

BATTERIES often seem like old hat technology, but with the greatly increased use in everything from battery powered children's (and adult's) toys to mobile phones and lap top computers, batteries are big business. Consequently, many manufacturers are competing for their section of the market, with the result that new technologies are being introduced, and older ones are being refined even more.

In recent years, new battery technologies such as Nickel Metal Hydride (NiMH) have become far more common, and others like lithium ion now have a respectable share of the market. But these are not the only technologies to be progressing.

Some of the more established technologies are being improved and new ones are arriving on the horizon or filling new niches of the market. All of these developments mean that battery technology is keeping up with the pace of the electronics industry in order to meet all the requirements being placed upon it.

There are a number of requirements being placed upon battery manufacturers. Size is an obvious constraint. Cellular phones are becoming ever smaller. In Japan, phones are even smaller than many on the market in the West. To enable these phones to operate satisfactorily, they must have batteries of comparable size and sufficient capacity.

Another requirement is that they must be competitively priced. Many batteries enter the consumer market where price is of paramount importance. Even in the professional field, there are many suppliers of batteries and this high degree of competition ensures that prices remain as low as possible.

## Rechargeable Alkaline

Over the years, a number of systems have been described for recharging ordinary primary batteries. This is not a process recognised by the battery manufacturers, many of whom state that it is dangerous. However, a new alkaline cell has been developed which is actually intended to be recharged. Although details about the exact internal chemistry are being kept secret, some details are available.

Called a rechargeable alkaline manganese (r.a.m.) cell, it has many of the characteristics of the familiar primary alkaline manganese cells (see Fig.1). It has the same terminal voltage and a similar charge capacity, about 1·5Ah against 2Ah for a typical AA cell.

Like the existing primary or non-rechargeable cells, this is largely dependent upon the load placed upon it. Self-discharge, a feature which is particularly important with rechargeable cells, is very low, only about 0·02 per cent per day, compared with about one per cent for a NiCd and as high as three per cent for a NiMH cell.

The life of the cells is considerably less than the established rechargeable cells. A maximum of around 200 charge/discharge cycles is expected, although 25 is said to be typical, and a minimum of about ten.

Although the life is not nearly as great as for a NiCd cell, the price is much less. This will make them very attractive for use in electrical items such as toys, photographic flash guns, radios and the like.

Chargers will be available for the cells. However, they are not the same as those used for NiCds, or those which claim to recharge alkaline primary (non-rechargeable) cells.

It will be interesting to see if these cells find a major sector of the market. The price seems to make them very attractive, but the additional cost of a charger, and the existence of established technologies like NiCds may make it a difficult struggle to achieve a large amount of the market share.

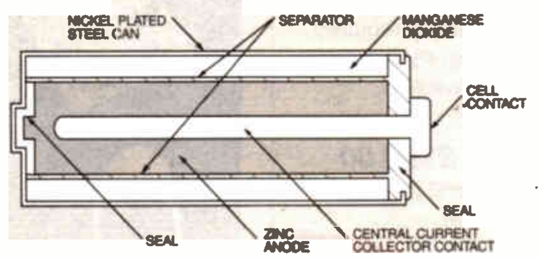



*Fig.1. Construction of a rechargeable alkaline manganese cell.*

## Flat Batteries(!)

Another area for development which is receiving a lot of attention is in the development of flat or thin batteries. There is a rapidly growing market for batteries for use in applications such as smart cards and a number of other innovative applications. One of these is for intelligent labels. These are likely to be used in the pharmaceutical industry for accurate monitoring and data capture.

These wafer thin batteries have to be less than 1mm thick and often under 0·5mm. In addition to this, they must be capable of holding a charge of around 20mAh or more. Furthermore, they must be rugged, and able to withstand the treatment they are likely to have to endure. A wide temperature range is essential as smart cards may be left in cars where temperatures can fall to −20°C or less in winter in some areas and up to +70°C at the height of summer.

Another requirement for many batteries, and in particular those used for labels, is that they should be flexible. This rules out many of the more familiar technologies forcing new ideas to be adopted for many situations.

## Lithium Polymer

One idea finding favour for many smart card applications is the new lithium polymer technology. This is based around the lithium cell, which is beginning to find favour in a number of the more conventional applications, but it uses a polymer electrolyte.

The cell voltage is about 3V, which is ideal for many applications. The cell from one manufacturer is also mechanically robust. It can tolerate a bend radius of around 100mm and can operate over a temperature range of −20°C to +75°C. Shelf life is also important, and this is said to be around ten years.

Other techniques are also being investigated. One example is a platinum silver cell which uses some advanced techniques in its manufacture. Silver is vacuum deposited onto a quartz substrate to create the first electrode. Next this is exposed to iodine vapour in a vacuum, to create a thin film of silver iodide which acts as the electrolyte. The second electrode is created by sputtering this structure with platinum.

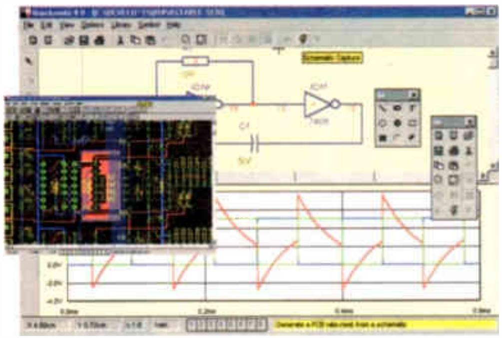
## Future

In due course, it is likely that batteries will be available in some totally new formats capable of being used in applications which could not have been conceived until recently.

In addition to this, other developments are taking place in the more traditional areas. It is expected that Lithium ion (Li-ion) cells will be the dominant secondary or rechargeable technology for the future, displacing NiCd and NiMH cells.

Although Li-ion cells are still being developed, their performance has reached the level where significant numbers of them are being manufactured, particularly in Japan, and it is expected that production will start in many other areas before long.

# Looks like Quickroute 4.0 has Got the Lot!



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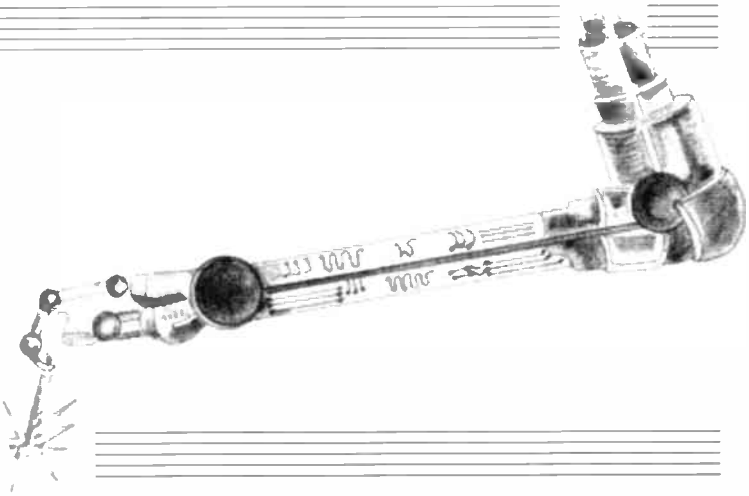


# CIRCUIT SURGERY

**ALAN WINSTANLEY**

***Ian Bell of the University of Hull lends a hand at the surgery and concludes his run-down on digital counters. We help with a transistor substitute and update you on the "Art of Electronics".***

CIRCUIT SURGERY is our monthly column which discusses a variety of readers' queries and problems related to electronics. We attempt to resolve points arising, and pass on technical tips and design hints. Ian Bell of the Department of Electronic Engineering at the University of Hull continues his authoritative discourse on the application of digital counters.

We hope Ian's input will help broaden the scope of the column, also, as we are receiving much more feedback from higher education than ever before – and thanks to our well-established Internet presence – from further afield, too!

## An American Dilemma

This month we start with a query from an American reader which highlights a few basic differences between European and American nomenclature and circuitry "norms" which might cause confusion amongst beginners. ***Toni Harter*** of Branson, MO, USA writes via E- mail:

*I'm new to all this and am trying to build a circuit from the UK but have got a few problems buying parts. Can you tell me anything about the ZTX300 transistor illustrated on Page 472 of the July 1997 issue of* Circuit Surgery*?*

*Is the pinout looking up from underneath? I'm trying to find a substitute because no-one has the ZTX300 over here. I have a 2N3711, would it be any good? I have a capacitor of 0·01µF here, it calls for a 10nF there! Will it work?*

*Help!*

Like all transistor pinouts, unless otherwise stated, the ZTX300 pinout shown on P. 472 is bottom view, i.e. ***from the underside looking up at the pins.*** There's nothing special about this particular transistor, except perhaps its useful current rating of 500mA in a small package (the so-called "E-line" plastic package). It is a general purpose small signal type, with plenty of scope for substitution.

Unfortunately I don't think the 2N3711 you have will be suitable as a replacement. It has a collector current ($I_c$) rating of only 30mA although it has a higher gain, according to the data. Instead you could try the 2N3704 which is good for 800mA collector current – better than the ZTX300. It is produced in a TO-92 package with pinouts B C E when viewed from the bottom, with the flat side pointing down.

Capacitor values are easy to understand once you have a little experience. We don't print values containing decimal points, because these can often reproduce badly during printing or photocopying, so that there is a danger of values being misinterpreted. We state smaller capacitance values using nanoFarads, which is common practice in Europe.

To convert from microFarads (µF) to nanoFarads, simply move the decimal point three places to the right.

0·0001µF = 0·1nF
0·001µF = 1nF
0·01µF = 10nF
0·1µF = 100nF

Then we would usually draw 1·0µF as 1µ, 2·2µF as 2µ2, 10·0µF as 10µ and so on, with the "mu" symbol replacing the decimal point. Similarly with resistor values, we would print "2·2k" (2,200 ohms) as 2k2, with the k representing the position of the decimal point in the resistance value, expressed in kilohms. The same goes for megohms (millions of ohms): a resistor value of 2M2 is 2,200,000 ohms.

This scheme might look a bit odd, but it actually saves readers lots of grief through accidentally misreading the capacitor values printed in drawings and components lists. Incidentally we are always happy to try to resolve any similar queries by E-mail or post, if any readers have problems concerning component substitutions.

## More Digital Counter Notes

Ian Bell of the University of Hull continues with his analysis of digital counting applications, something which we hope will help answer many readers' "counting problems" all in one go. ***J.J. Tarr*** of Great Missenden, Bucks asks for a bit of help concerning his local Bingo club! He writes:

*In order to help out my local Bingo club, I'm trying to develop a random number generator, which has to be a six figure type using a 4-inch display, and it should be as bright as possible. It needs to remain on until turned off, and I wish to use a transformer if possible. Please help!*

Here are a few pointers which might be useful. If you use something like an ordinary 555 astable to clock a digital counter at high speed (i.e. much faster than humans can follow) and arrange a switch to either disable the counter or gate the clock off (see later), then the number in the counter when the switch is pressed will be random; assuming the clock is constant then each number has an even probability of occurring.

## Potential Problem

There is a potential problem if you want to generate a large number this way, though, because the most significant digits (MSB) will change slowly. For example if you clocked a 6-digit BCD counter at 1MHz then the 100,000s digit would only be changing at a rate of 1/10 sec, and so it would be possible to influence the outcome somewhat, simply by looking at the display.

You could blank the display during counting, but if the most significant digit changed slowly enough it may still be possible for the user to have some control over the number. Note that CMOS devices can be clocked at higher speeds if you use 10V or 15V rather than 5V supplies. Whatever you do the counters should probably cycle completely in 1/10 to 1/100 sec to ensure they are not influenced by human reaction times.

For very many digits it may be possible to use *two* counters with fewer digits clocked from totally separate clocks at different frequencies. But it is not as simple as it seems. If one is an exact multiple of the other some numbers will not appear, or different numbers may

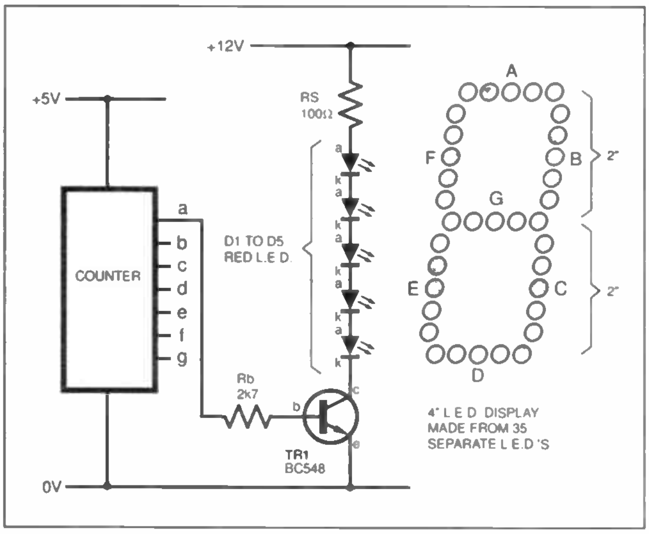



*Fig.1. Driving a giant-sized l.e.d. display using a transistor buffer. The transistor used in this instance is a BC548.*

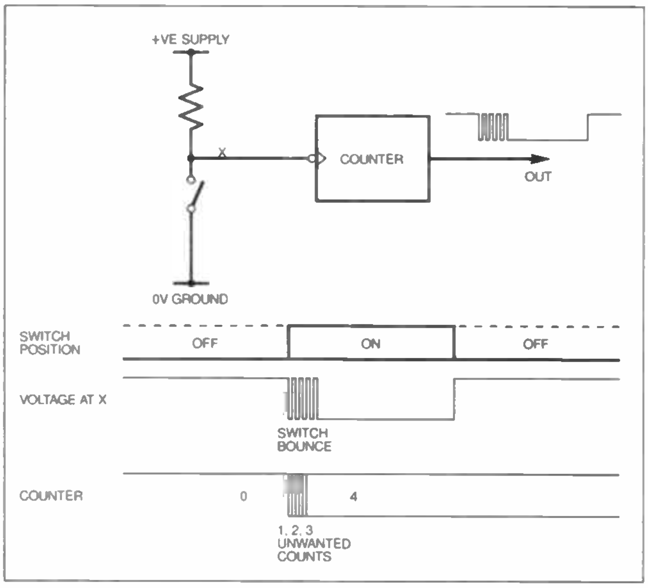



*Fig.2. A mechanical switch can suffer from "contact bounce" which causes unwanted counts to be generated.*

have different probabilities. Any mathematicians out there might like to work out the conditions for getting a fair number generator this way, and whether you can really get an effective reduction in cycle time. However, if the counters are manually stopped (see later) at different times their values will not be correlated even if their frequencies are.

A quick check in a Maplin catalogue highlights just the thing for the display in the form of a common anode l.e.d. 4-inch display (Cat. No. JX86T) made by Kingbright; it's actually formed of many individual l.e.d. chips, all integrated into a 7-segment display. Such devices are not cheap – your six-digit display would cost £120 alone!

## Giant L.E.D.

As an alternative, you could improvise using ordinary 5mm l.e.d.s wired individually to form "bars". These l.e.d.s. cost as little as eight pence each (**ESR Electronic Components, *Tel. 0191 251 4363***). If five l.e.d.s were used for the segments then a 7-segment 35-l.e.d. unit would cost under £3 (consider a bulk surplus pack of l.e.d.s, too) although it won't appear as sophisticated as a proper 4-inch device. Also consider buying high-brightness types but these will be more expensive.

Many chips only offer a milliamp or two of output current, so it's necessary to buffer this with a driver before you can do any useful work. (A higher output current may be available when a higher supply rail is used.)

We actually had quite a discussion concerning the best way to produce a giant-size l.e.d. display feasibly. If you wire the l.e.d.s in series, then they will require a relatively high drive voltage – say 10V forward voltage per 5-l.e.d. "segment" though the current required may only be about 20mA or so per segment, and only one series limiting resistor would be needed.

The trouble is that you would probably notice major differences in illumination of the individual l.e.d.s. Fig. 1 shows one suggestion, with a higher drive rail being used for the display. If you wire all five l.e.d.s in parallel, a lower drive voltage will be needed along with a greater drive current. It would then also be best to use a series resistor for each l.e.d., which is likely to be over-elaborate.

## Counters as Timers and Frequency Meters

If the clock to a counter is set at a particular frequency (such as 1 pulse per second) and the counter has an "enable" control or "clock gate", then the count value (assuming the counter started at zero) represents the time period for which the counter was enabled (in this case in seconds). The accuracy of the timing depends on the accuracy and stability of the clock frequency. This however lends digital counters to performing a variety of tasks.

If a counter is enabled, or the clock is gated on for a set period of time, then the count value is related to the frequency of

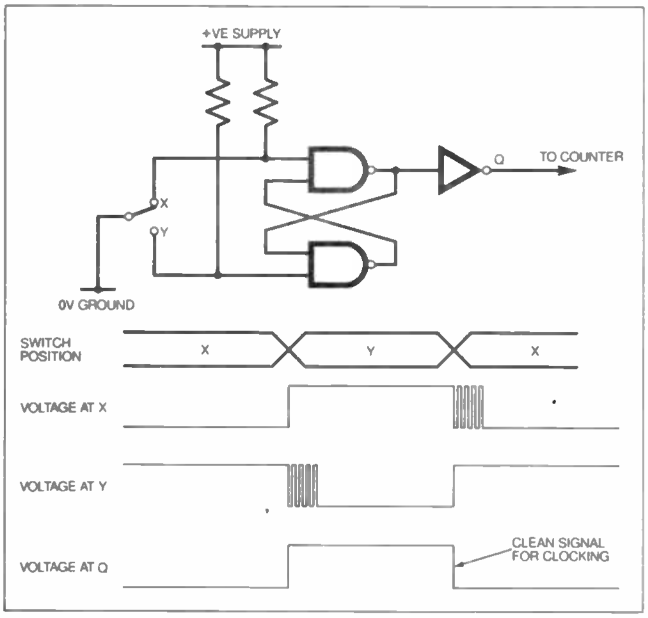



*Fig.3. A switch debounce circuit can be made using a Set-Reset (S-R) flip-flop.*

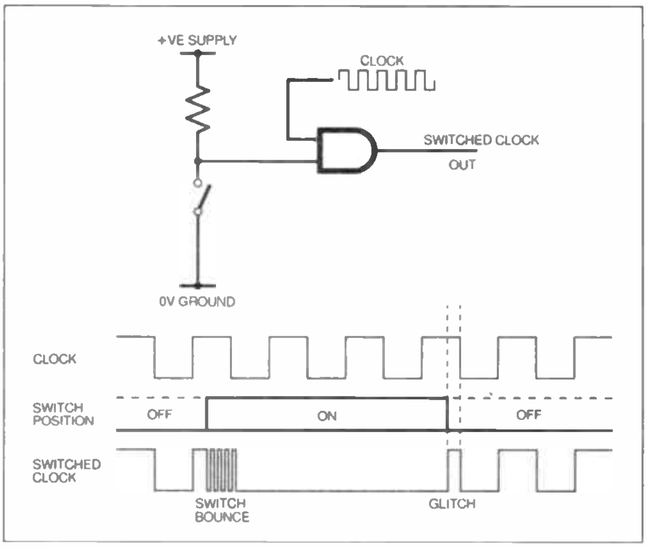



*Fig.4. Switching a clock signal can cause both "glitches" and bounce problems. To overcome these kinds of side effects, it is advisable to use a synchroniser circuit.*

the clock. For example, if a counter is enabled for one second then the count value will display directly the frequency in Hertz (Hz), so long as the counter has not overflowed (or cycled round multiple times), and the clock cycle is shorter than half the enable period.

For accurate measurement there should be many clock cycles during the enable period. The accuracy of the measurement depends on the accuracy of the timing of the enable period. If the frequency varies the count will reflect a sort-of average value of frequency over the enable period.

It would seem a simple matter to connect a switch to a counter input (Fig. 2) in order to count the number of times a switch is pressed. However, if you do this you will probably find that the counter steps by *more* than one (and a varying amount) each time the switch is pressed.

This is because mechanical switch contacts often "bounce", making and breaking the contact over a period of a few milliseconds, before coming to rest. Digital circuits can easily detect rapid transitions arising from multiple clocks being fed to the counter, which gives rise to unwanted counts. However, a debounced switch can easily be obtained using a Set-Reset (SR) flipflop as shown in Fig. 3.

## A Small Glitch

If you want to use a switch to control a clock (in a timer circuit, for example), then once again glitches (very short pulses which behave unpredictably) may be generated which can be detected by digital electronic circuitry.

How these problems manifest themselves in the switched clock output of the AND gate is shown in Fig. 4. To overcome these kinds of side effects, it is advisable to use a synchroniser circuit, as illustrated in Fig. 5a, which will prevent glitches.

The "control" signal can be derived from an S-R flip-flop which will debounce the signal from the switch ("clock on/off"). In fact the control signal for the clock can be derived either from a change-over switch or by using two separate push-buttons as a "start" and "stop" control.

The control signal derived then toggles a D-type latch whose output is used to gate the clock signal with an AND gate. Thus, the clock signal will be controlled without the possibility of switch bounce or glitches.

**CIRCUIT THERAPY**

*Circuit Surgery* is your column. If you have any queries or comments, please write to: Alan Winstanley, *Circuit Surgery*, Wimborne Publishing Ltd., Allen House, East Borough, Wimborne, Dorset, BH21 1PF, United Kingdom. E-mail **alan@epemag.demon.co.uk.** Please indicate if your query is not for publication. A personal reply cannot always be guaranteed but we will try to publish representative answers in this column.

## Teach-In '98

We're happy to offer both E-mail and postal support to followers of our new educational series *Teach-In '98: An Introduction to Digital Electronics.* If there are any particularly relevant queries arising, space permitting, we will try to cover them here in *Circuit Surgery*. An early query addressed to the Teach-In '98 desk (**Teach_In98@epemag.demon.co.uk**) was sent by ***Mike Simpson***, who asks:

*I'm starting more or less from scratch and am really looking forward to following your* Teach-In '98 *course. I have a couple of questions however. Question 1: are there any books I would find invaluable through this course, or any you would recommend as a point of interest? Question 2: I'm interested in learning how to program PLCs for electronic circuits, are there any magazines covering this area available, or can a book/course be recommended. Best regards from Mike Simpson (by E-mail).*

## Art of Electronics

In the global forum of the Internet newsgroups, the best all-round electronics text book in the world is generally considered to be *The Art of Electronics* (Second Edition) by Horowitz & Hill (Cambridge University Press, 1,125 pages, ISBN 0-521-37095-7), together with the optional accompanying Student's Handbook.

The "Art" starts with basics and treats the subject as a mixture of educated guess, hunches and experience. It's highly authoritative, very readable and it answers all those questions that crop up in practice but to which you will probably never find the answers otherwise. I like the style very much.

Co-author Winfield Hill in the USA tells me that a Third Edition isn't actually in the works right now, but they *will* be updating the book sometime in the near future. Then the process may take about three years.

They have been soliciting opinions about the best way to proceed with the Third Edition, the page count being restricted or they could go on for ever (we know the feeling!) and they wonder if the clamour for a new edition isn't really for more advanced material, but for more of a sequel!

Anyway, flick through a copy in your local book store. There is also a web site at **http://www.artofelectronics.com** to which I have previously linked via my *Net Work* Internet column.

## PICtorials

On to your second question, perhaps you mean PICs (Arizona Microchip's brand of microcontroller i.c.) – in which case our Technical Editor John Becker has an excellent *PIC Tutorial* series lined up for the not too distant future, something not to be missed as it will shed a lot of light on the black art of using microcontrollers. (A PLC – Programmable Logic Controller – is beyond the remit of *EPE*, being designed for industrial process control applications.)

Incidentally, the last I saw of John, he was glued to the computer screen of his brilliant new *EPE Virtual Oscilloscope* design, of which all IBM PC-compatible users should be eagerly anticipating the appearance! It's awesome!

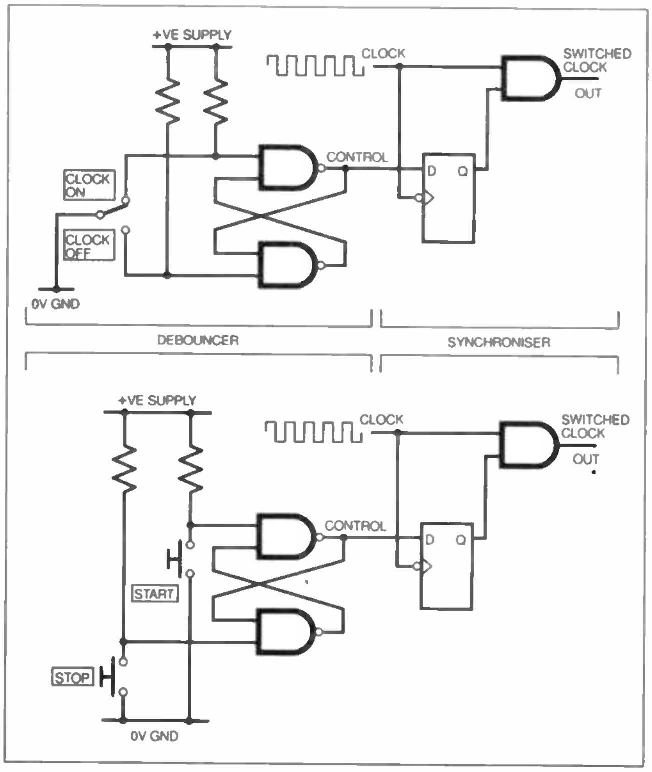



*Fig.5a (left). An S-R flip-flop and D-type latch provide full switched control of a clock signal, free of bounce and glitches.*

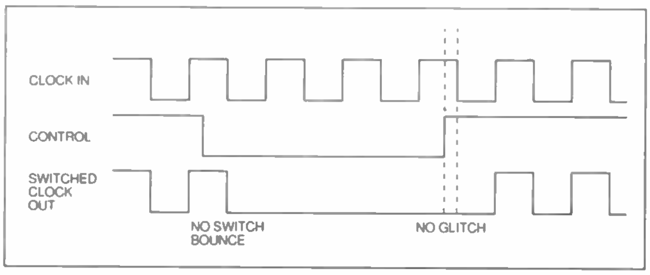



*Fig.5b. Output waveforms of the debounced synchroniser circuit of Fig.5a. Compare this with Fig.4.*

# Innovations

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

# Data Comms via the Mains

## Norweb and Nortel are investigating the use of mains power lines for long-distance communications, but it's fraught with problems. Barry Fox has the details

THE widely reported plan by Norweb Communications and Nortel (Norther Telecom, formerly STC) to pipe data through mains cables grew out of a scheme to provide a telephone or cable TV service. Nortel and Norweb patented the idea but after a first round of tests, abandoned the scheme and will instead try using the mains to provide access to the Internet. This will allow Internet telephony, which carries audio as packets of data and delivers only muffled, delayed and often glitched speech. Video will be subjected to the same compromises.

Although Norweb and Nortel have loudly claimed strong patent protection, they were unable to identify any of the patents which they own. They were also very secretive on technical details. There was no demonstration of working equipment and even limited trials will not begin until mid 1998. My personal search uncovered several hundred pages of patent applications filed over the last five years, which audit-trail the development and dashed hopes.

## HF CARRIER TESTS

Five years ago Norweb patented the idea of superimposing a high frequency carrier signal on the 50Hz mains, to carry digital sound and video. Tests began last year, using a modified version of the system developed for CT2, the second generation digital cordless telephone.

But to carry data at high rates, the carrier must be of high frequency. The mains wires then behave like a radio aerial, broadcasting the signal and causing interference to audio, video and computer equipment. To conform with European regulations on Electromagnetic Compatibility, Norweb must keep the HF carrier down to a few millivolts, compared to the 230V a.c. mains. So the carrier is always on the brink of being swamped by the random mush of interference which pollutes the mains because the cables behave as a receiving aerial.

Norweb initially planned a system which used coaxial cable or optic fibre to pipe the speech and vision to street units which then combined the weak signals with the mains for the last short run into the home. It is costly to lay extra coaxial cables, so Norweb will connect its transformer substations to the Internet and use combiners at each station to add a communications carrier to the mains. The carrier is a spread spectrum of different frequencies which smear over the background noise. So interference at one frequency still leaves most of the carrier untouched.

A filter unit, clamped to the subscriber's meter, separates the useful spread from the mains and background noise, and feeds it to a home communications network. A PC, which must be fitted with a suitable decoder card costing around £200, connects to the network and thus also the Internet.

Norweb will charge a monthly fee for access but has yet to fix a price which competes with the phone companies but recoups capital investment. MD Mark Ballett estimates it would cost the company £200 million to offer access to its two million electricity users in the North West of England.

## CRUMMY MEDIUM

Norweb's plan to put raw sound and video on the mains foundered because the weak carrier is completely destroyed by powerful noise spikes that are much stronger than the constant mush. The spikes come from dimmer switches, refrigerator or boiler thermostats and power tools anywhere in the street.

"The mains is a crummy medium for communications", says Ian Vance, Nortel's chief scientist, "it was never designed for this purpose".

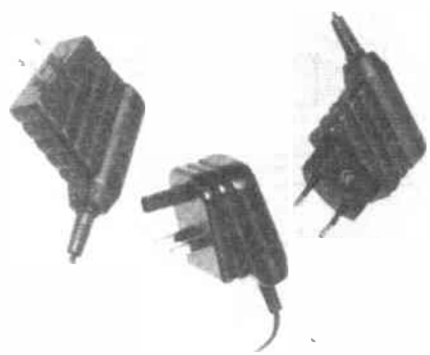
The Internet puts data in packets. When corrupted, they are sent again. This makes the signal robust against spikes, but adds delays which disrupt real time sound and vision.

After trials begin next year, Norweb will gather feedback for six months. Internet telephony will follow after two years. Data speeds of up to one megabit/second are promised, but this may not improve audio and video quality over conventional phone lines and modems. Even with a 64kbit/s ISDN line, which can carry broadcast quality digitised speech when used for a direct connection, the Internet currently delivers only muffled sound, which is delayed by the packetising process and often glitched.

Norweb and Nortel hope to licence their system to other electricity companies, in the UK and abroad. But not in the US. In Europe substations serve around 250 homes so it is cost-effective to modify them. North American substations, often on poles, supply only around a dozen homes.

# MINI POWER SOURCE

RELEC have introduced an accurate plug-in power supply so small that it is hardly bigger than a standard mains plug.



Mainy-N1 occupies exactly the same area on an a.c. power socket as a mains plug, thus making it possible for all adjacent outlets to be utilised. Any ardent hobbyist will appreciate *that* advantage in the workshop!

Added to this is Mainy's outstanding efficiency figure of around 70 per cent, which provides adequate evidence of a highly advanced switched mode design. It can maintain a d.c. output voltage to within one per cent of nominal, irrespective of loading or mains fluctuations.

The unit is offered in a range of ten standard output voltages between 3V and 24V, all with a 6W rating.

For further information, contact Relec Electronics Ltd., Dept. EPE, 124-126 Stockbridge Road, Winchester, Hants SO22 6RW. Tel: 01962 863141. Fax: 01962 855987. E-mail: sales@relec.co.uk.

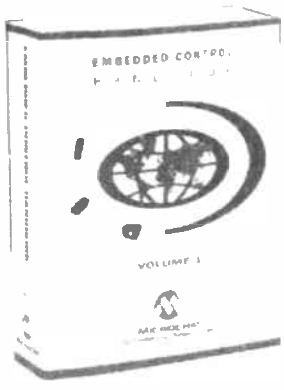
# PIC HANDBOOK

MICROCHIP have released the latest edition of their *Embedded Control Handbook*. Serious users of PIC microcontrollers will find this 1866-page book a powerful reference tool that provides current application notes, technical briefs and reference designs.

The book is available through any authorised Microchip agent, or at the company's website.

Also, don't miss our great PIC wall-chart to be published next month!

For further information contact Arizona Microchip Technology Ltd., Dept. EPE, Unit 6, The Courtyard, Meadowbank, Furlong Road, Bourne End, Bucks SL8 5AJ. Tel: 01628 851077. Fax: 01628 850259. Web: www.microchip.com.




# Data Down!

MAURITRON Technical Services, renowned for their excellent service manuals and technical books, have told us that they have dropped the price of their CD-ROMs to £24.95 (plus £2·50 P&P, plus VAT). If you are looking for technical data of any sort, find out what Mauritron has to offer:

Mauritron Technical Services, Dept. EPE, 8 Cherry Tree Road, Chinnor, Oxon OX9 4QY. Tel: 01844 351694.

Fax: 01844 352554.

E-mail: sales@mauritron.co.uk. Web: http://dialspace.dial.pipex.com/mauritron/.

# STRIPBOARD MAGIC

AN innovative new PC-based CAD layout program for stripboard and breadboard has been announced by Ambyr. Called StripboardMagic, it is intended to take the uncertainty and drudgery out of translating theoretical electronic circuit design into practical stripboard layouts.

Paul Kelsey, co-founder of Ambyr, says: "We believe that StripboardMagic is the first computer-aided circuit layout utility for stripboard and breadboard. Until now, if you wanted to use stripboard, you had to work out the layout by hand. Now time-saving, error reducing simplicity of auto-layout is no longer the exclusive preserve of p.c.b. constructors".

StripboardMagic features a simple drag-and-drop circuit editor, extensive component library, automatic circuit layout on stripboard or breadboard, a detailed construction diagram to guide the assembly stage and an automatic generation of component order forms.

The software package costs £39·95 including VAT (plus P&P).

For more information contact Ambyr Ltd., Dept. EPE, 23 Priory Road, Newbury, Berks RG14 7QS.

Tel/Fax: 01635 521285.

E-mail: info@ambyr.com.

Web: http://www.ambyr.com.

# Tool-up With Squires!

FRESH in from Squires Model & Craft Tools is their 1998 catalogue – and it's *free – totally free of any charge*, even postage! Squires' existing customers will, of course, have already received their own copy.

If you are not already a Squires customer, just give them a call saying *EPE* told you to! What you'll get is nearly 150 pages of A4-sized information and prices for practically any item of tooling you need for electronics and other craft work. From abrasive blocks to Xuron cutters, the range is extensive.

Squires will also be exhibiting at numerous events in 1998 – ask them to tell you of events near you.

For more information contact Squires Model & Craft Tools, Dept. EPE, The Old Corn Store, Chessels Farm, Hoe Lane, Bognor Regis, W. Sussex PO22 8NW. Tel/Fax: 01243 587009.

# EMMA AWARDED

THE Radiocommunications Agency has announced that the *Young Radio Amateur of the Year Award* has been won by 15 year old Emma Constantine from West Yorkshire, receiving £300 from the RA and a certificate signed by Margaret Becket, President of the Board of Trade. The award was made at the Radio Society of Great Britain's HF convention at Windsor in September.

The RSGB has also announced publication of its *RSGB Yearbook 1998 Edition*, priced £13·90, excl. P&P. Other new publications have been announced as well, including the *CallSeeker 98* CD-ROM which includes the complete contents of the Yearbook.

For more information about the RA Awards and RSGB publications, contact the Radio Society of Great Britain, Lambda House, Cranbourne Road, Potters Bar, Herts EN6 3JE. Tel: 01707 659015. E-mail: sales@rsgb.org.uk. Web: www.rsgb.org.uk.

# SPACE NET

NEW British ideas using satellites to provide superfast services have been awarded grants by the British National Space Centre (BNSC).

The initiatives, which include schools link-ups, are being developed with help from BNSC's Satellite Multimedia Application Demonstration Programme (SMADP), part of the DTI's Society Initiative.

Of particular interest will be the trial delivery of educational multimedia to teachers and students. *Espresso for Schools* will seamlessly integrate a rich mix of audio, video, text and data relating to geography, science and IT subjects within the national curriculum.

Announcing the grants, Barbara Roche, Minister for Industry, said, "Satellites have a major contribution to meeting the needs of the emerging Information Society. In the long run they could make using the Internet faster and cheaper, and enable it to be accessed from any point on the planet – no matter how remote."

Still in space, it's interesting to learn from the DTI that the recently launched mission to Saturn will use British-made parachutes to land the Huygens probe on the planet's moon Titan. Martin-Baker Ltd. of Uxbridge designed and produced the parachute system. (If memory serves us right, Martin Baker was the man who invented the aircraft ejector seat, in about 1949.)

For more information, phone the DTI's Public Enquiries number: 0171 215 5000.

# Inventors Take Note!

INVENTOR Patrick Lawrence has had his book *The Business of Invention* published, priced at £12.99. In it he shows how to turn a patentable idea into a profitable product, and provides a valuable and friendly guide through the minefield of patent agents, design agencies, licensees, county courts and the whole area of public and private support schemes for inventors, ending with a useful index of phone numbers to call for advice.

Lawrence has invented a number of household-name products and his book is based on his own experiences and partly on an investigation of the available sources of support for independent inventors in the UK.

The book is published by Management Books 2000, Dept. EPE, Cowcombe House, Cowcombe Hill, Chalford, Glos GL6 8HP. Tel: 01285 760722. Fax: 01285 760708. E-mail: 106002.3004@compuserve.com.

# PAYING THE NEWS PIPER

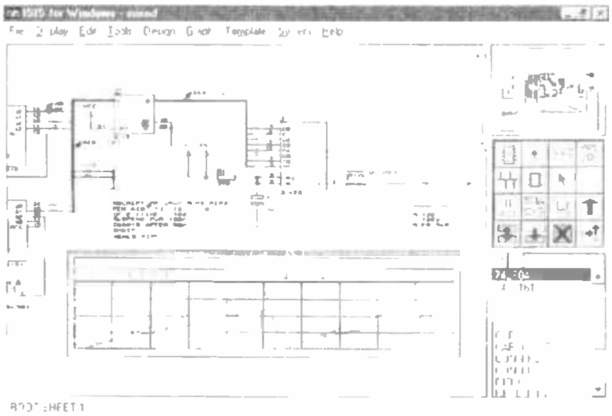
## Watermarking, wobbling and black-tone decoding aid in ensuring video copyrights are honoured and paid for – Barry Fox reports

WORLDWIDE Television News, the news-gathering subsidiary of Walt Disney's empire (and the company which employed John McCarthy when he was kidnapped in Beirut) has joined with Philips of the Netherlands and won a grant from Europe's Esprit program to develop technology which checks whether TV stations are paying to use hard-won news footage in their bulletins.

WTN distributes its news by satellite, which makes it easy to steal. "Sometimes even honest broadcasters forget to pay", says Gijs (Gerry) Wirtz of Philips Copyright Department. "So news services need a way of monitoring everything that is broadcast to check its origin."

### VIVA LA DIFFERENCE

Gerry O'Reilly, WTN's Vice President, told Philips what the news industry wanted and coined the name for the project, Visual Identity Verification Authority. A watermark, hidden inside a video sequence, can be sensed by a decoder. The mark should not cause any visible artefacts in the picture and must survive conversion between the different TV standards used round the world (NTSC for the US and Japan, PAL for most of Europe and SECAM for France). The mark must also survive digital coding for transmission on the Internet or by satellite, and conversion back into analogue form for display on a TV set or recording on a VCR.



## PROTEUS IV

LABCENTER Electronics have released the latest version of their PROTEUS Electronics Design System.

The major enhancements include: automatic component placement; improved autorouter; full control of schematic drawing appearance; more component libraries; pin-swap/gate-swap; new simulation types including Fourier and Audio analyses.

PROTEUS IV is available in five levels, with prices ranging from £295 to £1645. Trade-ins are available against both previous versions of PROTEUS and other EDA software. Demonstrations can be seen on Labcenter's website.

PROTEUS-Lite CAD software has also been released by Labcenter as freeware/shareware versions, enabling you to acquire powerful schematic capture and p.c.b. design modules. They are available for free download from the web address below.

For more information contact: Labcenter Electronics, Dept. EPE, 53-55 Main Street, Grassington, North Yorks BD23 5AA. Tel: 01756 753440. Fax: 01756 752857. E-mail: info@labcenter.co.uk. Web: www.labcenter.co.uk.

Philips has already tested existing systems and found them wanting. Existing systems modify some pixels or picture points in a predetermined pattern that is invisible to the human eye but detectable by a decoder which knows what patterns it is hunting. Philips found that the marks do not survive changes in the picture shape. If the video image is cropped, stretched or compressed, the pattern is distorted and the decoder no longer recognises it.

Philips is working on a quite different approach. A recently published patent application filed by Gijs Wirtz explains the technology.

Philips takes advantage of the fact that any black part of the video picture will have zero luminance (black and white information) and zero chrominance (colour information). If the colour information value is artificially raised, then the black area will still look black. But a decoder will be able to register the abnormal imbalance of luminance and chrominance signal.

Although there are always some black areas in any TV picture, their positions are always changing and unpredictable. Non-black areas of the picture will naturally have imbalance between luminance and chrominance. So the decoder has no way of knowing where it should be looking for unnatural imbalance. Philips solves this problem by temporarily adding a thin black line at the extreme top or bottom of the picture and unbalancing its luminance and chrominance values. The line is not noticed because it becomes part of the black borders which are always present at the extreme top and bottom of the picture and are usually masked by the casing round the TV tube.

The decoder knows exactly where it must look for a black marker, and where there would normally be zero luminance and zero chrominance. Any imbalance is thus a man-made watermark. Changing the black line between balanced and unbalanced state conveys a stream of digital 1s and 0s. This stream decodes as binary words which carries copyright information.

The mark survives conversion between different TV standards, and conversion between digital and analogue domains, because the convertors all handle the luminance and chrominance content separately and preserve any balance or imbalance.

### WOBBLING DVDS

Philips will use the same marking system on digital video discs as a part of a double check system. A DVD player will first look for any watermark in the picture sequence, and decode any copyright message it contains.

The player will then check whether the disc is an original, pressed in a factory, or a home-recorded blank. The difference is in the signals on the disc which guide the laser in the player. Pressing plants will add a "wobble key" to the guide signals. There is no wobble on a blank disc. The servo control in the player easily compensates for the wobble, but the fact that it is doing so confirms that the disc is an original. If a disc has no wobble key, but does have a copyright watermark, it is identified as a copy and the player refuses to play it.

Californian company Macrovision has already proposed and patented a similar idea for wobble keying. Wirtz confirms that Philips is now "in discussion" with Macrovision about who got in first with a patent claim to wobble keying.

Whatever happens, wobble protection relies on the manufacturers of DVD players agreeing to build the necessary detection circuitry into all future players. So far there has been no such agreement. Watermarking of news footage needs no such agreement.

If the system works, WTN will be able to monitor all news bulletins, look for its mark and check that the broadcaster pays for use.

EVERYDAY PRACTICAL ELECTRONICS

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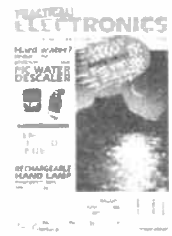

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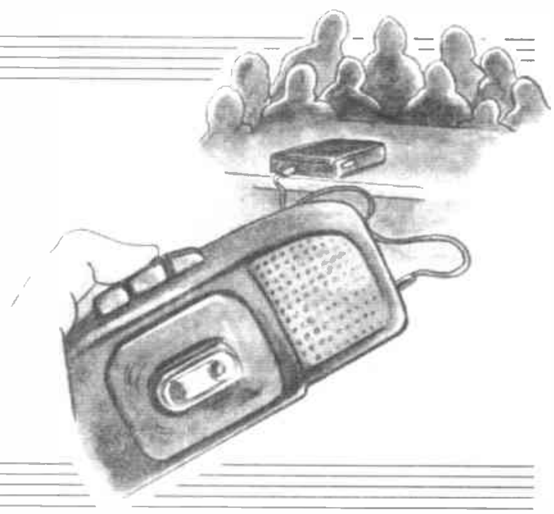
Constructional Project



# ACTIVE MICROPHONE

## ANDY FLIND

*It's remarkable what your cassette recorder might pick-up with a bit of simple input circuitry.*

WAY BACK in the May '96 issue of *EPE*, a tape-operated controller for the author's *Mind Machine* project was described. Readers may recall that this used a miniature pocket dictating machine for recording and replaying the programmed control signal.

These little "micro-cassette" recorders are now inexpensive and widely available. The one used for the controller project permits selection of a reduced tape speed for longer recordings with only a slight reduction in audio quality, and also has a "sound-activated" recording mode.

Their features could be very useful for recording meetings, lectures, speeches and the like, but unfortunately the effectiveness in such situations is severely limited by poor microphone sensitivity. The recorder appears to be designed to be spoken into at short range, probably to minimise external noise when used for dictation.

However, as an external microphone input socket is provided, it is clearly possible to use an amplified external microphone for applications requiring greater sensitivity. This project provides such a unit, which should be suitable for use with many of these little recorders.

### DESIGN OBJECTIVE

A design objective was that the unit should have an inconspicuous appearance as some lecturers might be distracted by the sight of a microphone pointing at them from the audience. In addition, there could be applications requiring completely unobserved recording, perhaps in security work.

Two further aims were that the unit should be self-contained and self-powered, with the connection to the recorder made through plugs and sockets so that the length of the connecting lead could easily be changed.

The use of an independent battery supply side-steps the possible problem of instability caused by feedback through the power rails, which might occur if the unit was operated from the same battery as the recorder.

A small "electret" microphone insert is used for signal input, with a simple amplifier to provide the necessary signal level boost. Achieving the required gain is easy, but the very low level of the input signal calls for an amplifier with a low internal noise level.

For further reduction of noise and interference, the frequency response is tailored to cover only the range required for speech, about 100Hz to 5kHz.

### PRACTICAL CIRCUIT

Early design experiments with the prototype were carried out using a TL071 op.amp i.c., but it was soon found that a circuit employing discrete transistors gave much less background hiss. Eventually, this led to the circuit of Fig.1, which provides excellent sensitivity and clarity with a minimum of background noise.

Electret microphones normally contain an internal buffer amplifier which requires a small amount of power. In Fig.1, the microphone insert, MIC1, is supplied with power through resistor R1 and the mic. input signal is taken through capacitor C1 to amplifying transistor TR1. This has a maximum voltage gain set to about 22, or 27dB, by resistor R7 and capacitor C3.

This capacitor also helps to set the low frequency roll-off point to about 100Hz. The upper frequency roll-off point is set with capacitor C2 to about 5kHz.

Smaller values of C2 can be used to increase the upper frequency response if required, but some capacitance is essential here as without it TR1 amplifies frequencies well into the radio spectrum, and can pick up all kinds of interference!

The output from TR1 appears at its collector (c) and is buffered by the second transistor TR2 to allow the driving of relatively low-load impedances, if necessary.

Capacitor C6 removes the d.c. potential from the output, which then goes to jack socket SK1.

The circuit is powered by a 9V PP3 battery, with capacitors C4 and C5 providing the usual supply decoupling. The current drawn by the circuit is very low, about 2mA, so prolonged operation is possible.

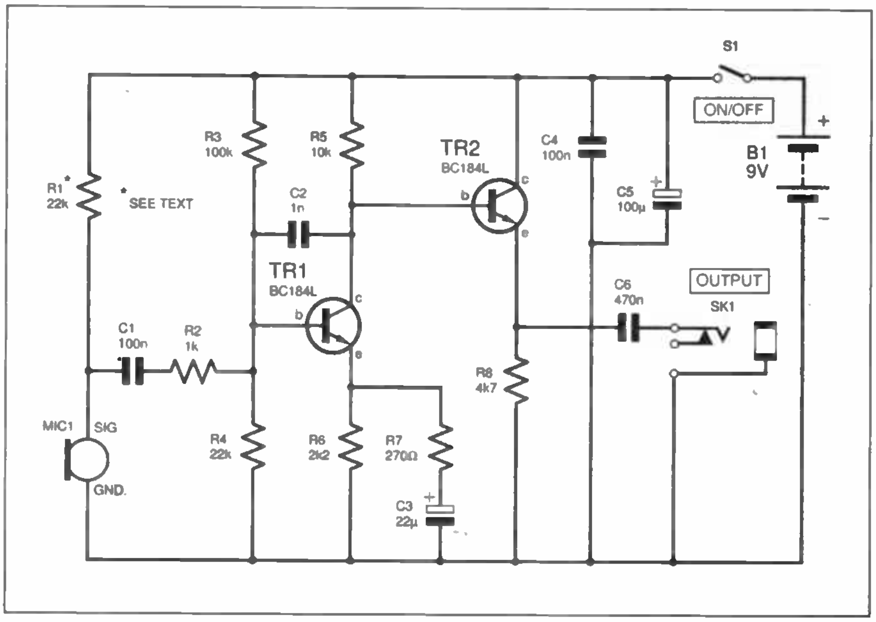



*Fig.1. Full circuit diagram for the Active Microphone.*

## CONSTRUCTION

The prototype is fitted into a diecast metal box with internal dimensions of just 96mm × 46mm × 21mm, so the layout of the circuit board is fairly compact. This is constructed on a piece of 2·54mm (0·1in.) pitch stripboard with seven strips of 18 holes.

This is first cut to fit into the guide slots provided in the case, ensuring a reasonably tight fit to prevent any amplified rattles if the unit is moved during use.

The lid of the box has a locating ridge around its inside edge and two corners of the board are notched to provide clearance for this. The breaks are then made in the underside copper strips as shown in Fig.2; there are 21 in all.

Note the line of breaks at each end of the board, these are intended to ensure that no part of the circuit inadvertently makes contact with the metal case. A plastic case could be used, but a diecast metal one is preferable for both screening and sound-deadening properties.

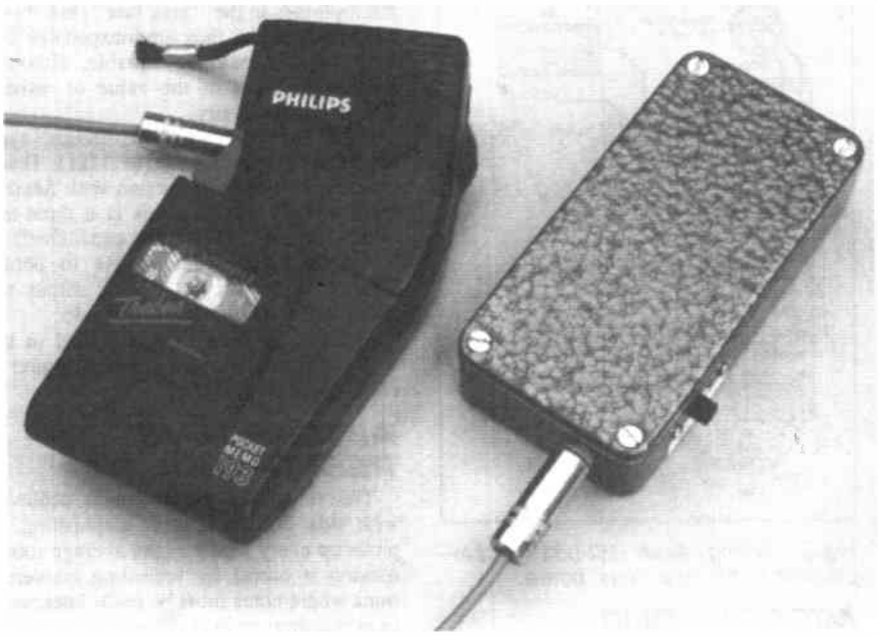
The track breaks should be checked with a magnifying glass to ensure no "whiskers" of copper remain around the edges as these are sometimes almost invisible to the naked eye.

Components are fitted as shown in Fig.2, starting with the four links. To keep the board as compact as possible, five of the resistors are fitted in a vertical position and capacitor C5 is placed horizontally on the copper side, with a bit of *Blu-Tack* to secure it in place.

## TESTING

Testing of the board is straightforward. When powered by a 9V supply, it should draw only a couple of milliamps. If an oscilloscope is available, the circuit can be checked for a voltage gain of between 20 and 30 at 1kHz.

However, if a d.c. voltage close to half of the supply is present at the collector of transistor TR1 and at the emitter of TR2, the circuit is probably working correctly. The emitter (e) voltage of TR2 will, of course, be about 0·6V lower than that of TR1's collector due to TR2's base-emitter (b-e) voltage drop.

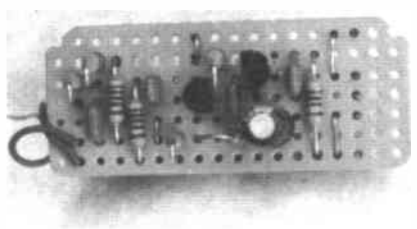



## ENCLOSURE

The unit can be housed in any case of the constructor's choice, though the prototype uses a small diecast metal box as described earlier. This is supplied with a grey "hammertone" paint finish and looks both neat and fairly inconspicuous.

The case is connected to the circuit's 0V supply (battery negative) to improve screening. Usually, this connection will be made automatically through metallic contact with the output jack socket SK1, though this should be checked and a separate connection provided if necessary.

Connections for this socket, power switch S1, battery B1 and microphone MIC1 are all shown in Fig.3. Connection to the recorder should be made using a screened lead.



*Completed stripboard showing component layout. Capacitor C5 is mounted on the underside.*

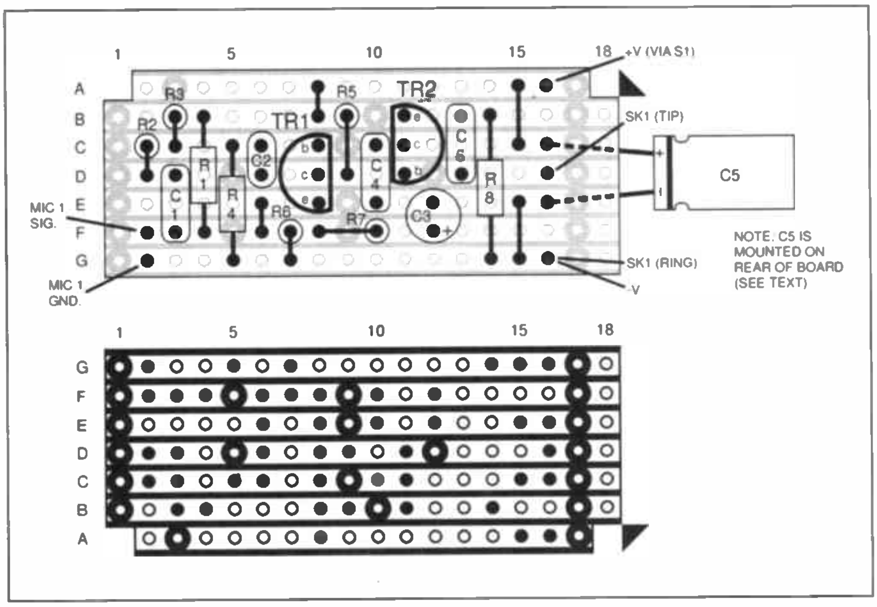



*Fig.2. Enlarged view of the stripboard topside component layout and underside details showing breaks in the copper strips for the Active Microphone.*

## COMPONENTS

**Resistors**

| | |
|---|---|
| R1 | 22k (see text) |
| R2 | 1k |
| R3 | 100k |
| R4 | 22k |
| R5 | 10k |
| R6 | 2k2 |
| R7 | 270Ω |
| R8 | 4k7 |

All 0.6W 1% metal film

See SHOP TALK Page

**Capacitors**

| | |
|---|---|
| C1, C4 | 100n resin-dipped ceramic (2 off) |
| C2 | 1n resin-dipped ceramic |
| C3 | 22μ radial elect. 16V |
| C5 | 100μ radial elect. 10V |
| C6 | 470n resin-dipped ceramic |

**Semiconductors**

| | |
|---|---|
| TR1, TR2 | BC184L *npn* silicon transistor (2 off) |

**Miscellaneous**

| | |
|---|---|
| S1 | on-off slide switch |
| SK1 | 3·5mm mono jack socket |
| MIC1 | electret microphone insert |
| B1 | 9V PP3 battery |

Stripboard, 2·54mm (0·1in.) pitch, size 7 strips × 18 holes; PP3 battery connector; diecast metal box, "hammertone" finish, 96mm × 46mm × 21mm; 3·5mm mono jack plug; screened connecting lead to recorder.

**Approx Cost Guidance Only £10 excl. batt.**

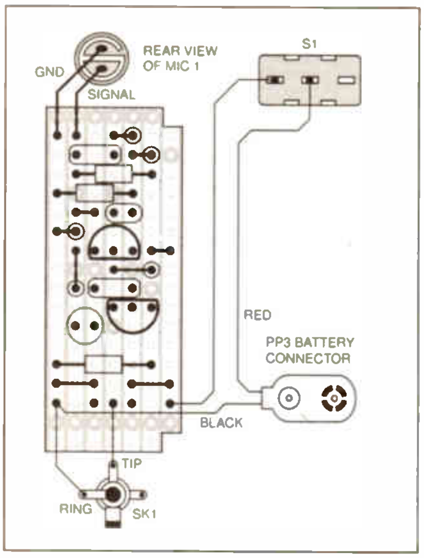



*Fig.3. Wiring from off-board components to full size circuit board.*

## MICROPHONE

Most electret microphone inserts have two connections similar to that shown in Fig.3, where one is obviously connected to the metal case. This should be connected to 0V (battery negative), whilst the other is normally connected to the positive supply through a resistor.

The microphone insert used in the prototype is a very small type taken from a piece of scrap equipment, along with its rubber mounting. Various alternative types have been tested and most worked as well or better.

Many readers will have such spare microphones in the "junk box", but if one has to be bought, they are inexpensive and most types should be suitable, although some adjustment of the value of resistor R1 may be necessary.

Tandy's inexpensive "PC-Mount" type works well with R1 set to 12kΩ. However, beware of their version with flexible leads already fitted as this is a three-terminal device (and it is more expensive!).

Adjusting the value of R1 to obtain about half the supply voltage across the insert will usually give good results.

A 3mm diameter hole is drilled in the wall of the box to allow adequate sound to reach the microphone.

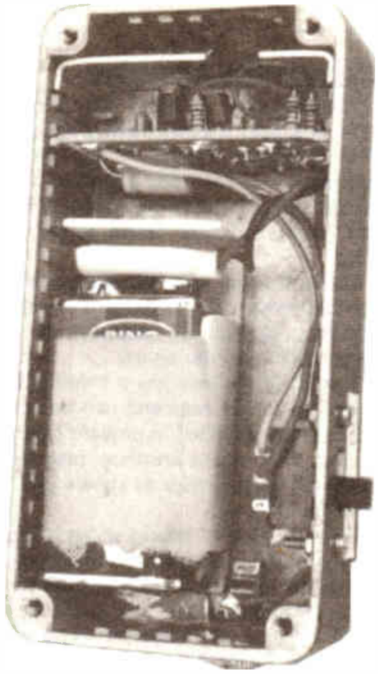
## ASTONISHING RESPONSE

The sensitivity improvement achieved with this little gadget is astonishing. It picks up every sound in the average room, making it useful for recording conversations where notes must be made later, such as at meetings or interviews.

It has been used to record lectures from a position well back in the audience, where it can be placed inconspicuously on a desk facing the speaker, whilst the recorder itself is operated from a position out of sight.

Operation of the recorder's "voice activated" recording facility becomes sensitive enough to allow "hands free" note-taking, which can be very useful when searching through reference books, or when designing and testing circuits!

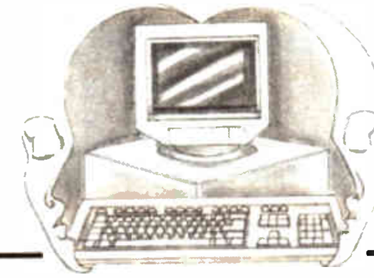
No doubt readers will be able to think of many other uses, perhaps in applications other than with a tape recorder. The sound quality is surprisingly good despite the limited frequency response, so it might even find applications in such pursuits as wildlife recordings.



*The circuit board slotted into the diecast box. Note the capacitor on the underside of the board.*

One final caution is to remember to switch it off after use! An l.e.d. could be fitted, perhaps a 2mA type, but this would still more than halve the battery life, so it was omitted in the prototype.

# INTERFACE



*Robert Penfold*

## SOUND CARD MIDI/GAMES PORT AND PC UPGRADING

As many readers will no doubt be aware, virtually all PC Sound Cards are equipped with MIDI input and output ports. If you wish to use an up-market sequencer with multiple MIDI output ports you will need to invest in a "proper" MIDI card that is compatible with the sequencer program, but for most purposes the MIDI ports of sound cards are perfectly adequate. Provided you have the drivers installed correctly, any normal MIDI software for the PC should be able to use the MIDI ports without any difficulties.

The only slight snag is that it can be difficult to get everything connected correctly. MIDI ports are supposedly standardised, and should use 5-way (180 degree) DIN connectors. However, computer MIDI ports do not always comply with the MIDI hardware standards.

With few exceptions, PC sound cards have a games port which also doubles as the MIDI input and output ports. (A THRU facility does not normally seem to be included). The games port has the usual analogue and switch inputs, but reallocates one ground pin and one +5V type to the MIDI ports. This still leaves two ground pins and three +5V types, incidentally.

### Getting Connected

We receive the occasional reader's letter requesting connection details for the PC MIDI/games port. Although it might seem reasonable to expect the manuals for PC sound cards to contain this information, in most cases it is not included.

At a price, ready-made PC MIDI leads are now available, but it is easy to make up your own low cost leads. Table 1 gives a list of the pin assignments for a PC sound card games port. Note that games ports on other forms of expansion card are strictly games ports, and cannot be used as MIDI ports.

**Table 1: PC Sound Card Games Port pin assignments**

| *Pin* | *Function* | *Pin* | *Function* |
|---|---|---|---|
| 1 | +5V | 9 | +5V |
| 2 | A-1 | 10 | B-1 |
| 3 | A-X | 11 | B-X |
| 4 | Gnd | 12 | MIDI OUT |
| 5 | Gnd | 13 | B-Y |
| 6 | A-Y | 14 | B-2 |
| 7 | A-2 | 15 | MIDI IN |
| 8 | +5V | | |

Wiring details for a games port MIDI lead are provided in Fig.1. Any good quality twin screened audio cable is suitable for this application. The screen of the lead is only connected at the MIDI outputs, since a connection through the screen would otherwise bypass the opto-isolation at the MIDI inputs. The maximum recommended length for MIDI cables is 15 metres (about 50 feet).

The 5-way DIN plug marked "OUT" is the MIDI output from the interface, and this plugs into the input of a sound module, synthesiser, etc. The plug marked "IN" is the MIDI input of the interface, and connects to the output port of a keyboard, MIDI guitar, etc. The connections to the games port are made via a 15-way male D-type connector.

### Upgrading

Things in the world of PCs seem to have moved very rapidly recently, with specifications increasing as rapidly as prices have fallen. If you have a humble 80386 or 80486 based PC you are very much a second rate citizen these days, with little chance of running the more sophisticated items of software currently on offer.

If you have an old PC that has had little or nothing added over the years, probably your best bet is to continue using it with your existing software until it is no longer usable. Converting it into a modern "all singing-all dancing" PC would require so many replacements and additions that you would be virtually building a new PC from scratch.

The situation is different if you have kept an old PC up-to-date with the addition of soundcards, speakers, CD ROM drives, and the like. You eventually end up with an excellent array of peripheral components that totally outclass the basic PC!

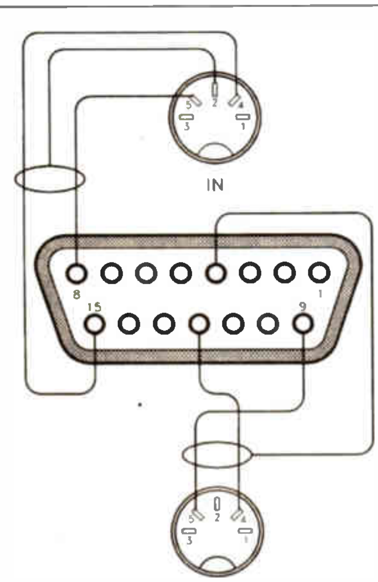



*Fig.1. Wiring details for a standard PC MIDI lead.*

A motherboard and CPU transplant can transform such a PC into one that rivals new multimedia PCs in terms of specification, but at much lower cost than simply going out and buying a new PC. Giving an old PC a "makeover" seems to be a major growth area, but is it really worth the effort?

Having undertaken some major upgrades of PCs a few years ago, I would have to say that I found converting an old 33MHz 80386 PC into a 166MHz MMX PC was remarkably simple by comparison. Things in general seem to be more rigidly standardised, and the hardware manufacturers now try to make it easier for users to install their products.

Even so, unless you are reasonably experienced with PCs it would probably be best not to attempt a major upgrade such as a motherboard and CPU upgrade. The safer but slightly more expensive alternative is to buy a ready-made base unit having a very basic specification, and then transfer items such as the CD ROM drive, sound card, etc. from the old PC to the new one.

### Chip Sets

The choice of CPU depends on how much you are prepared to spend, and on the computing power you require. A 166MHz MMX chip is now the simplest PC CPU in production, and a genuine Intel chip should only cost about £100 plus VAT.

Although it now represents the entry level PC processor, a 166MHz MMX chip is an extremely powerful processor that is more than adequate for most purposes. Most of the current motherboards are based on the Intel VX, HX, and TX chip sets, with the VX boards being the cheapest and the TX types the most expensive.

Manufacturers have now had time to perfect their designs, and there would seem to be little measurable difference in the performance of the numerous boards on offer. Any modern type that will take an MMX processor should give good results, and it is probably not worth paying high prices for the up-market boards. An ordinary AT style board is needed, and not an ATX type (which is only usable with a modern ATX style case and PSU).

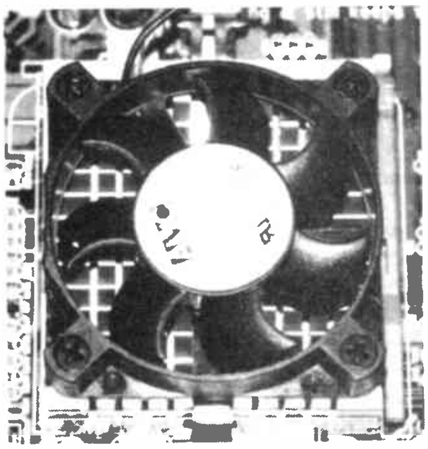
Fitting the CPU to the motherboard is very simple, and a missing pin ensures that the processor cannot be fitted with the wrong orientation. The motherboards are fitted with what is termed a "Socket 7", which is a form of zero insertion force socket.

The only real problem is that the processor and the motherboard are both vulnerable to static charges, and some anti-static precautions are essential. As a minimum, improvise an earthed worktop by using some aluminium foil on the workbench. The foil must be earthed, and this can be achieved by connecting it to the earth socket of a bench power supply using a crocodile clip lead. Connecting the foil to the chassis of any mains powered equipment that has a metal chassis should do just as well.

Touch the foil frequently so that any charge in your body is leaked away to earth before it has a chance to build up to significant levels. Alternatively, earth yourself to the foil via one of the special wristbands (which for safety reasons *MUST* include a high value resistor in the lead which connects to earth).

## CPU Fans

Do not forget that all Pentium class processors require both a heatsink and a cooling fan to ensure safe operation. Some processors need bigger and better heatsinks and fans than others, so it is best to buy a matching unit when you purchase the processor. The heatsink and fan are normally in a single assembly, and they clip on the CPU socket via a very simple spring-clip assembly.



*All Pentium class CPUs require a heatsink and cooling fan. It simply clips in place.*

The motherboard will have a 12V supply output for the fan, but the connector on the fan might be designed to tap off the supply from one of the disk drive supply leads. It does not really matter which method is used, but make quite sure that the fan does actually operate.

Unfortunately, advances in PC design mean that it will almost certainly be necessary to replace more than just the CPU and motherboard. The old PC will probably be fitted with memory in the form of 30-pin SIMMs, which are incompatible with modern motherboards that have sockets for 72-pin SIMMs and 168-pin DIMMs. It is possible to use 30-pin SIMMs with 72-pin sockets using special adapters, but this is a dubious practice.

There can be problems in fitting everything in place, the old memory will probably be too slow to get the best performance from a modern motherboard, and the cost of the adapters could well be higher than buying new RAM! A couple of 8Mb 72-pin EDO SIMMs should be about £40 or so, and will enable the motherboard to run at full speed.

It is likely that the old PC will have a video card that fits into an ISA expansion slot. A modern motherboard has both ISA and high speed PCI expansion slots, but the video card should be a PCI type.

A 2Mb PCI video card based on the S3 graphics chip is remarkably cheap these days, and will provide very good results. It is worth looking out for upgrade bundles which include the motherboard, heatsink/fan, CPU, and video card "thrown in" at little extra cost.

## All-a-board

Modern motherboards have the various ports provided on-board, rather than via an expansion card or cards. Consequently, any cards in the original computer which provide serial ports, etc. do not have to be installed in the upgraded PC. Some of the original leads and connectors might not suit the new motherboard, but motherboards are usually supplied with a full set of leads and connectors.

The motherboard must be set to the correct CPU voltage and frequency, and the appropriate board clock rate using the usual DIP switches or jumpers. The manual should make this easy by providing a list of settings for all the supported CPUs.

Fit the CPU and memory modules before installing the new motherboard in the case, as it can be difficult to get at the board once it is in place. It should be possible to recycle the mounting screws and stand-offs of the old board. Do not rush the reassembly, which is not difficult, but will probably take much longer than you expected.

It may be necessary to do a little juggling with the positions of the port connectors in order to get everything nicely in place, Removing the expansion cards and the old motherboard should be easy enough, and the new motherboard should fit into place without too much difficulty.

There will be a large number of leads to connect to the motherboard, and it is difficult to make a really neat job of things. It is more important to get it right than to be a neat.

Many of the connectors are not polarised, and you must be careful to fit them the right way round. Pin 1 is normally marked as such on each motherboard connector and on peripheral devices such as disk drives. The convention is for the red coloured lead on ribbon cables to carry the pin 1 interconnections. The flying leads on the port connectors are always wired with the red lead connecting to pin 1.

## Turned On

It makes sense to thoroughly check the completed installation, and ideally you should also get someone to check it for you. When switched on, if all is well the screen should show the usual BIOS start-up messages, and the delete key should then be pressed to take the computer into the built-in set-up program.

These programs get ever bigger and better, but to a large extent you can settle for the default settings. However, you must go into the "Standard" CMOS set-up to check that the drive settings are correct.

For the hard drive you can simply use the same settings that were used with the original motherboard. If the hard drive is an EIDE type you can simply select the "Auto" option, and the BIOS will then read the drive's parameters and control it accordingly.

On saving the settings and exiting the set-up program the computer should boot up normally if it has DOS/Windows 3.X as the operating system. The change of display card means that Windows will only run properly once the Windows Setup program has been run, and the new screen drivers have been loaded.

With Windows 95 the start up routine may detect the new display card and ask for the drivers disk, or you may have to start up in protected mode and then install the new card via the Settings/Control Panel/Install new hardware route. If you upgrade the hard disk as well (as I did), you must boot from drive A, use FDISK to set the disk partions, and the FORMAT /s command to make drive C: bootable.

Alternatively, many disk drives are now supplied complete with a utility program which greatly simplifies installation of a new hard disk. If the drive is supplied with software of this type it is probably best to use it. No low level formatting of EIDE hard drives is required, as this is done at the factory.

If you are using the upgrade version of Windows 95, it is worth noting that you do not have to install Windows 3.X and then upgrade it. You can install Windows 95 from MS/DOS, but you will have to put the Windows 3.X setup disk in drive A when prompted, to prove that you do actually have something to upgrade from.

Despite falling prices, a motherboard and CPU upgrade is still quite expensive, but if you have a suitable PC to upgrade it seems to be very worthwhile. With something like a tenfold increase in speed, most of the older software runs much better, and you can run modern high power programs that the original PC simply could not run at all. You will also get a bidirectional printer port that is ideal for PC based projects.

*The upgraded PC. The case and 3·5" floppy drive are all that remain from the seven-year-old original.*

# An Introduction to DIGITAL ELECTRONICS

Ian Bell, Rob Miles, Dr. Tony Wilkinson, Alan Winstanley

TEACH-IN is designed to support candidates following the City and Guilds (C&G) syllabuses, see facing panel, but includes further material as well. It is aimed initially at the complete novice or apprentice technician, and therefore commences with the most fundamental theoretical and practical aspects of electronics. The series then progresses straight into digital electronics, dealing with basic logical systems before moving on to more advanced levels.

Even if you are not undertaking the City and Guilds syllabus, there is much to be learned from following *Teach-In*, whether you are a GCSE or "A" Level student, hobbyist or you simply want to discover how to do things digitally.

## Lab Work

Throughout *Teach-In*, attempts are made to involve the student with practical "Lab Work" experiments and demonstrations, and complex mathematics and physics will be avoided unless really necessary – and even then, plenty of help is to hand! We make a point of identifying practical components in special sections of *Teach-In*, so that you will learn to recognise parts, even if you don't necessarily use them yourself just yet.

We also take a light-hearted view of things from time to time, because electronics really is *fun* to learn, so we'll sometimes "have a laugh" at the same time!

## Reader Support

We encourage you to contact us with your queries and feedback, either by writing to the *Teach-In* Team c/o the Editorial address, or by E-mail: **Teach_In98@epemag.demon.co.uk.** So help is never very far away. Please do not use any other E-mail address at all, for *Teach-In* queries, nor use it for anything other than questions related to the series. We hope you will find this series instrumental in stimulating your interest in electronics. I.M.B., R.S.M., A.J.W., A.R.W.

## ABOUT TEACH-IN

*Teach-In* is a ten part series which aims to support students undertaking *City & Guilds 726 Information Technology*, with reference to the following specific syllabuses:

- ♦ **7261/301** ***Introductory Digital Electronics***
- ♦ **726/321** ***Elementary Digital Electronics***
- ♦ **726/341** ***Intermediate Digital Electronics***

For the benefit of overseas readers, the City & Guilds of London Institute (more commonly called "City and Guilds") is Britain's largest technical testing and qualifying body. It is an independent organisation which operates under a Royal charter. It works closely with industry, education and Governmental departments, and each year some half a million candidates undertake a wide range of subjects under the auspices of City & Guilds.

The certificates awarded are accepted world-wide as evidence of achieving a standard in a recognised technical skill. Potential candidates can contact them at Customer Services Enquiries Unit, City & Guilds, 1 Giltspur Street, West Smithfield, London, EC1A 9DD. Tel. 0171 294 2801, Fax 0171 294 2405. E-mail: **enquiry@city-and-guilds.co.uk.**

*Teach-In* has been co-written for *Everyday Practical Electronics* by Rob Miles, Ian Bell and Dr. Tony Wilkinson who are lecturers in the Department of Electronic Engineering at the *University of Hull*, England. Regular readers will know Alan Winstanley, of course, as the author of several columns in *EPE*: Alan has written for this magazine for over twenty years and is known internationally for his efforts to promote an understanding and interest in electronics. Alan has co-ordinated the series.

## Part Two: CAPACITORS, INDUCTORS AND THE SEMICONDUCTOR DIODE

### Changes Over Time

PART ONE of *Teach-In* considered electricity as a flow of "charge carriers" travelling down a conductor. To make things more interesting, an analogy was introduced; namely the behaviour of shoppers going to a sale!

We said that each shopper (or "charge card carrier"!) is driven by an urge to snap up those bargains, in the same way that electrical charge carriers are driven by a potential (*voltage*). We'll use this analogy later on to enliven the description of other electronic components.

All the measurements that have been made on circuits so far have been taken at a "steady state". Whether a given voltage is measured now, or in ten minutes time, has been irrelevant because the same voltage would be seen now or later. Take an ordinary alkaline battery and measure its output voltage, for example. A graph displaying the voltage against the time would look something like Fig. 2.1.

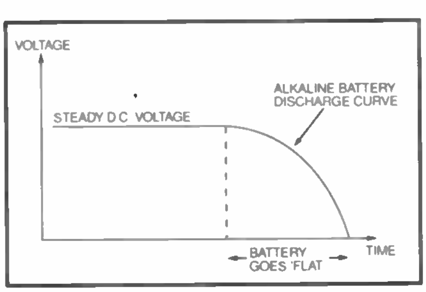



*Fig.2.1. A graph showing how the output of a battery remains at a steady d.c. level over time.*

The voltage will remain at a high level during the active life of the battery, and only start to fall away to nothing, when the battery gradually becomes flat. It is only then that the voltage starts to change with time, otherwise it is pretty constant.

## *Alternating Current*

Up until now, we have only looked at *direct current (d.c.)*, in which the voltage or *potential difference* in the circuit is constant. Batteries such as the alkaline one just mentioned, produce direct current; however, the mains adaptor we are using for our experiments takes *alternating current* (a.c.) from the mains supply and converts it into direct current. Alternating current flows from mains electrical sockets, whilst direct current is produced by sources such as low-voltage batteries.

Two measurements are used when talking about alternating signals – frequency and amplitude. ***Frequency*** is usually expressed in units called Hertz (**Hz** for short) which is shorthand for "cycles per second". In the UK, the mains electrical supply to your house is supplied as alternating current which has a frequency of 50 Hertz. You'll see this mentioned on the ratings plates of much mains-powered equipment. It means that, 50 times a second, the voltage goes through a cycle where the potential difference between the supply wires changes direction.

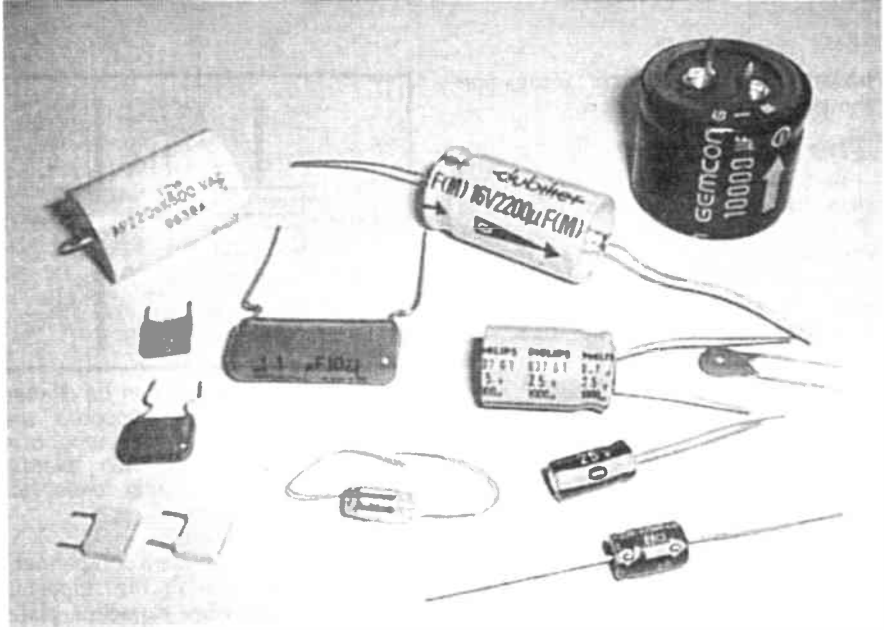
The frequency of 50Hz is just too fast to be observed on a digital voltmeter (DVM), but if we were able to slow the frequency right down to say one to two Hertz we would then see a potential first one way, and then the other, rising and falling in between. In fact, there is an expensive instrument called an *Oscilloscope* which does indeed let you see what is really going on, almost regardless of the frequency of the a.c. signal. Oscilloscopes simply plot a graph of voltage against time, on a screen. Check the separate topic box *Oscilloscopes: For Your Eyes Only*.

What an alternating current actually looks like is depicted in Fig.2.2a. Notice how the potential changes smoothly from one polarity to another over a cycle. The shape of this particular waveform is called a *sine wave*. The more rapidly the sine wave is repeated, the higher the frequency. There is a simple formula which calculates the frequency of a particular signal and this is:

$$f = \frac{1}{t}$$

If you know the *period* (*t*) of the signal – how long it takes for one complete cycle to occur – then you can calculate its frequency. For instance, a signal with a period of 0·02 seconds (20 milliseconds) has a frequency of 50 Hertz.

The graph in Fig.2.2b shows a simple *d.c. voltage* (9V) – which is a constant voltage over time, whilst Fig. 2.2c illustrates a *sine wave* superimposed onto a d.c. voltage: we often say that the sine wave has a d.c. "bias" in it because, unlike the sine wave in Fig. 2.2a, it isn't changing polarity around the 0V level. It has been "raised up" by the d.c. bias.



Just a small selection of the various types of capacitors available to the experimenter.

## *Amplitude Signal*

***Amplitude*** is the other parameter relating to alternating signals. It's a measure of how "large" the signal is.

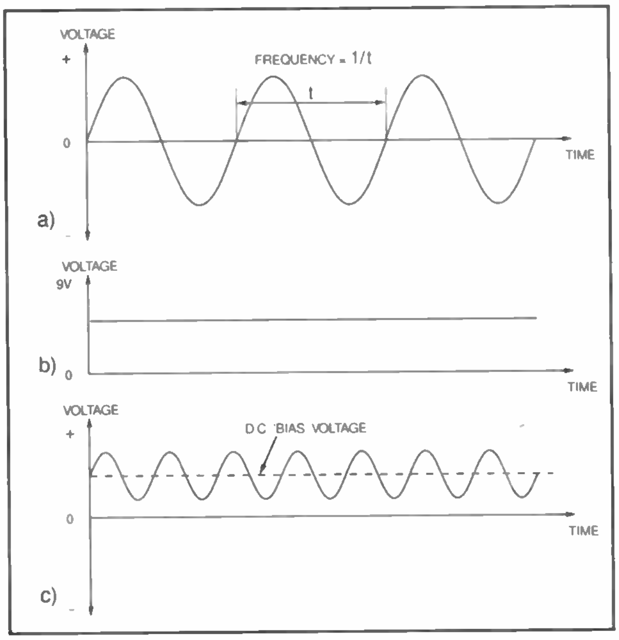



*Fig.2.2. a) An alternating current changes direction over time. b) a 9V d.c. voltage remains steady over time. c) A d.c. voltage with an a.c. voltage (sine wave) superimposed on it.*

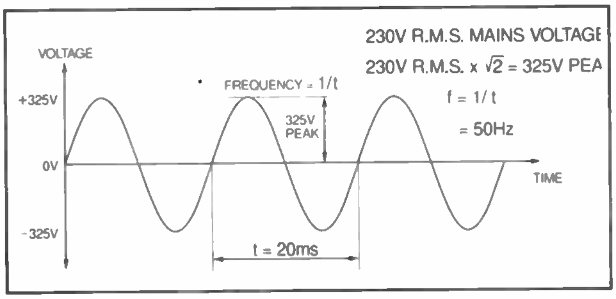



*Fig.2.3. The UK 230V a.c. mains supply is an "r.m.s." value and peaks at 325V.*

The figure of mains voltage (230V in the UK) we all talk about is actually known as a *root-mean-square* (***r.m.s.***) value. This r.m.s. figure represents the equivalent d.c. voltage which would cause a simple resistor to warm up to the same level as that caused by the r.m.s. alternating voltage. In other words, if you connected them across a known resistance, a 230V ***r.m.s.*** (alternating) voltage would have the same heating effect as a 230V ***d.c.*** voltage.

However, a 230V r.m.s. mains voltage actually *peaks* much higher than 230V. Fig. 2.3 shows how the mains supply really has a peak value of 325V. It can be shown mathematically that:

$$V_{r.m.s.} \times \sqrt{2} = V_{peak}$$

$$\text{so} \quad 230\text{V r.m.s.} \times 1{\cdot}414 = 325\text{V peak}$$

*When we talk about the amplitude of an alternating signal, we usually mean the r.m.s. value.* Unfortunately, some audio equipment manufacturers quote "peak" ratings to inflate the performance of their audio equipment to pretty dramatic levels, which look far more impressive in brochures than a more realistic r.m.s. value!

We saw in *Teach-In* Part One that *resistance* is a measure of how much a component impedes the flow of direct current. A similar measure, called ***impedance*** is used to express the resistance of a component when *alternating* current flows through it.

The impedance of a component is often given at a particular frequency. Your hi-fi loudspeakers are a good example. Their impedance is usually implied as being their "resistance" at a certain frequency (say, 1 kHz). Again we are using multipliers with our units: "kHz" or "kilohertz" means one thousand cycles per second.

## The Capacitor

Back to our bargain-hungry shoppers. Imagine what would happen if a crowd of shoppers appeared from out of nowhere, with lots of money to spend (retailers dream of nothing else). Because of the laws of supply and demand, you can bet that you would soon find shops full of bargains springing up for them to spend their money in, see Fig. 2.4a. Imagine that a blockage appears which prevents our shoppers from snapping up those bargains – maybe the doors have jammed!

A ***capacitor*** is a fundamental electronic component which has the ***capacity*** to store charge. It uses the properties of electrical charge in an analogous way: consider two conducting surfaces or *plates* which are separated by an insulating material, see Fig. 2.4b.

We can put a charge onto one of the surfaces by applying a voltage to it. This would cause an equal and opposite charge to appear on the other surface: shops springing up to absorb the buying power of all those shoppers!

What is *really* interesting though is to consider the behaviour of a capacitor when we put a voltage across it. In the circuit of Fig. 2.5a, before we close the switch S1 we have no current flowing. As soon as the switch is closed, charge carriers will be able to move out of the positive terminal of the battery, through the resistor R and onto the surface of one of the capacitor plates. When they arrive there, they have nowhere else to go, because of the presence of the insulator, so a charge builds up on that plate.

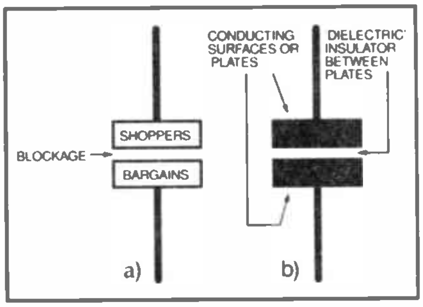



*Fig.2.4. a) A capacitor can be likened to a system where shoppers are attracted to "bargains" appearing. b) A capacitor is formed of two "plates" separated by an insulating "dielectric" layer.*

Their presence creates a complementary set of carriers of the opposing polarity on the other capacitor plate, where the charge is *depleted*. Overall, the capacitor has acquired a fixed electrical charge.

## Measuring Up

We measure the capacitance of a capacitor in units called ***Farads*** (F), so named after the English pioneer Michael Faraday. Due to the laws of physics, the Farad is generally far too large a unit to deal with, so we use further shorthand to denote capacitance in much smaller units:

**μF** – the microFarad – one millionth of a Farad ($1 \times 10^{-6}$ if you use scientific notation)

**nF** – the nanoFarad – $1 \times 10^{-9}$ Farads

**pF** – the picoFarad – one million millionth of a Farad ($1 \times 10^{-12}$ Farads)

So, 1μF = 1,000nF = 1,000,000pF.

Don't worry too much about these strange symbols, because you will get used to them with experience. (It is quite common to drop the F from the abbreviation and just use the multiple symbol.)

The greater the capacitance, the more *charge* a capacitor can hold. By making the area of the plates larger, we can make a bigger capacitor. Additionally, by putting the plates closer together we can also increase the capacitance. The formula which ties all these things together is:

$$C = \epsilon A/L$$

$C$ is the capacitance in Farads, $A$ is the area of the plates in $m^2$ and $L$ is the distance between them in metres.

The plates are separated by a dielectric which can be various plastics or even fresh air. The symbol $\epsilon$ gives the **permittivity** (or dielectric constant) of the insulating dielectric between the plates, and is a measure of how effectively the plates are insulated from one another.

The better they are insulated, the more "powerful" our capacitor: if you want to make an enormous capacitor you must obtain two huge plates, place them very closely together and fill the gap with a good dielectric – which is what you would expect.

In order to express the *charge* which is held by a capacitor, multiply the voltage across the plates by the capacitance they have:

$$Q = C \times V$$

where $Q$ is the charge (measured in units called *Coulombs*), $C$ is the capacitance (in *Farads*) and $V$ is the *voltage*.

## Check Out: Capacitors

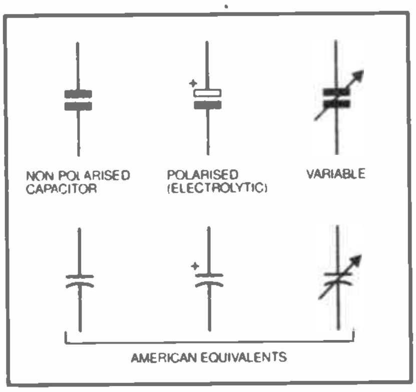
Catalogues are full of different types of capacitor. They are mainly distinguished by the type of insulating material used as their *dielectric*. Some dielectrics are often more suitable in some applications than in others. The most common ones you will come across include ***polyester*** which are suitable for general purpose applications in digital and analogue circuits, timers, audio amplifiers, test equipment, etc. They range from 1nF (0·001μF) to 2μ2F in value.

***Polystyrene*** capacitors are often used where tiny values of capacitance (a few picoFarads) are called for, whilst ***silver mica*** dielectrics have a high stability making them ideal for high quality radio circuits. ***Polypropylene*** capacitors are usually associated with high voltages, e.g. mains circuitry.

None of the above capacitors are *polarised*, which means you can connect them into a circuit either way round. Care is needed to ensure that their working voltage is not exceeded, though.

An alternative type is the *polarised* type of ***electrolytic*** capacitors. These are associated with very large values (anything from 1μF to 22,000μF or more), and they are used as reservoir capacitors or "smoothing capacitors" in power supplies. They are manufactured in "radial" (p.c.b. mounting) and "axial" styles.

Electrolytics suffer from a high "leakage" current (because the dielectric isn't very good as an insulator) and they have a very poor tolerance – typical 50% or so! But they are the only way of obtaining higher capacitance values. ***Tantalum bead*** capacitors are also polarised, and have a lower leakage. *Memory retention capacitors* have an enormous capacitance – an incredible 1F or more!




*Capacitor circuit symbols as used in Europe (top) and America.*

- One critical aspect of using electrolytic capacitors is that they **must** be polarised correctly in circuits. They must never be subject to reverse voltages, because an internal chemical reaction could then result in serious damage or even personal injury. Their polarity is always clearly marked, so check carefully before use. It is highly dangerous to mess about with electrolytic capacitors, so treat them with respect, they are perfectly safe if used correctly.

We show separately, the symbols for capacitors as used in Europe, but you will commonly come across the American symbols shown too, especially in American data sheets.

In real life, there is a limit to the amount of voltage you can put across a given capacitor before the dielectric fails and allows the charge to dissipate. This is equivalent to enticing our bargain-hunters so much that they break down the doors and burst into the shop to get them! We examine voltage ratings and types of capacitor in the *Check Out: Capacitors* panel.

## On Charge

If we were to plot a graph of the voltage across the capacitor, against the time from when the switch is closed, we would get something like Fig. 2.5b. The rate at which the capacitor charges up depends on the value of the resistor we put in *series* with it. (A larger resistance limits the current which can flow into the capacitor and causes it to take proportionately longer to reach the full voltage.)

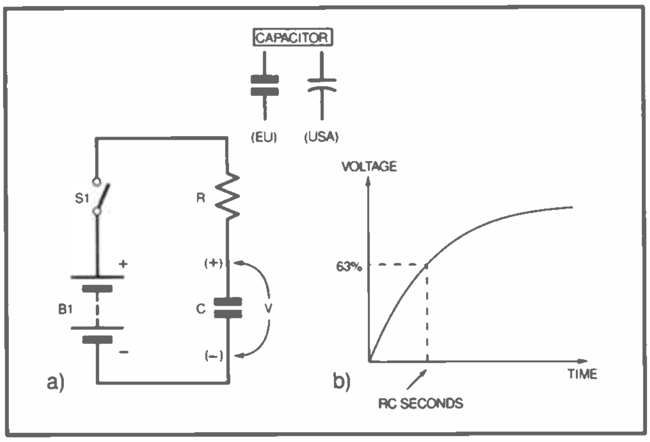



*Fig.2.5. a) A capacitor will slowly charge up through a resistor R when the switch S1 is closed. b) A typical graph showing how a capacitor charges in a curve. It reaches 63 per cent of its final value in RC seconds (see text).*

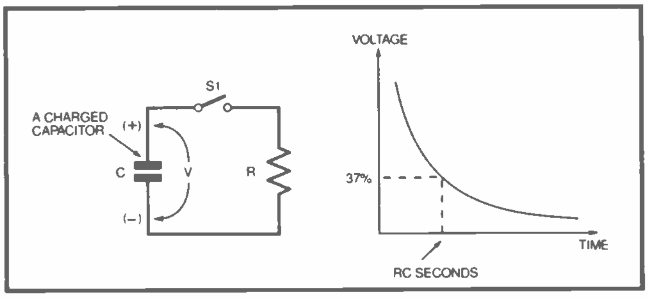



*Fig.2.6. A charged capacitor will discharge through resistor R as per the curve shown. The value RC seconds is the time for its voltage to fall to 37% of its final value (see text).*

What we have, in fact, described is what is commonly called an *RC network* – a capacitor in series with a resistor. Whenever you see an *RC* pair in a circuit, think "time delay". The value of **R (*Ohms*)** × **C (*Farads*)** is called the *time constant*, in seconds.

Whilst capacitors do not charge in a straight line (linear) fashion over time, but charge in an *exponential* curve instead, some rules of thumb are helpful when dealing with RC networks – the *RC* and *5RC* rules:

R (ohms) × C (Farads) = the time in seconds for the capacitor voltage to charge up through resistor *R* to 63% of the applied voltage; or

R (ohms) × C (Farads) = the time in seconds for the capacitor voltage to discharge through resistor *R* to 37% of its final value;

5 × R (ohms) C (Farads) = the time in seconds for the capacitor to get to within 1% of its final or "terminal" voltage.

Thus, if you have a 100µF (*micro*Farad) capacitor in series with a 1M (one megohm) resistor, applied across a 12V supply, the capacitor will charge to 63% (7·56V) in 100 seconds, and it will be as good as fully charged in approximately 500 seconds. You will perform some simple experiments later, in the **Lab Work** section, to demonstrate this.

Note that if there is *no* resistor but instead the capacitor is connected directly across the battery, then in the instant after the switch is closed we will have *infinite* current flow through the circuit for a brief period because the capacitor is "empty" (discharged) and is able to take all the charge carriers we can throw at it. *You should be careful to avoid placing capacitors directly across voltage sources without a series resistor, because the capacitor, voltage source or even yourself could be damaged by doing this!*

There are some cases, though, where it is acceptable to do exactly that. Large value capacitors can be used as *decoupling* capacitors when they are connected across batteries. Then, they help to compensate for the fact that the battery may be unable to keep up with a sudden change in demand (for example a loud note on your transistor radio) by acting as a "reservoir" of electrical charge.

At this stage we should recall that a movement of *charge carriers* constitutes an electrical current. However, it is very important to realise that a current has not actually flowed "through" the capacitor – because an insulator is placed between the two plates – although it seems as though a current actually has done so by the illusion of adding a charge onto one plate, and depleting the charge on the other!

The charge cannot move "through" the capacitor because the two plates are separated by an insulating layer or *dielectric* – see the box *Check Out: Capacitors*. Some types of capacitor perform better in some circuits than others, so the choice of dielectric is important. Furthermore, some capacitors including ***electrolytic*** types are *polarised*, so it's critical that they are connected the right way round or serious damage can result.

Once the capacitor is charged, the potential exists between the two plates, *even if the battery is removed or the switch is then opened.* Some capacitors can hold such potential differences for quite some time. This is why it is highly dangerous to fiddle around inside such things as TV sets **even if the power is off.** There are capacitors inside a TV which can hold very high voltages, easily enough to kill you! These can retain their charge for a very long time, and the ratings printed on the capacitor's body will give you a good clue as to their likely contents!

One of the dreams of electrical engineers is to produce a capacitor which has a very large capacitance but in a very small package. If we had such beasts we could use them instead of batteries. Capacitors used as batteries have lots of advantages; they would charge very quickly and hold their voltage for a long time. Memory back-up capacitors are commonly used, including the popular "Gold Cap" which might find its way into a hi-fi, where it would help the tuner to remember its frequency settings even when the mains power is switched off.

## Discharge

A capacitor will be *discharged* by connecting the plates together, i.e. by touching one terminal wire to the other. This allows the charge carriers stored on the capacitors' plates to move, in order to balance the charge on each plate. It results in a current flowing which can be very large, if short lived. For this reason you should *not* connect the two capacitor terminals directly together; instead you should ***always*** discharge your capacitor through a "bleeder" resistor which will limit the current flow to a safe value.

A typical discharge curve of a capacitor is shown in Fig.2.6. Once again, an *RC* network is used to generate a time delay, this time by discharging a fully-charged capacitor down through a resistor towards 0V. However, we need to use further electronics before we can do anything useful with the time delay in a practical way.

## In Parallel

You can *increase* the value of a capacitor in a circuit by adding another capacitor in *parallel* with it. It is the same as adding another set of plates alongside the existing pair. When two or more capacitors are in parallel, merely add their values together to calculate the total capacitance. (This is the exact opposite case of resistors in parallel, which are *reduced* in value overall, when placed in parallel.)

$$C_{total} = C1 + C2 + C3\ etc.$$

If we waggle the potential (voltage) on one plate of the capacitor by applying an a.c. signal to it, the potential on the other plate will change in a corresponding way. The higher the frequency of the a.c. signal, the easier it is for this transfer to take place. This means that the impedance of a capacitor **decreases** with frequency. A special term is used to describe the impedance of a capacitor – it is **capacitive reactance**, symbol $X_C$.

For now, all you need to know is that a capacitor's reactance will fall when the frequency increases. This frequency-dependence makes it useful in the world of "filters" – e.g. a simple tone control on a radio – where we might want to reduce certain frequencies within a signal.

## Inductors

Meanwhile, back at the January Sales in our department store, a crowd of shoppers is queuing at one door when they see another crowd moving purposefully towards another door. Sensing bigger and better bargains to be had, they decide to follow those shoppers and they start moving themselves! Surprising as it may sound, *charge carriers* behave just like this!

Without getting too much into the physics, it is known that a moving charge carrier generates a ***magnetic field*** around it, which exerts a ***magnetic force*** on other moving charges. If the carrier is moving at a constant speed, the magnetic field is constant: change the speed of the charge carrier and the magnetic field around it changes. The relationship between a magnetic field's charge carriers, and the surrounding magnetic fields themselves, is such that:

a) a moving charge carrier produces a magnetic field, and

b) a change in magnetic field causes other charge carriers to **move**.

## Coil

Normally, the magnetic field produced by charge carriers on the move doesn't affect other charge carriers, because we lay wires out in straight lines so you don't notice the tiny magnetic field. However, if we wind our wire closely together to form a ***coil*** then the effect becomes much more pronounced.

When you apply power to a coil, charge carriers moving through it generate a magnetic field which surrounds the coil. This "growing" magnetic field acts on other charge carriers, absorbing energy and dragging them along, just like one crowd of shoppers might cause another to start moving.

Once the *current flow* is established and the magnetic field is constant, the coil conducts just like an ordinary piece of wire. However, changes in the current flow will cause changes in the magnetic field, the magnetic forces of which will act on other charge carriers and affect the way that the current flows.

If we suddenly disconnect the power to a coil, the magnetic field surrounding it collapses in an instant and "implodes", **inducing** large charge carrier movements in that split second, which can cause sparks to appear! This trick is often used to good effect, for example the huge voltages needed to make a spark jump across a spark plug and ignite the petrol in a car engine, are produced by an "ignition coil" in this way.

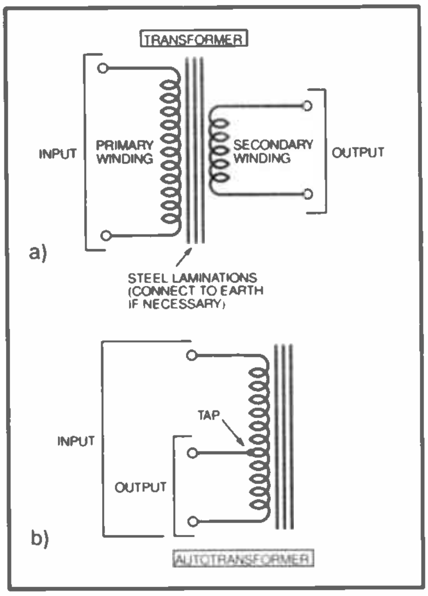


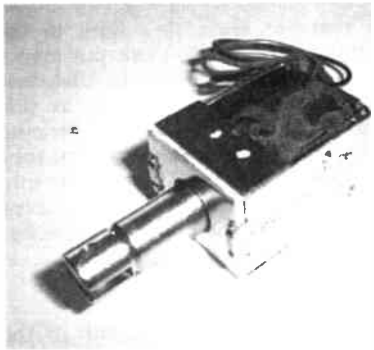

*Fig.2.7. a) The transformer's schematic symbol showing primary and secondary windings, plus the steel laminations that make up the core. b) The autotransformer has electrical "taps" on its main winding instead of separate secondary windings. They do NOT provide electrical isolation from the supply.*

## Back E.M.F.

In other words, when power is removed, a coil can have a voltage *induced* into it when its surrounding magnetic field implodes back into the coil. This causes serious problems in microelectronics because even a low-voltage coil (operating at say, 6V), generates a massive reverse pulse when it's switched off, say –300V or more! This is called ***back e.m.f.*** and precautions are needed to ensure that it is suppressed so that it does not cause any damage to sensitive electronics.

It is no surprise then that the alternative term for a coil is ***inductor***. It is convenient to think of inductors as having the reverse characteristics to capacitors. A capacitor will only appear to "conduct" if the voltage on one of its plates is changing, i.e. capacitors "like" changing voltages!

A coil acts in quite the opposite way. If you start changing the voltage on a coil then voltages will be induced which will try to stop you; they "hate" changing voltages. This means that the *impedance* of coils **increases** with frequency. The term used for the impedance of an inductor is ***inductive reactance***, symbol $X_L$.



*The solenoid converts a current flow through a coil into mechanical movement to operate a lever or bolt.*

The magnetic field produced by a coil is often used to do real work. A ***solenoid*** is a device which is used to convert a current flow into mechanical movement of a lever or plunger. Current passing through the coil in the solenoid magnetises an iron core which then attracts the moving component.

A ***relay*** is simply a solenoid which moves a set of electrical contacts forming a switch. Relays are used to allow a small signal (say a low d.c. voltage) to switch a larger one (e.g. a large mains load).

If you had the will, you could construct a computer entirely by using relays as your switches (this is how the first computers were actually made).

However, the rate at which a relay can turn on and off would severely limit the speed of your device. Modern digital electronics uses the ***transistor***, a switch which can be made to turn on and off many millions of times in a single second, as we shall see in forthcoming parts of *Teach-In*.

## Coils and Alternating Current – Transformers

If we pass an alternating current (a.c.) through a coil, it will create a surrounding magnetic field which rises and falls at the frequency of the applied voltage. If we place another coil in a changing magnetic field, this will induce a voltage into that coil. This is the principle by which ***transformers*** work. One coil generates the magnetic field, the other has voltages induced into it.

The useful thing about a dual-coil transformer is that there is no *direct* electrical connection between the two coils. This benefit is called *electrical isolation*. The fact that we can transfer voltages in this way is a strong argument in favour of an alternating current mains supply.

When considering what makes up a transformer, you find that they usually contain at least two coils (see Fig. 2.7a). The coil which is connected to the main supply input is called the ***primary***. This produces the magnetic field which induces a voltage in the ***secondary*** coil placed nearby. The "turns ratio" of the transformer is the ratio of the number of turns of wire (*winding*) on the primary coil to the number of turns on the secondary coil.

As an example:-

- If we have 1,000 turns on our primary coil and 500 turns on our secondary coil, then we have created a *step down* transformer with a 2:1 ratio. If we put a 230V a.c. signal across the primary we would see a 115V a.c. signal across the secondary. (Such things are sometimes used to connect devices made for the American (115V) market, to the European 230V a.c. supply).
- We can use other transformers to step down from the potentially lethal mains voltage, to a safe low a.c. voltage, say, 6V a.c.

A transformer in a simple mains adaptor which needs to produce a low voltage will have a large number of turns on the primary side, with a smaller number of turns on the secondary. A transformer actually known as an *isolating transformer* has a 1:1 turns ratio, and it means there is no direct connection to the mains supply. Workmen using power tools will often be seen to use an isolating transformer for safety.

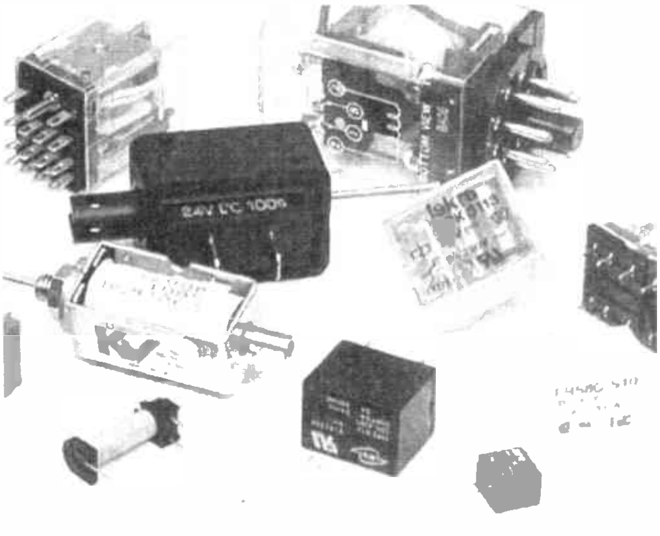
Transformers are manufactured in two common styles, either for chassis-mounting or p.c.b. (printed circuit board) mounting. A third type called a *toroidal transformer* is spheroid-shaped and is used in high quality applications. Note too that most transformers are wound around a laminated steel core, and this may be shown in the circuit diagram as a series of vertical lines – in some applications, this may need to be connected to electrical Earth for safety.

An *autotransformer* (Fig. 2.7b) only has one winding with electrical "taps" taken from the coil in place of having a separate secondary winding, somewhat like a voltage divider (see the previous part of *Teach-In*). This means there is ***no isolation from the primary***, something which must be remembered when safety issues are at stake.

## *The Diode*

**Semiconductor materials** are special substances which are neither perfect conductors nor perfect insulators; they can, however, be "persuaded" whether or not to allow charge carriers to pass through them. By taking certain chemical elements, introducing minute impurities into them and then placing differently treated pieces next to each other, you can create semiconductor devices with very complex behaviours.

A full course in semiconductor technology is beyond the scope of *Teach-In*, instead each device will be presented purely in terms of what it is seen to do




*Small collection of relays.* (Courtesy Maplin.)

### Coils, Extension Leads and Molten Plastic

The fact that a wire will behave differently when wound into a coil, is the reason why you can have problems with mains extension leads. Most of these come packaged on a little winder or cable reel. When you want to use the extension, you unwind one end to the desired length. This leaves you with a ***coil*** inside the winder. The expanding and contracting magnetic field caused by the alternating current flowing through the coil causes it to absorb energy, which eventually produces *heat*.

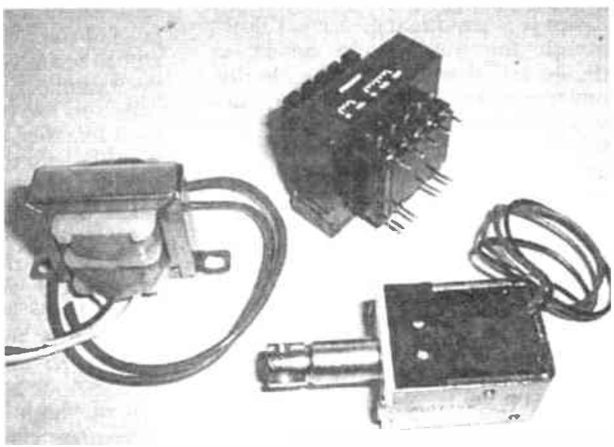
Consumers have actually melted their extension cables by using them to drive small appliances which would normally be well within the cable rating; they failed to unwind enough cable, so they had a coil remaining in the cable winder. When using mains extension cables, you should unroll **all** of the cable before you switch on, to avoid starting an electrical fire. You often find them marked with two current ratings – one wound and the other unwound.

## TRANSFORMERS and POWER

- It might be thought that we can use transformers to amplify an alternating signal. For example, starting with a one volt a.c. signal, which we want to transform into 100 volts a.c., a possible design would be for a step up transformer with a turns ratio of 100:1. If the one volt signal is fed into the transformer we could expect to see 100 volts on the output.

  However, there is an old Yorkshire principle which states "You don't get 'owt for nowt". A 100V signal would appear at the output of our transformer, but the ***current*** which would be available from the signal might be too small to do any useful work.
- It must be remembered that to do "electrical work" you need **power**, and that power is the product of voltage and current ($P = I \times V$). A transformer can increase an alternating voltage, but because you cannot get more power out than you put in, the amount of current which would be available on the output would be greatly restricted. Hence, the power on the primary winding side is about the same as the power on the secondary side.
- If you want to **amplify** a signal then rather than trying to boost it with, say, a transformer you must use that signal to turn another larger one on or off. This principle is used right throughout electronics, from relays to valves to transistors as we will see in the next part of *Teach-In*.

  A transformer is often used to change a voltage, but it can never be used to amplify something. Furthermore, it's worth remembering that transformers can't do anything with *direct current* signals, though they will respond to pulsed signals.



*(Left to right) miniature chassis mounting mains transformer, p.c.b. mounting mains transformer and a typical "bolt" type solenoid.*

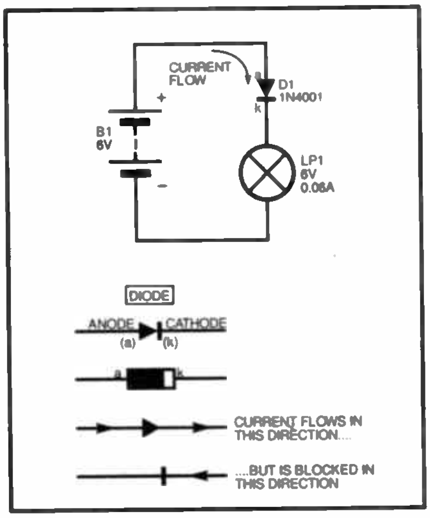



*Fig.2.8. Application of the diode as a "one-way" conductor of current. The diode D1 is "forward biased".*

when connected in a circuit. The ***diode*** is the first of these *semiconductor* based devices.

A diode is unique in that it will only allow a flow of charge carriers in one direction. Harking back to the shopper analogy, a diode is the shopper equivalent of a turnstile. Shoppers can pass through the turnstile in one direction, but will be stopped by the ratchet if they attempt to travel the other way.

Diodes have two terminals clearly marked as shown in Fig. 2.8. They are the ***anode*** **(a)** and the ***cathode*** **(k)**. In practice, diodes are marked with a stripe at one end which usually identifies the cathode terminal. Heavy-duty diodes which are capable of carrying lots of current are called ***rectifiers***.

For a silicon-based semiconductor diode to conduct, the anode must first of all be 0·6V more positive than the cathode. This is similar to a shopper having to press hard enough to operate the turnstile to begin with, after which he can freely walk through.

Once it is conducting, current flows through the diode from anode to cathode and it maintains roughly this same forward voltage constantly, with the anode staying 0·6V more positive than the cathode. In its conductive state, the diode is said to be ***forward biased***.

A diode will not normally conduct in the reverse direction, when it would be ***reverse-biased***. However, if the reverse voltage is sufficiently high the diode itself will break down and begin to conduct. This is the same as our shoppers seeing so many attractive bargains on the far side of the turnstile that they smash their way through and force the turnstile to rotate in the opposite direction!

This may or may not cause irreparable damage, depending on the type of diode, because if we know at what point this breakdown occurs, we can take advantage of this very effect to create a fixed *reference* voltage – one that it stable. This principle is utilised in the *Zener* diode, discussed shortly.

## The L.E.D.

The ***light-emitting diode*** (or l.e.d.) is made from a very special form of semiconductor material which emits light when it conducts. The light is given out at a particular frequency, which determines the colour of the light emitted. L.E.D.s are more efficient than light bulbs in converting a current flow into light, and they last a lot longer – virtually for ever.

Although they could be used as simple diodes, they are most often used for signalling and displays. Even some car lighting systems now use l.e.d.s in place of their filament counterparts. Some l.e.d.s are available which include a miniaturised flasher circuit. Other versions operate at infra-red, not visible to the human eye (your TV remote control uses these).

The schematic symbol of an l.e.d. is shown in Fig. 2.9, with pinouts. Again they have an anode (a) and a cathode (k), and they must be correctly polarised or they won't illuminate. (In fact they will be damaged if connected to too high a reverse voltage). Notice how a series limiting resistor R1 has been used.

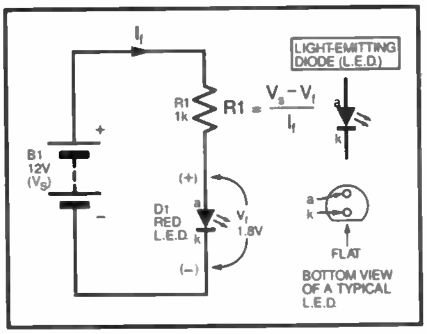



*Fig.2.9. The basic operation of a light emitting diode (l.e.d.), with a series limiting resistor R1.*

The forward voltage ($V_f$) of a typical red colour l.e.d. is about 1·8V or so, and this voltage appears across the l.e.d. when it is illuminated. The purpose of the resistor is to limit the current to a safe value, and also to "drop" the remainder of the voltage in the circuit. You'll often see limiting resistors used like this, and you need to understand how to calculate their value.

First, obtain the forward voltage value $V_f$ from any data available (e.g. a catalogue or data sheet). At the same time, determine the forward current ($I_f$) value. (In the case of l.e.d.s, there is nothing to be gained by running the device at maximum current, so anything between 10mA to 20mA or so is fine, lower in the case of "high efficiency" types.) Also determine the supply voltage, $V_s$, then the series limiting resistor is calculated as follows:

$$Rs = \frac{(Vs - V_f)}{If} \text{ ohms}$$

A typical 1·8V l.e.d. running from 12V at 10mA would require a 1·02k resistor – so use the nearest value, a 1k E12 type. The resistor will dissipate ($I^2R$) 100mW so a 250mW type is fine.

## The Zener Diode

Unlike ordinary diodes which conduct when forward biased, ***Zener diodes*** are deliberately used back to front! By *reverse* biasing them (see Fig. 2.10) a stable voltage will be observed, which can be used to place a steady voltage across a load. Later in the series you'll learn that digital devices require a reasonably stable supply voltage to work reliably, and the Zener diode is one way to create cheap, low-power stable voltages.

The Zener diode, D1 in Fig.2.10 requires a series current limiting resistor *R*, to prevent damage. Zener diodes are manufactured in a range of fixed values, and they usually have a tolerance of 5 per cent or so.

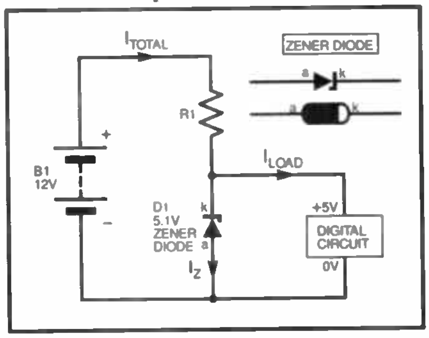



*Fig.2.10. Basic arrangement of a Zener diode. D1 provides a 5V regulated supply to a digital circuit.*

In Fig. 2.10, the current $I_{TOTAL}$ is the total of the current drawn by the load ($I_{LOAD}$) plus the current taken by the Zener ($I_Z$), and is a constant figure. When the load current varies, the Zener draws more or less current to compensate. This means that if no current at all is taken by the load (a digital circuit in this example), the entire current $I_{TOTAL}$ will flow through the Zener, whose power dissipation rating should allow for this.

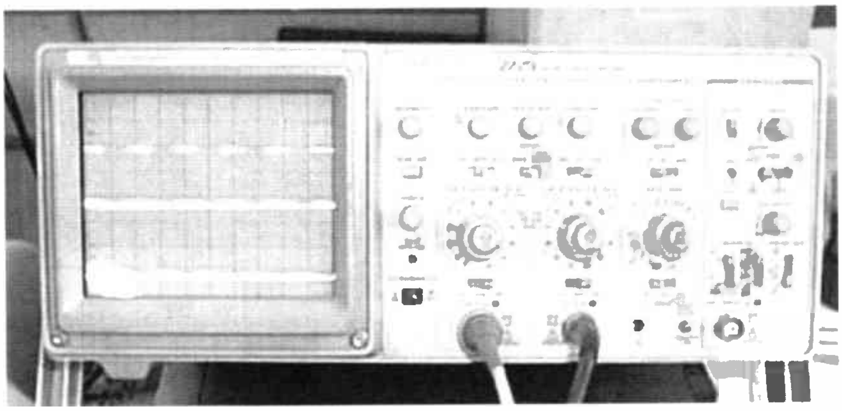
Zener diodes are cheap and effective at providing voltage *regulation* (also called *stabilisation*) – the ability to provide a constant voltage even if the load current varies – but there are better ways in the form of *integrated circuit regulators*. These are overheat-proof and short-circuit proof, and indeed one such device, the highly popular LM317T, is used in the recommended mains adaptor.

In the next parts of *Teach-In* coming up, we get to grips with power supplies in preparation for utilising our first digital chips. We'll describe a way in which the reader can add a 5V d.c. range to the suggested mains adaptor, ready for it to operate digital circuits.

We shall also be discussing the use of ***transistors*** as switches, which form the very basis of all logic devices, after which we introduce the first fundamental logic integrated circuits (i.c.s).

Now go to the Lab Work section and try our simple practical experiments using capacitors, RC networks and a variety of simple semiconductor components outlined in this part of *Teach-In*. If you need a refresher on using your Digital Multimeter and plug-in "Breadboard", check back to Part One.

# OSCILLOSCOPES: For your eyes only



Oscilloscope screen and front panel controls.

An oscilloscope is a piece of test equipment which traces a graph of voltage against time, so that you can actually see what is going on in a circuit. A cathode-ray oscilloscope (c.r.o.) uses a cathode-ray tube (c.r.t.) like a small television screen to display the graph, whilst liquid-crystal displays (l.c.d.) may be used on the latest compact instruments.

A *twin-beam* oscilloscope has two independent channels so that you can compare one signal against another. The most advanced *digital storage* oscilloscopes have a memory in which waveforms can be saved for future reference – or even printed out – and they may show even more data on the screen, including a digital readout of the signal frequency and amplitude. It is also possible to utilise a personal computer as an oscilloscope, by using suitable PC software and hardware.

## In Control

The voltage/time graph is plotted on a screen grid or *graticule*. The vertical deflection of the blip or *trace* is directly related to the input voltage being measured. This will be controlled by a switch calibrated in Volts per Division – so the larger the signal voltage, the higher the trace will be deflected up the display.

The horizontal setting is directly related to time, and a control called the *timebase* causes the trace to sweep across the screen at a fixed rate (anything from microseconds to seconds or more, per division). This determines how many waveform cycles you can squeeze into the available space on the graticule.

The other basic controls of an oscilloscope include an *input selector switch*, to select either a ***d.c.*** or ***a.c.*** signal (where, if desired, you can remove any d.c. bias from the signal, if present); a *trigger control* which will synchronise the trace so that it locks the waveform into place on screen, and *focus* and *intensity* controls to adjust the cathode-ray tube trace.

## Caution

Great care is needed when connecting an oscilloscope because the 0V input terminal is linked to (mains) earth. There is a real danger of shorting out a mains voltage signal if you accidentally connect a "live" voltage directly to the oscilloscope 0V input. A trainee should never attempt to measure higher voltages with an oscilloscope unless under proper supervision.

Oscilloscopes have a high input impedance so that they don't load the circuit under test. However, an oscilloscope *X10 probe* may be used to increase the input impedance by a factor of ten, which may help prevent loading of the circuit under test.

Although only the serious enthusiast or engineer will want to own an oscilloscope, it's important that you recognise their basic controls, how to set them up and how to interpret the display, but this only comes with experience and training. Try to check one out if you possibly can, being careful to treat them as delicate instruments.

# Computer Simulators

Professional circuit designers often make use of *computer simulators.* A simple example simulation is shown here – it is a SPICE (*Simulation Program with Integrated Circuit Emphasis*) simulation. SPICE is an industry- standard type of analogue circuit simulation. It helps you to design circuits and analyse their behaviour, on a computer screen.

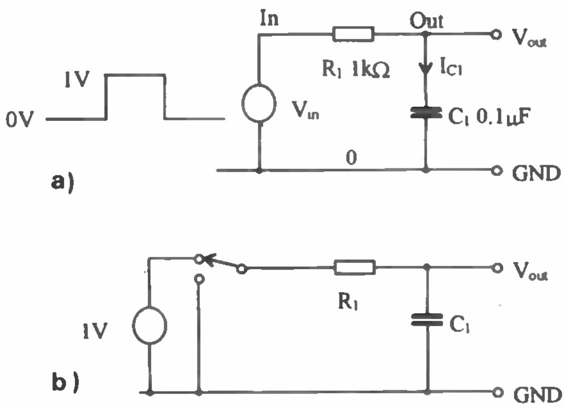
Most simulators have graphical user interfaces which allow you to draw circuit diagrams of the circuit you want to simulate, however the real guts of the simulator (which calculates what happens in the circuit) reads a text file (created by the graphical user interface, or typed in by the user)

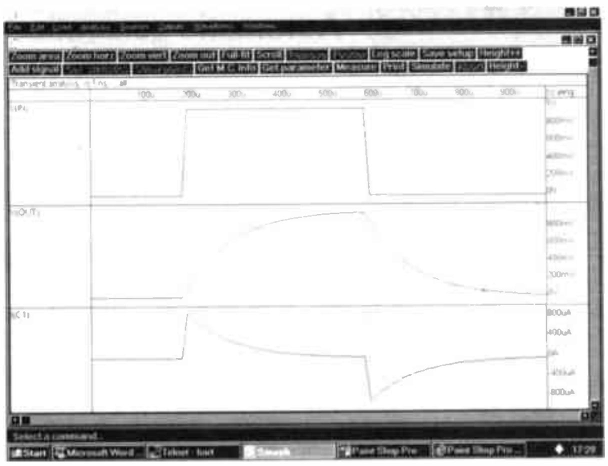
The *RC* circuit (a) has a voltage source which switches between 0V and 1V. This causes the capacitor to charge and discharge as shown in the screenshot. The second circuit shown in (b) will behave in a similar way, this simply shows more explicitly how a voltage switched between 0V and 1V might be achieved using a two-way switch.

The upper waveform plot shows the input voltage labelled $V_{(IN)}$, the middle waveform is voltage across the capacitor (labelled $V_{(OUT)}$) and we can even calculate the current flowing on and off the capacitors plates as it charges and discharges (labelled *I*(C1)).

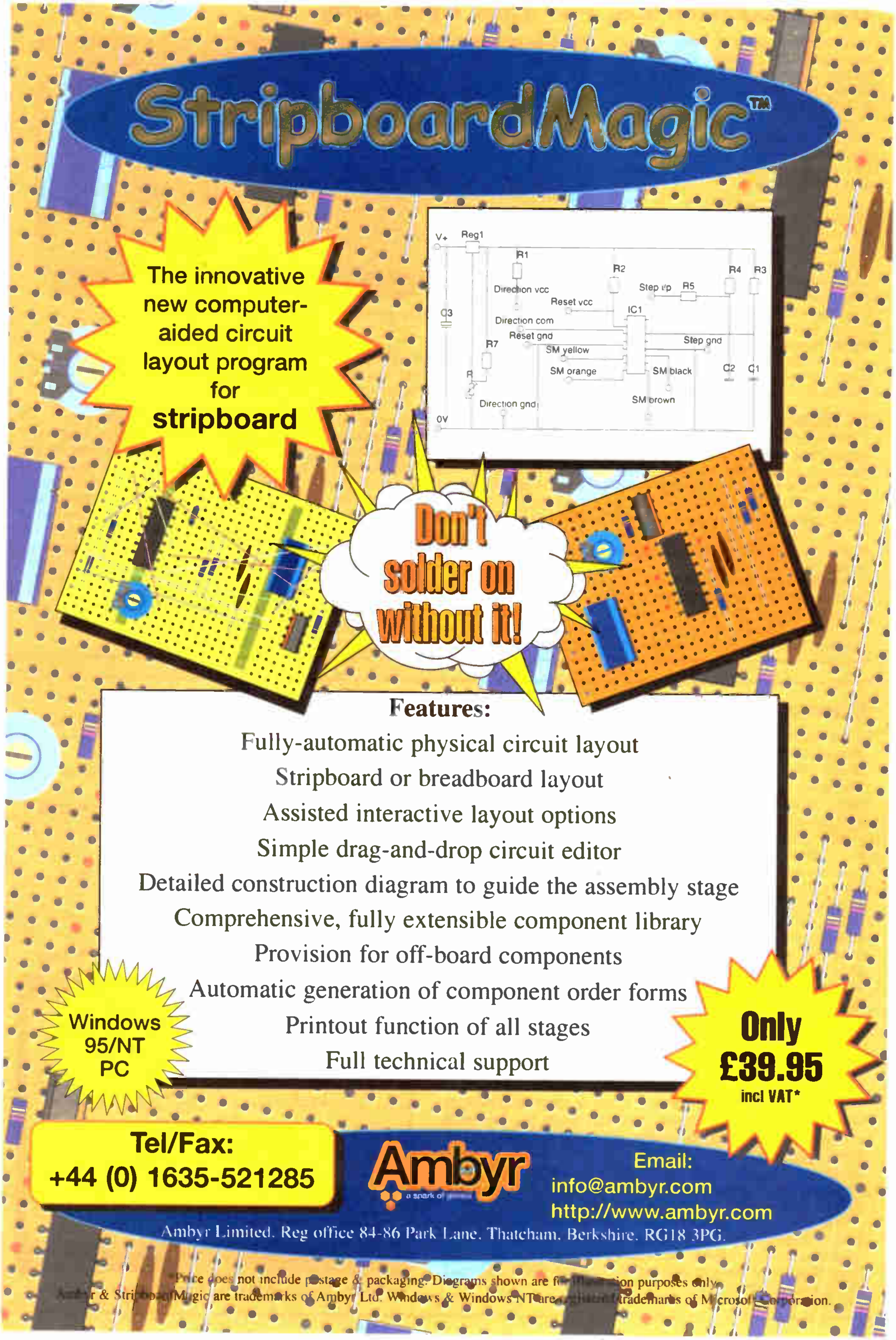
Simulation lets you try out your ideas or alternative designs without building any hardware. You can prove the functional correctness of your design before you build it. Simulation allows you to study a circuit's behaviour under a wide range of conditions. You can study best and worst case scenarios (e.g. variations in temperature and component specifications), which may be difficult to set up using a prototype in a lab.

Computer Aided Design (CAD) tools (of which a simulator is one example) help designers manage the complexity of modern electronic design. Computers can handle large quantities of data and perform detailed calculations, while designers provide the creative input.



Screenshot of the charge and discharge of a Capacitor.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R1
R2
R4
R3
Direction vcc
Step up
R5
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C3
IC1
Direction com
Reset gnd
Step gnd
R7
SM yellow
SM orange
SM black
C2
C1
Direction gnd
SM brown
0V
Don't solder on without it!
Features:
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# LAB WORK 2

*Objectives: observing the charge and discharge characteristics of a large-value capacitor; making allowances for a multimeter's internal resistance. Testing the conduction and forward voltage of a rectifier diode, and utilising a light-emitting diode with a series resistor.*

## Lab 2.1

ALTHOUGH your multimeter is your best friend, even the best of friends can mislead you from time to time! It's important you understand that test equipment can be far from perfect. This experiment highlights an imperfection in a typical modest multimeter, as we attempt to test a capacitor charging through a resistor.

In Fig. 2.11, R1 is a 1M resistor and C1 a 100µF *electrolytic* capacitor across a 12V supply. What is the theoretical *RC* constant for this network? (100 seconds). So in theory the capacitor should reach 63% of its full voltage (say 7·5V) in 100 seconds or so.

Set your mains adaptor to 12V d.c., then build the *RC* network of Fig. 2.11. Use your solderless breadboard to connect the two components. The electrolytic **must** be connected the right way round (either an axial or radial type will be OK). Hook over to your mains adaptor as before, improvising with test leads as necessary. Set your multimeter to 20V d.c. and apply the probes across the capacitor.

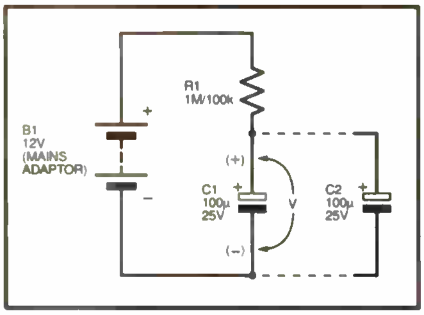



*Fig.2.11. An RC network charging from the 12V mains adaptor. Connect a second capacitor C2 and repeat the measurements.*

Check the slowly rising voltage and maybe record some results (say, every five seconds) to see how the charge curve develops for a few minutes. Did the capacitor charge up fully as expected? We doubt it!

The chances are that your capacitor will *fail to charge* to the full supply voltage, but will seem to stick at well below the 12V, say 6V or so. Strange! The reason is that your multimeter has an *internal resistance* of its own. The spec. sheet for the Monacor DMT-1010 says it has an *input resistance* of 1M (one megohm).

It means that you are placing a nominal 1M resistance *in parallel with* the timing capacitor, so you are forming a potential divider along with resistor R1. Thus, by potential divider action, the capacitor voltage is eventually "clamped" at half the supply rail.

*Your meter has loaded this circuit undesirably, affecting its performance by a huge margin. The ironical thing is, the circuit* ***will*** *behave properly and the capacitor* ***will*** *charge fully, but only if you* ***do not*** *connect the meter to see it in the first place!* Thus your meter has influenced your test results in this example.

For this demo., one way round this is to compensate by reducing resistor R1. The meter's resistance will then have comparatively less effect, being larger in comparison to the timing resistor and loading the circuit less.

Repeat the test using a 100k resistor for R1. The capacitor will now gradually charge to some 11V or so. Sketch a simple graph using your latest readings. Add a *second* 100µF electrolytic capacitor C2 in *parallel*, and repeat the experiment. What

## You Will Need

- **Resistors:** *1k, 100k, 1M ¼W, optional 33k and 220 ohm to 2k2 resistors as available.*
- **Capacitors:** *two 100µF 25V electrolytic capacitors, optional 470µF or 1,000µF electrolytic capacitor.*
- **Semiconductors:** *1N4001 rectifier diode, a variety of different coloured light-emitting diodes as available, including red.*
- **Miscellaneous:** *6V 0·06A MES bulb in holder, connecting wire and test leads.*
- **Equipment:** *digital multimeter, solderless breadboard and multi-output voltage mains adaptor.*

  • *A power supply capable of producing 6V and 12V d.c., and around half an amp (0·5A) of current.*

  We suggest a "regulated" *short-circuit proof* plug-in mains adaptor capable of providing at least 6V, 9V and 12V d.c. at up to 500mA (0·5A) or more. You could improvise with test leads (e.g. crocodile clip leads) to hook up between the mains adaptor, low voltage, d.c. output leads and the demo circuits.

  Some readers may be able to solder together a suitable adaptor lead, enabling you to use red and black insulated crocodile clips as "flying leads". We made such a lead by soldering a pair of wires to an in-line socket that matched one of the mains adaptor's d.c. output plugs.
- *A modest digital multimeter* (DMM) capable of measuring d.c. voltages, d.c. current (perhaps with a 10 amp socket), and resistance up to 2MΩ or more, will be fine. Check out the box "How to use your multimeter" before starting your lab work (Part 1).
- *A set of modest hand tools:* electronics wire cutters/insulation strippers, pointed-nose pliers, flat-blade screwdriver to get you started.
- Initially, in order to avoid soldering, a *solderless plug-in "breadboard"* is used. This means that low-power, low-voltage circuits can quickly be built and modified. E.G. a "Protobloc 2" which has two banks of 64 rows, plus supply strips. These interlock with other Protoblocs for larger projects.

- *Some wire* (obviously). Single-core "bell" wire is best here because it is easiest to push into the breadboard. Consider buying a few metres of different colours so that you can colour code the various connections to help with checking. Even surplus telephone wire is fine.

When considering your lab work, it is worth bearing a few things in mind. You'll discover that many components are fussy about their polarity (i.e. which connection is *positive* and which is *negative*). Incorrect connection can therefore have potentially messy (and expensive) results. Do NOT adjust your circuit with the power *switched on*; assemble everything first, check it and then apply the power.

does this tell you about parallel capacitors? (You add their values together.)

As an optional experiment, to compensate for the meter's resistance even more, reduce the resistor further (say 33kΩ), and increase the capacitor more – to 470µF or 1,000µF, whatever you have available. You will gradually observe a more ideal curve when you plot these results. The time constant witnessed will not be very accurate, because of the high leakage and poor tolerance of electrolytic capacitors.

- A meter's internal resistance can have a *loading effect* on some circuits under test, which affects the accuracy of the readings. This problem is reduced on test equipment having a very high input resistance (= a good thing to have).

  Otherwise, try to ensure that the input resistance of your meter is, say, ten times greater than the resistance of the circuit being tested, to avoid loading effects.
- In a low energy circuit like this one, you can short out the capacitor with a wire to discharge it and start again. Generally, you should discharge electrolytics through a low value resistance (e.g. 100 ohms or more) to play safe.

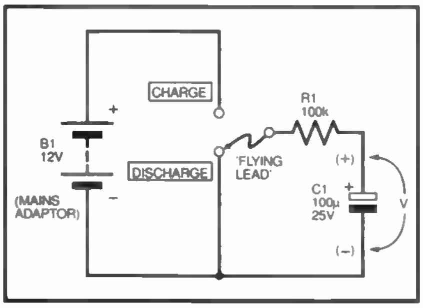



*Fig.2.12. Experimental circuit to observe the discharge of an electrolytic capacitor.*

## Lab 2.2

Attempt to measure the discharge of the capacitor C1 in Fig. 2.12. Assemble resistor R1 and electrolytic capacitor C1 on the breadboard, observing C1 polarity, and use a wire (a flying lead) like a switch, to connect the resistor first to the +12V rail (*charging*), then to the 0V rail (*discharging*).

Try using different values of resistor and capacitor to see what time delays are produced. Plot a graph accordingly.

## Lab 2.3

Check through a supplier's catalogue and see how many different types of capacitor dielectric you can identify. Compare prices, size, voltage and dielectric. Also check through the transformer section to see what's available, and the styles they are manufactured in.

- *Variable* capacitors are used for tuning radio frequency and oscillator circuits. They have a very low value (*picoFarads*), and some of them use fresh air as a dielectric!

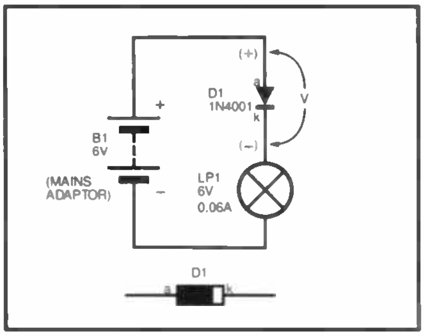



*Fig.2.13. Investigating the conduction of a rectifier diode. The cathode (k) end is usually denoted by a coloured band.*

## Lab 2.4

The circuit of Fig. 2.13 shows a rectifier diode D1, type 1N4001, placed in series with a 6V 0·06A bulb LP1 (as used in the previous *Lab Work*). **Set your mains adaptor to 6V.**

See if you can assemble this circuit by inserting the diode into your solderless breadboard. Identify the rectifier's anode (a) and cathode (k) leads. Hook up the adaptor and bulb using solid-core wires connected to the breadboard. Which way round must the rectifier be, to make the bulb illuminate?

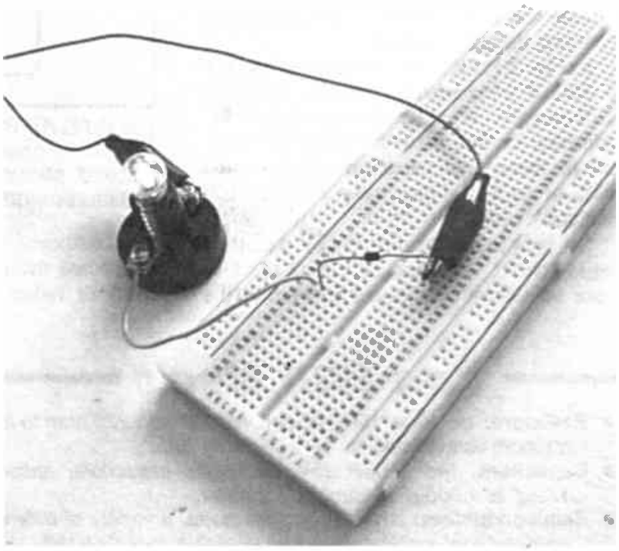
- Current will only flow through an *ordinary rectifier diode* from anode to cathode.

## Lab 2.5

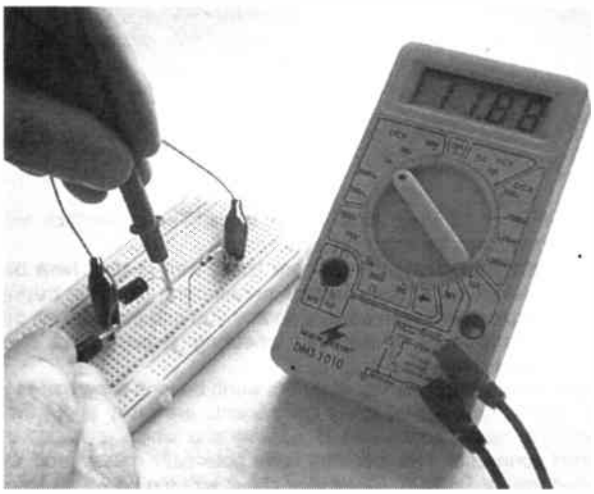
Retain Lab 2.4, and use your voltmeter on its 2000mV (2V) range to measure the voltage appearing across the rectifier diode. What is this *forward voltage*? (We measured 766mV.) Which is the more positive end of the diode? The voltage drop means that there is less voltage available to drive the light bulb.

If you have the recommended multimeter, **disconnect the power supply**, then select the "Diode" symbol on the Range switch (diode check). The meter will now measure the forward voltage of any ordinary diode, and display the forward voltage in mV. We measured 800mV – you can expect very slight discrepancies because the forward voltage slightly depends on the current flowing through it.

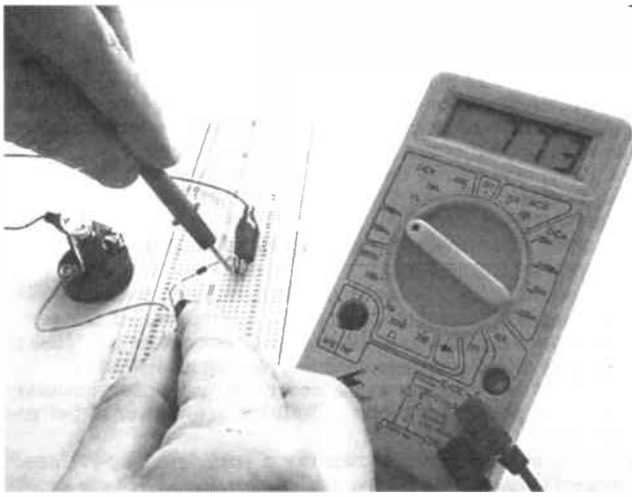
- A diode can sometimes be checked for "go-no-go" operation by using the diode check range in *both* directions. It may display an overflow "1" in the l.c.d. display when reversed. This plus a forward voltage of roughly 700mV indicates correct operation.



*Set-up for connecting the bulb and adaptor (6V) in series with the rectifier diode (D1). The adaptor supply leads are the ones with insulated crocodile clips attached.*



*Measuring the voltage across the electrolytic capacitor.*



*Measuring the voltage appearing across the diode D1.*

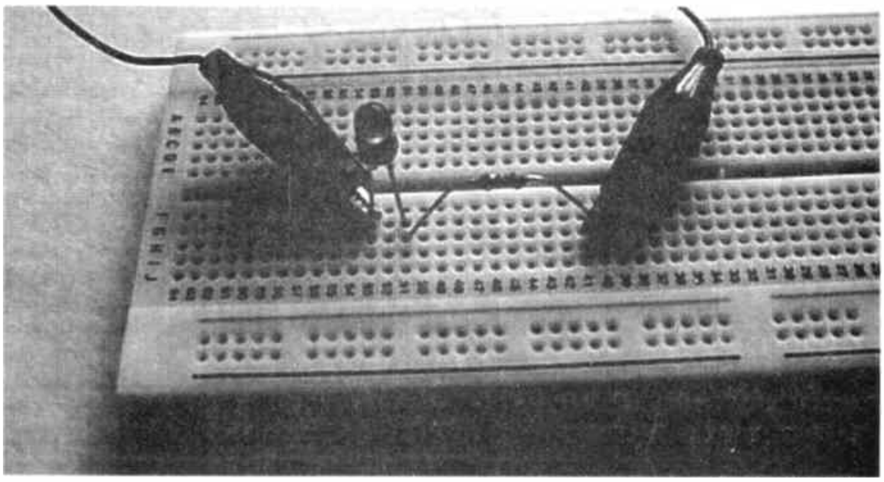
### Lab 2.6

The circuit diagram of Fig. 2.14 shows a light emitting diode D1 in series with a 1k limiting resistor R1. Assemble this on the breadboard.

Using any ordinary red l.e.d., identify its anode (a) and cathode (k) leads before pushing them directly into the breadboard, correctly polarised, then add the resistor. Set your mains adaptor to 12V and apply the voltage. The l.e.d. should illuminate (if not, re-check the pin-outs).

Use your voltmeter to measure the voltage dropped by R1 and across the l.e.d. Also measure the current flowing into the resistor, by setting your meter to a safe 200mA current range initially.

See if you can confirm the equation for calculating the series limiting resistor, as described in the main tutorial. Can you calculate the resistor's power dissipation? ($V^2/R$).



*Using the breadboard to wire a light emitting diode in series with a limiting resistor (R1)*

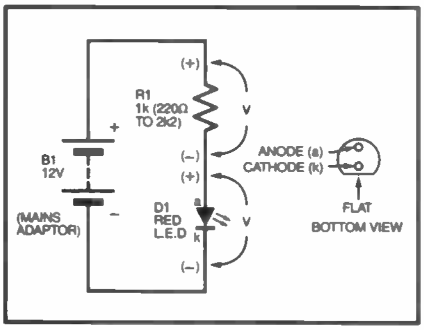



*Fig.2.14. Using a light emitting diode (l.e.d.) with a series resistor. See what effect changing R1 has on the brightness of the l.e.d.*

If possible, substitute different colour l.e.d.s and notice the difference in forward voltage. Also try using a high-efficiency (high brightness) type to see what difference this makes.

- Try substituting the series resistor for lower or higher values (anything between 220 ohms to 2k2) to see what effect this has on the brightness of the l.e.d. – there's little to gain by running them "flat out" at 50mA or so!

### End of Lab 2 Tasks

You should now know how capacitors *charge* and *discharge* through a resistor, and can observe this with a digital voltmeter. You can utilise rectifiers and light-emitting diodes and identify their lead-outs, and calculate series limiting resistors for l.e.d.s. You can also perform basic diode checks on rectifiers using your multimeter.

Don't forget that you can write to us or E-mail us at **Teach_In98@epemag.demon.co.uk** if you have any *specific* queries or comments about this series.

In **Lab Work 3**, we shall delve further into power supplies, then with the foundations laid we prepare to enter the world of digital electronics, commencing with that most fundamental component of digital wizardry, the **Transistor**.

## EPE NET ADDRESSES

*EPE* FTP site: **ftp://ftp.epemag.wimborne.co.uk**
Access the FTP site by typing the above into your web browser, or by setting up an FTP session using appropriate FTP software, then go into quoted sub-directories:

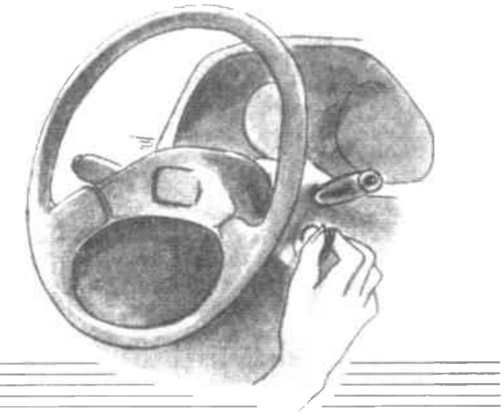
PIC-project source code files: **/pub/PICS**
PIC projects each have their own folder; navigate to the correct folder and open it, then fetch all the files contained within. *Do not try to download the folder itself!*

*EPE* text files: **/pub/docs**
Basic Soldering Guide: **solder.txt**
*EPE TENS Unit* user advice: **tens.doc** and **tens.txt**
*Ingenuity Unlimited* submission guidance: **ing_unit.txt**
New readers and subscribers info: **epe_info.txt**
Newsgroups or Usenet users advice: **usenet.txt**
Ni-Cad discussion: **nicadfaq.zip** and **nicad2.zip**
UK Sources FAQ: **uksource.zip**
Writing for *EPE* advice: **write4us.txt**
Ensure you set your FTP software to ASCII transfer, when fetching text files, or they may be unreadable.

*EPE* Website: **http://www.epemag.wimborne.co.uk**
Check it for up-to-date information on FAQs, subscribing, buying PCBs and Back Issues via our new Secure Server.

**E-mail addresses:**
Circuit Surgery: **alan@epemag.demon.co.uk**
Reader services: **editorial@epemag.wimborne.co.uk**
Teach-In '98, queries and feedback:
**Teach_In98@epemag.demon.co.uk**
Webmaster, for comments and feedback about the web and FTP sites: **webmaster@epemag.demon.co.uk**

# CAR IMMOBILISER



PAUL BRIGHAM

*Here's a novel jack-in-the-box to fool Jack-the-Lad's intentions on your car!*

With the ever increasing rate of car crime we all hear and read about (who do you know who hasn't been a victim?) the author decided to design an anti-theft device which could be fitted to his car in the hope he would not become a victim too.

The Car Immobiliser is intended to be more than just a deterrent. It immobilises the vehicle by cutting vital electrical circuits after a set period once it has been parked, actively helping to prevent it being stolen.

The unit has also been designed to prevent the vehicle from being "hot wired", bump started or started via the ignition switch, unless the correctly "coded key" is first inserted into the dash mounted socket.

It was felt to be important that no additional inconvenience should be caused to the authorised user when starting the car, otherwise the unit would prove to be impractical. Thus, prior to starting the car, all that is necessary is for a 6mm jack plug to be inserted into a dash mounted socket and then pulled straight out again. From this point onwards the car can be started and driven as if the unit was not fitted at all.

Once the ignition is switched off, the unit will self-arm without any further intervention from the driver, ensuring the car returns to its safe immobilised state.

The author's unit works perfectly and without inconvenience. It even allows enough time to re-start the car after stalling it, and it provides peace of mind to know that it will self-arm after every journey.

## CIRCUIT DESCRIPTION

Referring to the circuit diagrams in Fig.1 and Fig.2, the design is based predominantly around IC1, a type 324 quad op.amp. which is wired as a voltage comparator. The i.c. compares a fixed voltage of 6V, set by resistors R6, R7 and R8, with that of an input voltage set by R4 and the resistor inside the jack plug, R5.

Any value between about 1kΩ and 100kΩ can be used for R4 and R5, providing they are equal. For obvious security reasons, a precise value is not suggested.

To prevent a potential thief from "scanning" the key with a potentiometer to find the correct value for R5 (should the nature of the jack plug key be known) a special type of jack socket (SK1) is used. The socket incorporates a changeover switch which is operated when the plug is inserted.

Upon insertion of the plug, R5 is placed in circuit between R4 and transistor TR1

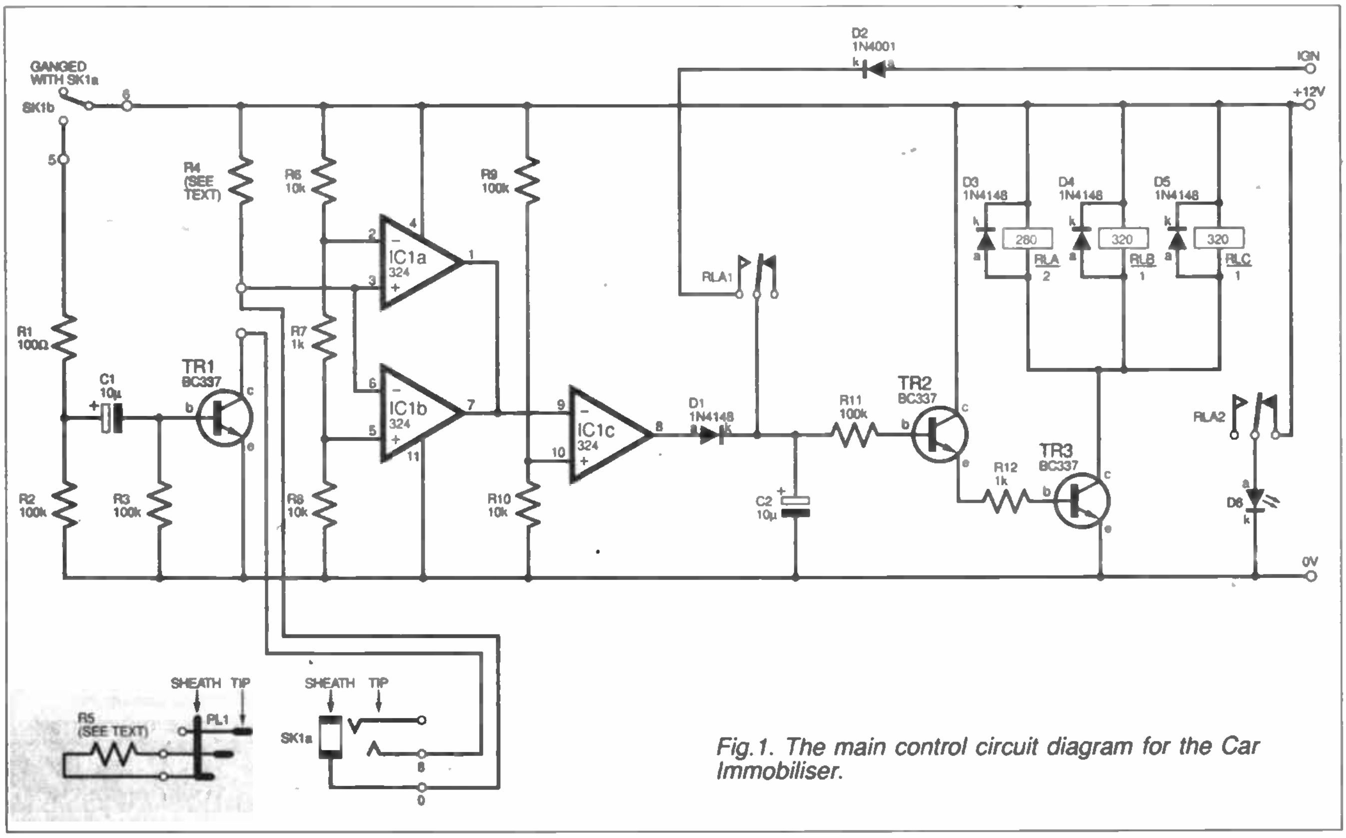



*Fig.1. The main control circuit diagram for the Car Immobiliser.*

via socket contacts SK1a. At the moment of insertion, the contacts of SK1b close and TR1 is switched on briefly via R1 and capacitor C1. This completes the "coded" voltage path through R4 and R5.

IC1a and IC1b now compare the voltages present on their input pins. If R4 and R5 are equal in value (i.e. the correct "key" has been used), the output at IC1c pin 8 will go high. Via diode D1, this voltage rapidly charges capacitor C2, causing transistors TR2 and TR3 to turn on, which in turn activates the three relays RLA, RLB and RLC.

The *RC* network of resistor R11 and capacitor C2 acts as a timer, holding on the relays for a duration of approximately 30 seconds, allowing the vehicle to be started. The duration may be changed by altering either value (a value increase lengthens the delay).

Relay RLA1 contacts are used to ensure that TR2 and TR3 remain switched hard on via the ignition supply and diode D2 while the vehicle is in use. This relay's second set of contacts, RLA2, are used to switch on the dash mounted warning l.e.d., D6, when the unit is in its immobilised state.

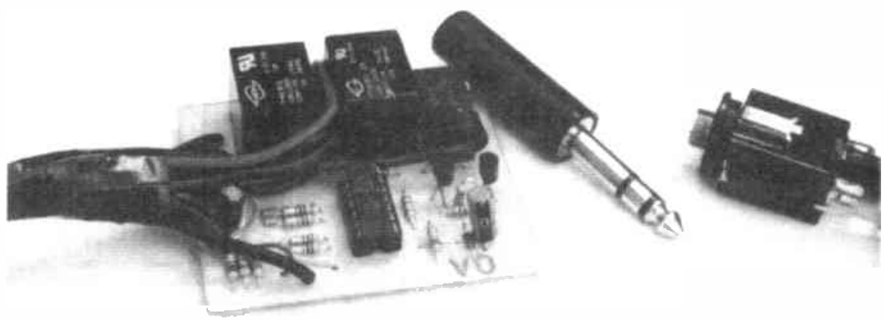
Relays RLB and RLC are both 10A s.p.d.t. relays which are used to cut the desired circuits in the vehicle when it is not in use, e.g. ignition coil, starting motor or fuel pump.

The addition of R7 between R6 and R8 is to allow compensation for any discrepancies in the tolerances of the two key resistors, R4 and R5. This allows the circuit to be triggered by a "key" voltage of between about 5·8V and 6·2V, as opposed to a strict 6V, which would be the case without the inclusion of R7.

Since TR1 is only conducting for a fraction of a second after the key has been inserted into the socket, there is no time for a potential thief to attempt to scan the key. Resistor R2 is used to discharge capacitor C1, and R3 is used to clamp the base of TR1 to 0V, to prevent false triggering of the circuit.

The unit is very simple to use, the jack plug is simply inserted into the dash mounted socket and then removed, by which action l.e.d. D6 will be turned off and the relays will latch, allowing the vehicle to be started.

After switching off the ignition, the unit will self-arm after 30 seconds, i.e. after C2 has fully discharged via R11, TR2, R12 and TR3.



*The three parts of the immobiliser system: the control board, "coded" jack plug, and its activating socket.*

The unit consumes 18mA when the car is in the immobilised state and 130mA when it is in use.

## CONSTRUCTION

Details of the printed circuit board (p.c.b.) are shown in Fig.3. This board is available from the *EPE PCB Service*, code 175.

Assemble the components in order of link wire (note that it goes *under* R10), resistors and diodes, i.c. socket. Next, solder in the capacitors and transistors, ensuring that they are the correct way round. Then solder in the relays and wire up the l.e.d.

Make up the jack plug with its resistor (R6) as shown in Fig.4. It is suggested that one or more spares should be made up as well.

Test the unit thoroughly, ensuring that the jack plug causes the actions already described to be performed. The next step is to drown the p.c.b. in potting compound within an ABS box. Wrap the cables in insulating tape at the point where they come away from the p.c.b. for about 100mm, then lower the board into the box and pour in the compound.

Also fill the jack plug bodies with the compound and leave them to stand in a vertical position until set. Once fully set, bench test the unit again then prepare to install it into the vehicle.

## INSTALLATION

You now need to refer back to Fig.2 for the other wiring connections, and also to your car's wiring diagram.

The diagram in Fig.2 shows, very basically, the electrical circuit of any vehicle in relation to its starter circuit and ancillary electric pumps which may be fitted, together with details of how the relays RLB and RLC are wired into this circuit.

**Extreme care must be taken when installing the unit into the vehicle because any poor connections could result in the car stalling whilst it is being**

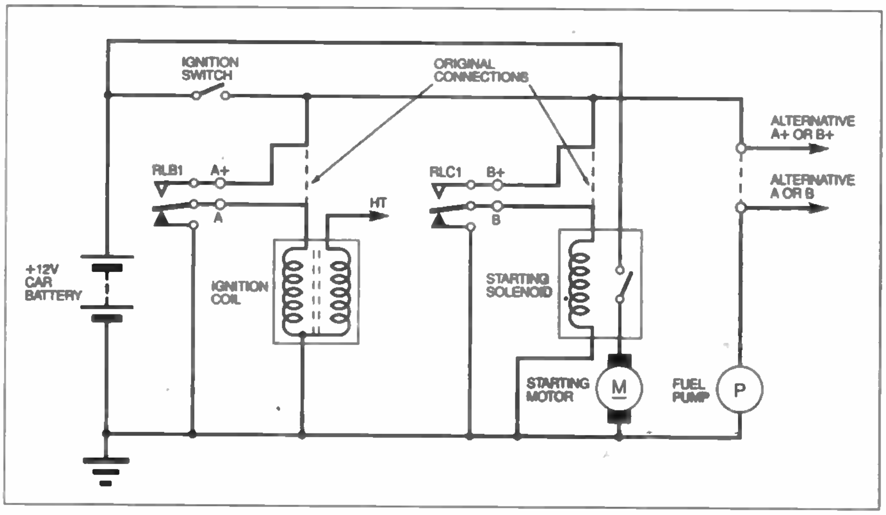



*Fig.2. Showing how the relays are connected to the car electrics. This figure should be referred to in conjunction with the wiring diagram in your car's manual.*

## COMPONENTS

**Resistors** — See SHOP TALK Page

| | |
|---|---|
| R1 | 100Ω |
| R2, R3, R9, R11 | 100k (4 off) |
| R4, R5 | see text |
| R6, R8, R10 | 10k (3 off) |
| R7, R12 | 1k |

All resistors 0.25W 5% carbon film.

**Capacitors**

| | |
|---|---|
| C1, C2 | 10µ radial elect. 25V (2 off) |

**Semiconductors**

| | |
|---|---|
| D1, D3 to D5 | 1N4148 signal diode (4 off) |
| D2 | 1N4001 rectifier diode |
| D6 | red l.e.d., flashing, low current |
| TR1 to TR3 | BC337 *npn* transistor (3 off) |
| IC1 | 324 quad op.amp |

**Miscellaneous**

| | |
|---|---|
| RLA | d.p.d.t. 12V 1A relay |
| RLB, RLC | s.p.d.t. 12V 10A relay (2 off) |
| SK1 | switched stereo jack socket, 6mm, Maplin type BW80B |

Printed circuit board, available from the *EPE PCB Service*, code 175; plastic case, 105mm × 72mm × 32mm; stereo jack plug, 6mm (see text); l.e.d. holder; single core cable (see text); 2-core cable; 4-core cable; potting compound; cable ties; insulation tape; solder, etc.

**Approx Cost Guidance Only £17 excl. cables**

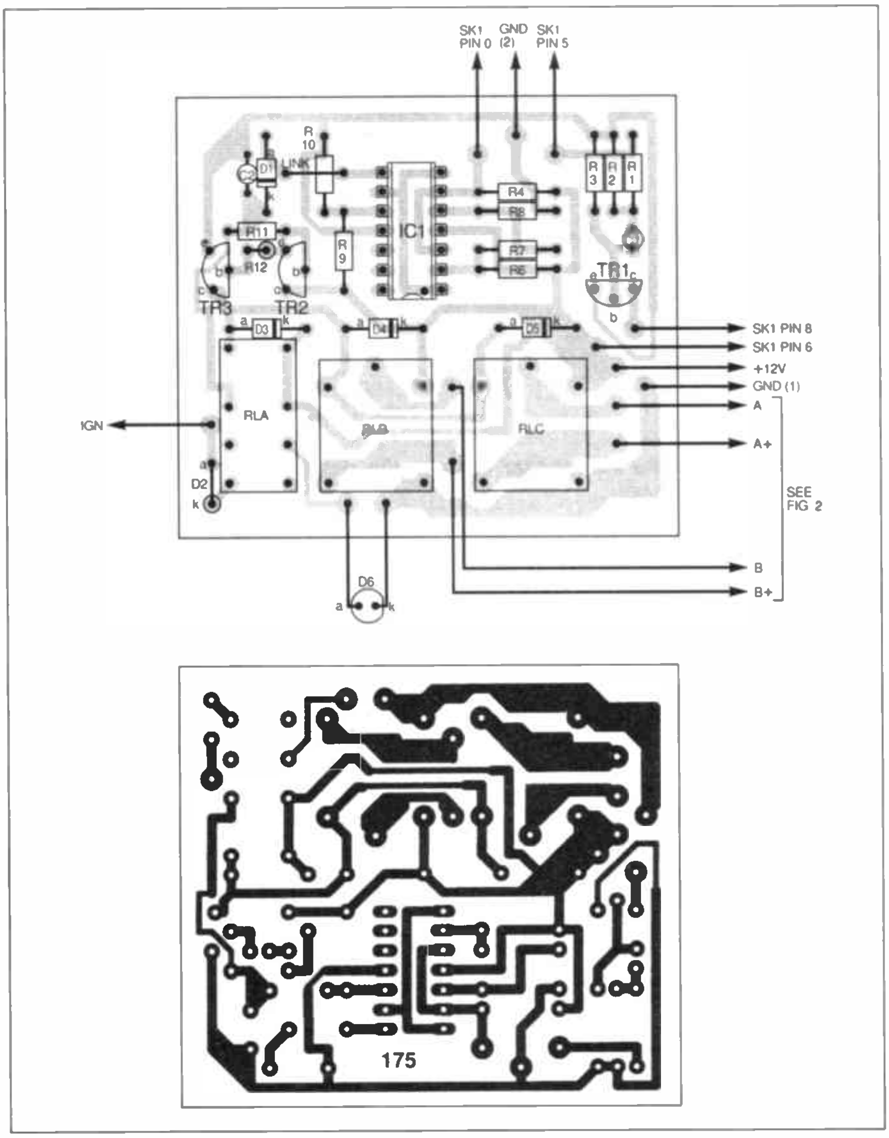



*Fig.3. Printed circuit board component layout and full size underside copper foil track master pattern for the Car Immobiliser.*

**driven, which could cause an accident. The cables must be rated to suit the vehicle's current demands.**

It is imperative, therefore, that two good earth points are used and that all other connections are soldered and wrapped in insulating tape or heat shrink sleeving.

Connecting to the ignition, permanent live and earth lines in the vehicle should be straightforward. However, when connecting the remaining wires, immense care must be taken because any errors here could cause permanent damage to the unit.

The first step is to find the two wires within the vehicle's wiring harness which, when cut, will immobilise the vehicle. When these wires are found, you need to cut them and measure which side of the wire is or becomes live when the ignition is switched on. The side which becomes live is connected to the "A+" or "B+" of the two relay circuit connections on the p.c.b., with the other side going to its corresponding letter, "A" or "B", as appropriate.

It is important to note that when connecting into the starting motor circuit, the feed to the *solenoid* is cut and *not the feed to the motor* itself. This is because of the extreme high current which flows in this feed when the car is being cranked over, as opposed to the relatively small current which flows in the coil of the solenoid (which is basically a heavy duty relay).

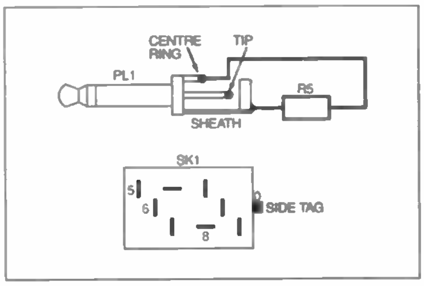



*Fig.4. Details of the jack socket and jack plug wiring.*

## ANTI-TAMPER

It is best to try and locate the wiring inside the vehicle since this makes it even more difficult for the potential thief. To this end the car's user manual will need to be referred to, to help identify the wiring colours and relative locations.

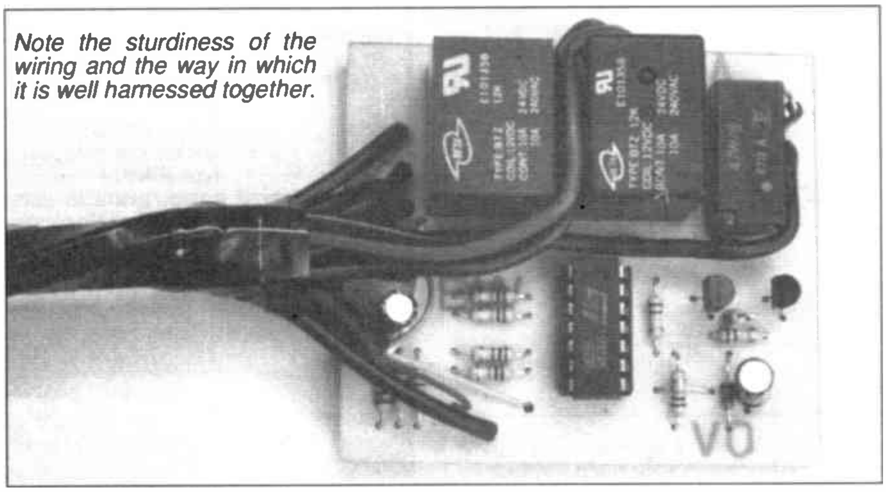
*View of the jack socket connections, with jack plug inserted, and of the tabbed coding of the other wires before connection.*

However, if in doubt, the wires from the positive side of the ignition coil, solenoid or fuel pump can be traced back into the vehicle and picked up just as they enter.

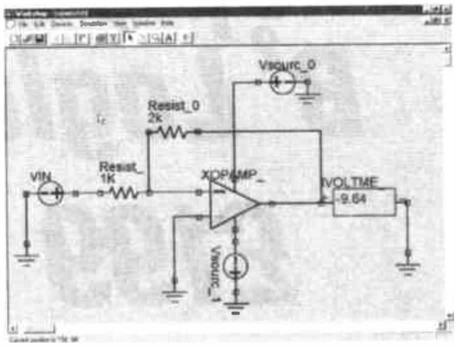
Remember that when each pair of cut ends is being checked, it may be necessary to turn the ignition switch fully clockwise, i.e. to the starter position, to ascertain which wire is positive and hence which gets connected to A+ or B+ on the p.c.b.

The l.e.d. should be mounted in a highly visible position on the dashboard and the socket is best mounted adjacent to the ignition switch.

The main control unit should be mounted up behind the dashboard and secured in place, along with all the wiring, by using cable ties. This will ensure a clean, professional and safe job.



*Note the sturdiness of the wiring and the way in which it is well harnessed together.*




# B² SPICE/LOGIC REVIEW

ROBERT PENFOLD

*Reviewing two programs that will assist with the design and testing of analogue and digital circuits.*

It is no coincidence that several of the circuit analysers currently available include the word "SPICE" in their names. These programs are all based on the same algorithms which were developed by the University of California at Berkeley. SPICE is an acronym for Simulation Program with Integrated Circuit Emphasis, and these algorithms are generally regarded as the most accurate and reliable of those currently on offer.

The differences between the circuit simulators currently available are not so much in the basic simulation algorithms, but in the means used to produced the netlists for the simulator, and the routines that process and present the results. A netlist is basically just a list of components in a circuit, and the connections between the components.

While netlists can be quite straightforward, SPICE netlists tend to look rather like computer program listings, and are not particularly user-friendly.

## B² SPICE

B² Spice is based on the latest 32-bit version of the SPICE algorithms (version 3F5). It is available for both Macintosh computers and PCs running Windows, but only the Windows version was reviewed.

The use of Windows 95 or NT is recommended, but B² Spice will run under Windows 3.1 at reduced speed. The minimum recommended hardware is an 80486 processor and 8Mb of RAM. For this review the program was run on a 133MHz Pentium PC running Windows 95.

The program provides a user-friendly front-end in the form of a schematic capture program which integrates seamlessly with the simulation routines. Once a simulation has been completed the results can be displayed on the screen in graph form, and can also be printed out to any Windows compatible printer.

For a circuit simulator to be of real use it is essential that it has a large library of component models. B² Spice comes complete with a library of over 1000 parts, including a wide range of operational amplifiers, plus the usual passive components. There are a number of common semiconductors which I could not find in the library, but more devices are being added. No matter how many devices are included, it is inevitable that the library will be found lacking from time to time. Sometimes it may be possible to use a near substitute. Alternatively, there is a device editor which enables new models to be added, or existing ones to be modified.

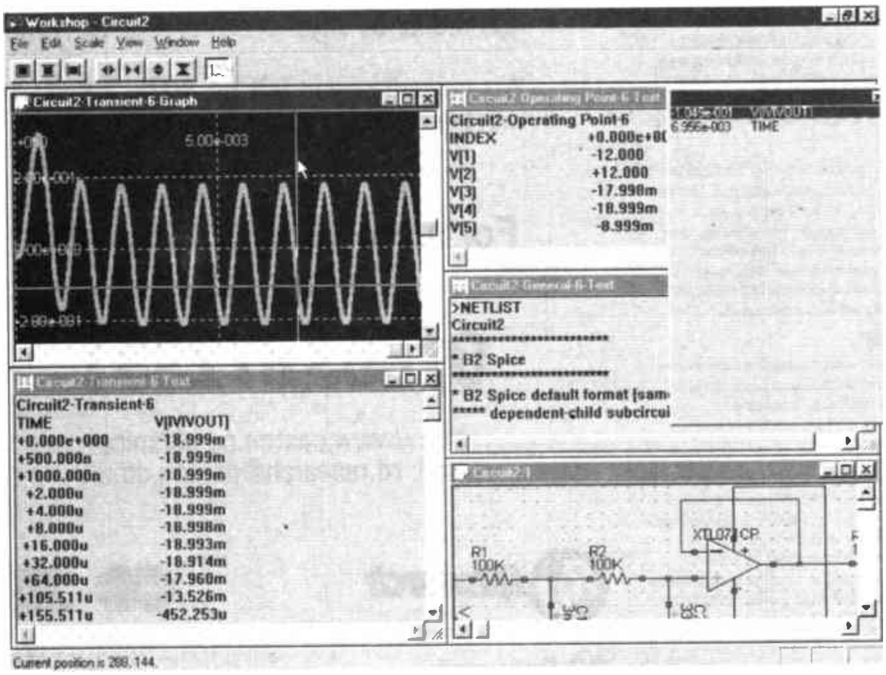
## GETTING STARTED

The CD-ROM version of the program was supplied for review, and installation proved to be something less than straightforward. Unfortunately, there were a few errors in the manual originally supplied, and following the installation instructions resulted in the Windows NT/95 program and Windows 3.1 database engine being loaded onto the hard disk.

Once this mix-up had been sorted out it was not difficult to get the right files loaded into the computer, and the program then ran without any problems. This error has been corrected in the current version of the manual and the package now uses the standard Install Shield-Wizard.

The A5 size ring-bound manual includes some simple tutorials to help get you started with the program. This is very helpful, but the step-by-step approach needs to be carried out carefully if it is to work well. What is given as a single step in the manual sometimes turns out to be two steps when using the actual program. Also, some of the screen illustrations in the manual seem to be different to the actual screens obtained from the program. However, the simple tutorials still make it reasonably easy to get underway with this software. They demonstrate various types of analysis, including a.c., d.c., and transient analysis.

A traditional Windows screen layout is used, with a title bar at the top and the menu bar immediately beneath this. There is the usual row of control buttons beneath the menu bar. Apart from standard functions such as save, print, etc., there are buttons which provide basic drawing



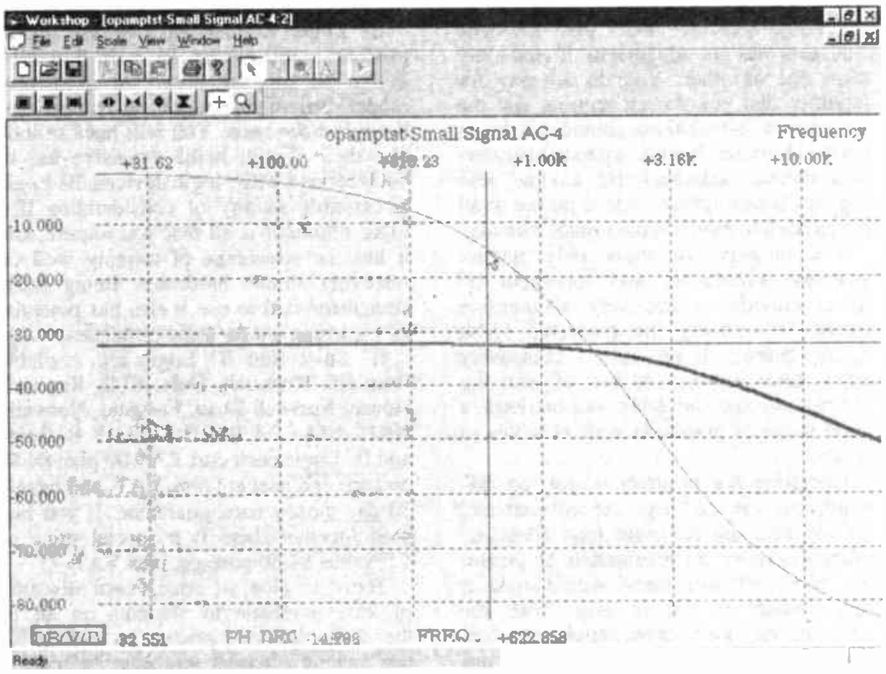

*Multiple screen display showing the circuit, netlist, test results and graph.*

and editing functions. There is a status bar along the bottom of the screen, and there are the usual scroll-bars, but the vast majority of the screen is available for the circuit diagram.

Selecting components and placing them within the drawing area is generally simple, as is the wiring-up process. The latter is manual, with no automatic help. Components are selected via the "Devices" pull-down menu, and there is a range of generic components available as well as numerous semiconductors under specific type numbers.

Editing component models via the device editor seems to be reasonably simple, but you obviously need to have all the necessary data before a new model can be produced. Unless you know what you are doing it is best to settle for near equivalents or idealized generic components.

Simply changing the value of a passive component is more simple. Double "clicking" on a component brings up a dialogue box which enables its value to be edited. There is also a keyboard shortcut. In general, changes are easily made to circuits, and the schematic editor is very easy to use.



A phase and frequency response graph covering 20Hz to 20kHz.

## SIMULATIONS

A variety of simulations are catered for by the SPICE algorithms, including a.c. (phase and frequency), d.c., transient, noise, distortion, and Fourier analyses. Setting up the required analyses is reasonably easy, but with any circuit analyser you have to get things absolutely spot on if you want to get the right answers. Once the simulation has been completed you are provided with a graph for each simulation together with a table of results. The netlist generated by the program is also provided. These are all available in individual windows.

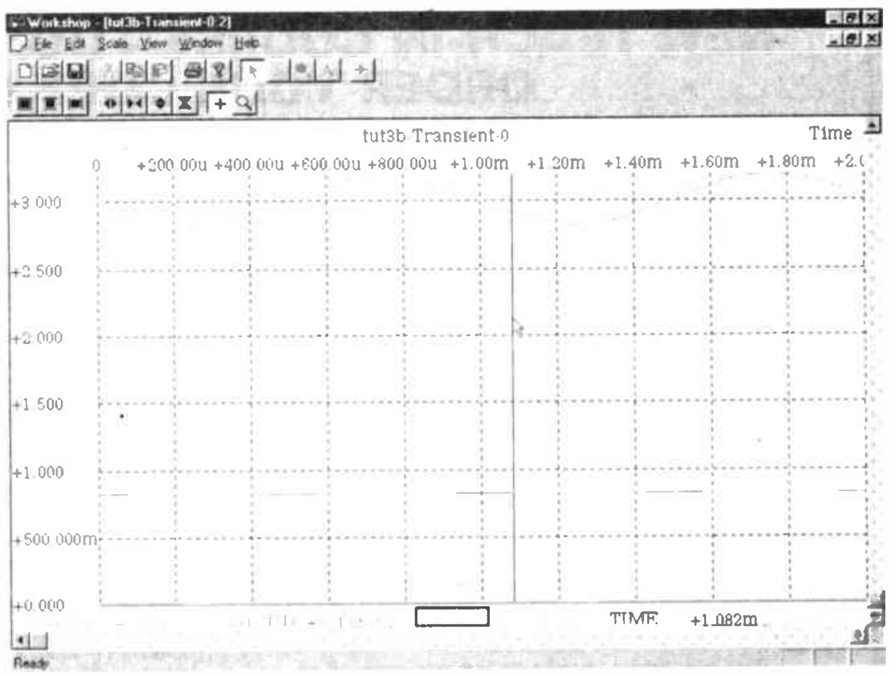
Simulation programs are not really noted for the clarity of the graphs they produce, and the version of B² Spice originally reviewed was certainly no exception to the rule. The graphs made exclusive use of scientific notation, and the labels tended to encroach onto the graphs. The default settings did not always provide results that were easy to read, although it was possible to select colours for each part of the graph, change the text font size, and vary the zoom level. This made it possible to improve the clarity of the graphs and optimise results with a given display resolution. There were sometimes problems with display flicker, and one or two further rough edges which marred the graphics output of the original program.

On the plus side, multi-trace graphs are possible, with the active trace highlighted and the others dimmed. An optional window provides individual test results in conjunction with a movable cursor on the graph.

Credit must be given to the producers of B² Spice for responding to the original criticisms. The current version of the program retains the versatility of the original graphics generator, but clears up most of the weaknesses. In particular, there is now the choice of scientific or engineering notation for the labels, and the graphs can be interpreted much more quickly and easily.

Although there is no virtual oscilloscope as such, the transient analysis function produces an oscilloscope style graph. It is acceptable to use a sinusoidal source instead of some form of pulse signal, making it possible to use this facility to show clipping and other severe forms of waveform distortion.

A good range of analyses are available for a program in this price bracket and, although not the quickest simulator I have tried, it works reasonably fast. With complex circuits things naturally slow down a great deal, but this is the same with all circuit simulators. Incidentally, the maximum number of nodes and components that can be handled is governed by the amount of memory fitted to the computer, and not by any limits imposed by the program itself.



The transient function can produce an oscilloscope style display.

## B² LOGIC

The B² Logic simulator is supplied on a single 3·5 inch high density disk, and it is compatible with Windows 3.1 or later. It loaded into Windows 95 without difficulty. A PC having an 80286 processor and 2Mb of RAM is the minimum requirement. A Macintosh version of B² Logic is also available, but was not reviewed. The B² Logic simulator does not utilize SPICE algorithms incidentally, and the SPICE routines are not actually applicable to logic circuits.

The supplied library of parts includes about 100 basic TTL devices ranging from simple gate packages like the 7400 through to more complex components such as the 74381 arithmetic logic unit. These are available in the standard TTL, LS TTL, Fast CMOS and Advanced CMOS logic families. A few further models are included, such as ROM and RAM chips, delay elements, and a user programmable logic device. As an avid user of 4000 series CMOS devices I was disappointed to find that these do not seem to be catered for. The device editor makes it reasonably easy to edit component models, to alter the propagation delay for example. In this way a device from one logic family can be converted to its equivalent in another logic family.

When the program is activated you are greeted with a largely blank screen. There is the usual title bar at the top, and a menu bar beneath this which has "File" and "Window" headings. Amongst other things, the "File" menu enables an existing circuit to be loaded, or you can opt to start work on a new circuit.

With the "New" option selected or an existing circuit loaded the screen becomes more like that of $B^2$ Spice, with more menu headings and a small "floating" toolbar. Also, a floating menu of component models appears, and this takes the place of the "Devices" menu in $B^2$ Spice. Simply double-clicking on a component name brings up the symbol for that component so that it can be positioned in the drawing area.

With multi-gate packages, multiple flip/flops, etc. each section is effectively a different component. Repositioning components, wiring them together, etc. is reasonably fast and straightforward. Provided your PC is equipped with sufficient memory, $B^2$ Logic can handle large circuits.

## INS AND OUTS

Little is available in the way of virtual instruments, but simple logic state generators are available, and these can generate logic 1 or logic 0 levels. They can be switched from one state to the other by a "click" from the mouse. If necessary, a number of these can be used to form a simple word generator. The latest version of the program includes a logic generator which can handle up to 32 bits, and accepts hexadecimal values via a dialogue box.

A clock generator having individually adjustable mark and space times is also available and this is clearly essential for most testing. Unused inputs can be tied to pull-up or pull-down resistors. Logic outputs can be monitored using simple logic indicator symbols, and a number of these can be used to monitor buses.

The main means of monitoring the circuit is via a trace function which can be accessed via one of the pull-down menus. This provides a logic analyser style display which shows the waveform at each point in the circuit that is monitored by one of the virtual logic probes. It also shows the output levels of the logic generators, which can be altered during the course of the simulation.

The waveforms are of course recorded, and it is possible to scroll smoothly through the recorded data with the aid of the usual scrollbar. In use the logic analyser function is simple and straightforward to operate and it provides results that are easy to interpret. A table of results is also available.

## CONCLUSION

Having separate logic and analogue analysers has its advantages if you only want one or other. You do not pay for facilities that you do not require, and the accuracy of simulations should not be in doubt. However, having separate analysers is a definite drawback for anyone who requires both functions, and is no use at all if you need to model mixed-mode circuits.

The majority of users only require analogue simulation, and for them $B^2$ Spice provides a relatively inexpensive means of utilizing the powerful 32-bit Spice routines. It provides a reasonably quick and painless means of entering circuits into the simulator, and produces a good range of graphs as well as tables of results.

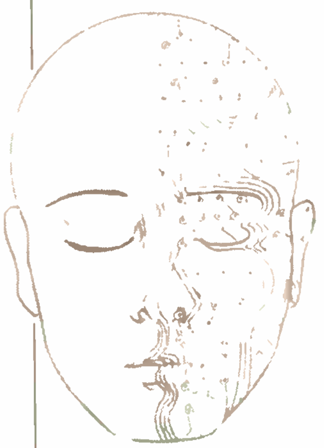
Operating the program is not too difficult, but the 123-page A5 manual and on-line help are no more than adequate. More extensive documentation or greater use of virtual instruments would make it much easier to get to grips with the program. Anyone with the requisite technical knowledge should soon learn to use this program though, and SPICE based simulators are not really intended for beginners. Testing of the final version was something less than extensive, but this program seems to be stable and bug-free.

While not exactly cheap by general software standards, $B^2$ Spice is at a bargain price for a 32-bit SPICE based simulator. As originally supplied for review the program seemed to have no advantages over the opposition apart from a lower price. In most respects it seemed to fall slightly short of the standards set by the competition. However, RD Research acted on our criticisms and improved various aspects of the program. The version now on sale incorporates these improvements and the excellent graphics output and other facilities of the "improved" version make $B^2$ Spice more competitive. Some will no doubt prefer this program for its facilities rather than any cost considerations. It is certainly a program that anyone buying this type of software should give careful consideration.

$B^2$ Logic is quite easy to use and it produces good results. Its main limitation is that the supplied library of component models is perhaps not quite as extensive as it might have been. You will have to look elsewhere if you make extensive use of 4000 series CMOS logic devices. $B^2$ Logic is certainly worthy of consideration if a logic simulator is all that you require, and it has the advantage of running well on relatively simple hardware. Being fairly straightforward to use it also has potential as a learning aid for logic principles.

$B^2$ Spice and $B^2$ Logic are available from RD Research, Dept. EPE, Research House, Norwich Road, Eastgate, Norwich, NR10 4HA (Tel. 01603 872331). $B^2$ Spice and $B^2$ Logic each cost £199·00 plus £4·50 postage and packing plus VAT, and have a 30 day money back guarantee. If you buy both together there is a special price of £298 plus £4·50 postage, plus VAT.

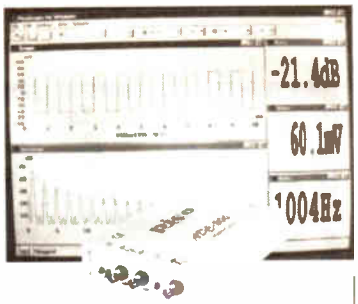
There is also an educational discount of 25% available to students on all of the above software prices. To qualify for this student discount you must be able to provide proof of your student status. □



# INGENUITY UNLIMITED

Our regular round-up of readers' own circuits. We pay between £10 and £50 for all material published, depending on length and technical merit. We're looking for novel applications and circuit tips, not simply mechanical or electrical ideas. Ideas *must be the reader's own work* and **not have been submitted for publication elsewhere.** The circuits shown have NOT been proven by us. *Ingenuity Unlimited* is open to ALL abilities, but items for consideration in this column should preferably be typed or word-processed, with a brief circuit description (between 100 and 500 words **maximum**) and full circuit diagram showing all relevant component values. **Please draw all circuit schematics as clearly as possible.**

Send your circuit ideas to: Alan Winstanley, *Ingenuity Unlimited*, Wimborne Publishing Ltd., Allen House, East Borough, Wimborne, Dorset BH21 1PF. They could earn you some real cash **and a prize!**




**WIN A PICO PC BASED OSCILLOSCOPE**

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If you have a novel circuit idea which would be of use to other readers then a Pico Technology PC based oscilloscope could be yours.

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

## Model Railway Train Lights

### – Go Loco With A Green Light

A PROJECT which controls a set of British model railway lights, similar to those used at the ends of railway stations to signal to the loco driver whether it is safe to proceed or not, is shown in Fig.1.

When a train passes the signals, the lights turn red for a period of three seconds after which one amber signal lights, then two amber signals and finally a green signal ten seconds after the last train has passed. Details are given showing how this could be adapted to cut off the power supply to a section of track when the red light is showing.

The train's position is sensed by embedding a reed switch S1 within the track. A magnet on the underside of the train will close this switch as it passes over it. (For authenticity, the magnet could be attached underneath the last carriage.)

The reed switch discharges the electrolytic capacitor C1, which then immediately starts to re-charge through preset VR1; wired as a variable resistor. The trimmer resistor can be used to adjust the time taken for the full sequence of signal changes to occur.

When the potential "$V_C$" across C1 reaches certain values, these are detected by a number of twin op.amps IC1 to IC3 connected

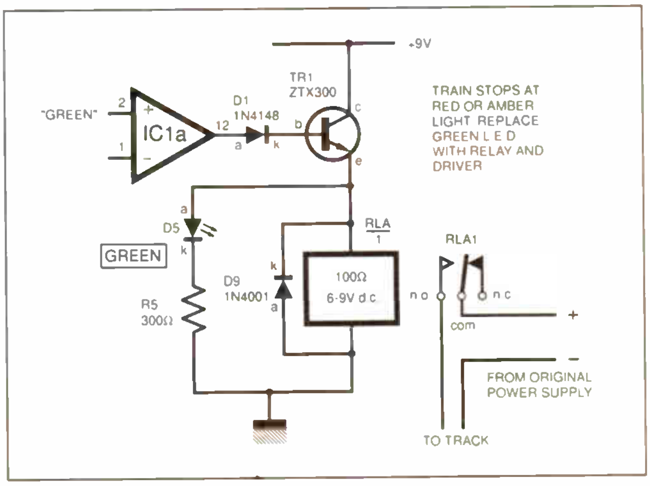



*Fig.2. Adding a driver transistor and relay to the "Green" circuit.*

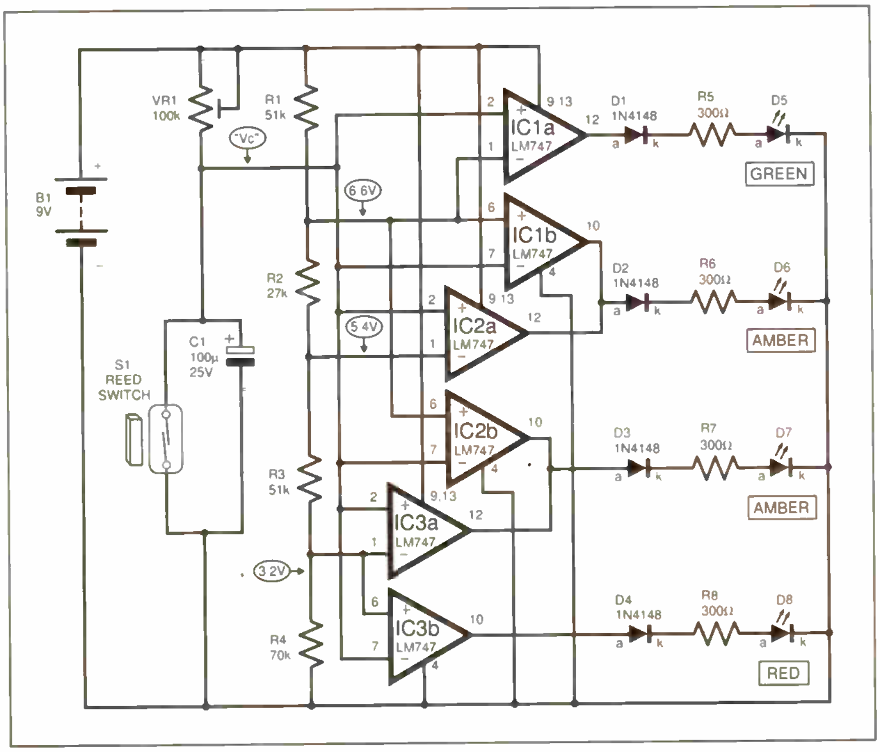



*Fig.1. Circuit diagram for Model Railway Signal Lights.*

as comparators, each of which operates one or more l.e.d.s. The op.amps each have a reference voltage derived from a set of resistors R1 to R4. When $V_C$ is less than 3·2V the Red lamp D8 illuminates, the Amber l.e.d.s D6 and D7 when $V_C$ is between 3·2V and 5·4V, and Green if higher than 6·6V.

For more realism, by including a driver transistor and relay (TR1 and RLA in Fig.2), on the green indicator circuit, the train can be made to stop at the red or amber light. The relay contacts will only connect the track power supply when the green l.e.d. is showing. The l.e.d.s are arranged to form a

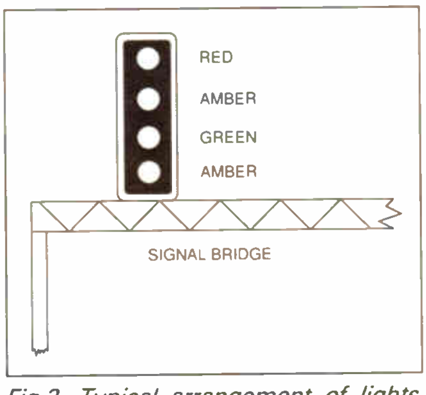



*Fig.3. Typical arrangement of lights on a trackside signal bridge.*

trackside signal as shown in Fig.3. The power supply can be derived from an internal battery (B1) or from a mains adaptor, or roughly 9V to 12V d.c. from a transformer.

For economy, B1 could be controlled using, say, a normally open relay powered from the railway track, such that when the power is removed, the relay will disconnect the battery from the model railway signals.

*Oliver White,*
*Walton on Thames, Surrey.*

# Mechanical Vibration Sensor – Check Those Vibes

THE Mechanical Vibration Sensor circuit diagram of Fig. 4 was developed to monitor the frequency of mechanical vibration of a large d.c. motor. It utilises an a.c. bridge network with the two grounded arms being resistors R1 and R2, and two differential inputs via the variable capacitors VC1 and VC2. The circuit requires an input signal of 10kHz, 10V peak-to-peak, and is powered at ± 12V.

Vibration is detected using a sensor (Zs) which is fabricated from two squares of 1mm copper sheet, sized 35mm square, joined physically at one end by a double-sided sticky pad (see inset diagram). This creates a simple capacitor of around 15pF with one end free to move in sympathy with the vibration of the motor. Greater sensitivity may be achieved by elongating the sensor plates if required.

Once the bridge has been balanced by the variable capacitors, the 10kHz carrier wave is of equal amplitude on both inputs of the differential amplifier formed by IC1a and surrounding components, and the output will be zero. Any movement of the sensor will result in a change of capacitance and thus the impedance to the carrier wave. This creates an imbalance in the differential amplifier, thereby creating a modulated output waveform.

This waveform is demodulated by D1, R5, C1 and C2, and amplified by the non-inverting op.amp IC1b. The remaining circuitry converts the amplified signal into a constant amplitude square wave at the same frequency as the input. This is then differentiated, rectified and averaged to give a d.c. output voltage on meter ME1 which is directly proportional to the frequency of the vibration. The d.c. voltmeter may be a surplus type or a multimeter, and the series resistor Rm selected as required, if needed.

On setting up, preset VR1 should be set to match the f.s.d. of the meter and the maximum frequency of vibration expected. This is best achieved by temporarily removing C4 and injecting a known frequency into resistor R9, checking your readings at full scale and in between. A voltage of +8V for a frequency of 8kHz is the maximum available for a linear scale. VR2 is trimmed for zero offset.

*Dave Stringwell,*
*Scunthorpe, North Lincolnshire.*

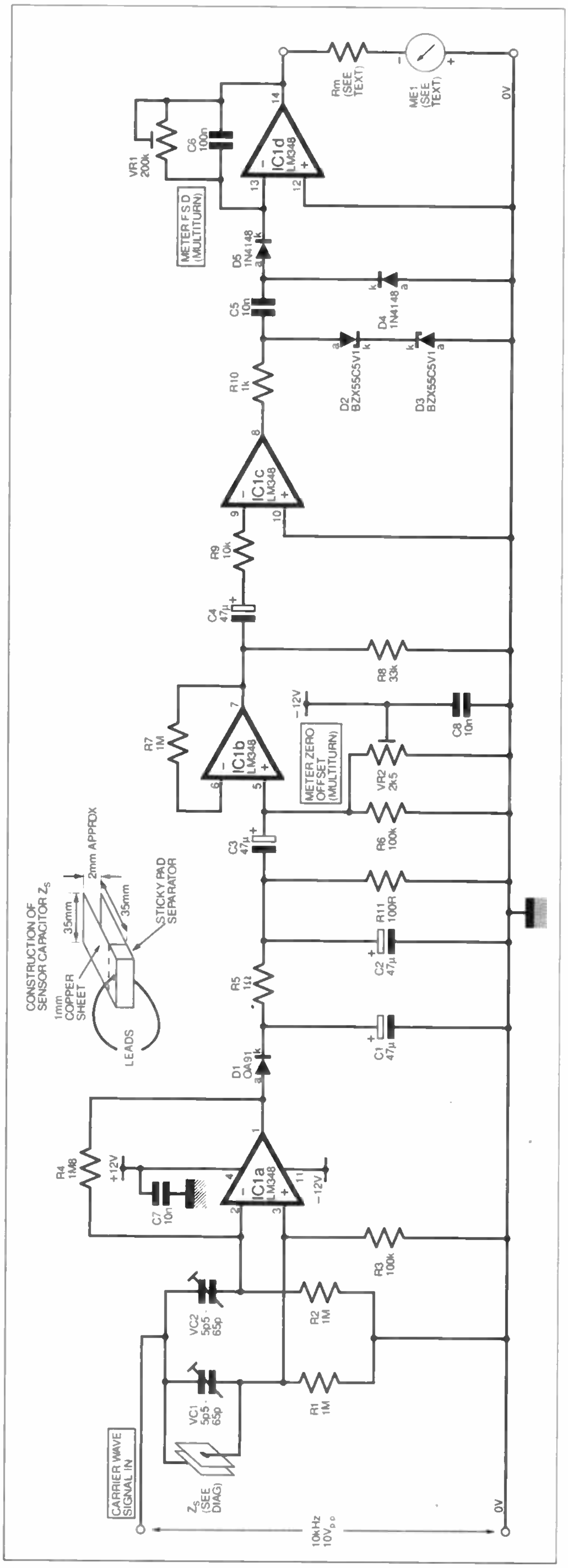



*Fig.4. Circuit diagram for the mechanical Vibration Sensor. Details of the home-made sensor capacitor Zs are shown inset.*

**MORE READERS CIRCUIT IDEAS NEXT MONTH**

## PICO PRIZE WINNERS

It's six months since Pico Technology started to sponsor IU and it's time to award some prizes. The various IUs published over the last six months (June to November '97 issues) were judged by Alan Winstanley and Mike Kenward on the following criteria:

- Any "lateral thinking" or novelty in resolving a design objective, implying the use of ingenuity.
- Technical merit, feasibility and practicality of the suggested solution.
- The resourcefulness and likely originality of the idea.
- Appropriate and justifiable use of electronics technology over a mechanical or alternative discipline.
- The general presentation and completeness of a submission.

*The prize winners are:*

**1st prize – A Pico ADC200-50**
PC-based digital storage oscilloscope:

**19kHz Reference Source – September 1997** (B. J. Taylor). A cleverly executed example of lateral thinking, by effectively adapting the f.m. pilot tone to generate an accurate reference signal for test purposes.

**Runners-up – Pico ADC-40** PC-based single channel oscilloscopes:
**Novel Fibre Optic Tester – July 1997** (John Barker). A brilliant example of lateral thinking to solve a high-level problem – the testing of telecommunication fibre optic "patch cords".

**IR Camera Shutter – August 1997** (Stephen Browne). A thoroughly-worked example of a practical solution to time-lapse photography involving an electromechanical interface.

**Our thanks to Pico for their on-going sponsorship**

***Why not send in your circuit idea – it could earn some cash and a prize!***

# ALTERNATIVE AND FUTURE TECHNOLOGIES

**CLIVE (call me "Max") MAXFIELD** **Part 1**

*A smorgasborg of technologies which may or may not influence the future of electronics. (Reproduced from Chapter 21 of the book* Bebop To The Boolean Boogie *with kind permission of the publishers and Max - see the* EPE Direct Book Service *pages for ordering details).*

ELECTRONICS is one of the most exciting and innovative disciplines around, with evolutionary and revolutionary ideas appearing on almost a daily basis. Some of these ideas skulk around at the edges of the party, but never really look you in the eye or take the trouble to formally introduce themselves; some surface for a short time and then disappear forever into the twilight zone from whence they came; some tenaciously manifest themselves in mutated forms on a seasonal basis; and some leap out as if from nowhere with a fanfare of trumpets and join the mainstream so quickly that before you know it they seem like old friends.

This closing chapter introduces a smorgasbord of technologies, many of which have only recently become commercially available or are on the cutting-edge of research and development. Even the most outrageous topics presented below have undergone experimental verification, but nature is a harsh mistress and natural selection will take its toll on all but the fittest. Although some of the following may seem to be a little esoteric at first, it is important to remember that a good engineer can easily believe three impossible things before breakfast. Also remember that the naysayers proclaimed that it was impossible for bumble bees to fly (although they obviously could), that man would never reach the moon, and that I would never finish this book![1]

## Reconfigurable Hardware and Interconnect

The term "*hardware*" is generally understood to refer to any of the physical portions constituting an electronic system, including components, circuit boards, power supplies, cabinets, and monitors.[2] However, this discussion concentrates on the subset of hardware consisting of circuit boards, electronic components, and interconnect.

Unfortunately, the phrase "*reconfigurable hardware*" is akin to the phrase "*stretch-resistant socks*" – they both mean different things to different people. To the young and innocent, "*stretch-resistant*" would tend to imply a pair of socks that will not stretch. But, as those of us who are older, wiser, and a little sadder know, "*stretch-resistant*" actually refers to socks that *will* stretch – they just do their best to resist it for a while! Similarly, the term "*reconfigurable*" is subject to myriad diverse interpretations depending on the observer's point of view.

As a starting point, reconfigurable hardware refers to an electronic product whose function can be customised to a specific system or application. There are obvious benefits to making one product (that can be customised) many times, as opposed to making many application-specific products once. The problem is, the perception of what is implied by "*reconfigurable*" is a moving target which evolves over time as new techniques and technologies become available. Throughout most of the 1980s, the most sophisticated level of customization was displayed by products based on programmable logic devices (PLDs) such as PROMs, PLAs[3], and PALs, or variants of read-only memory such as PROMs[4], EPROMs, and $E^2$PROMs[5]. Products using these devices were usually targeted at a particular application and then focused towards a specific implementation. By comparison, the advent of field-programmable gate arrays (FPGAs) in the late 1980s and early 1990s opened the door to products that could be almost totally customized for diverse applications.

As you have hopefully surmised by now, *Bebop to the Boolean Boogie* does not simply describe "where we are," but also attempts to show "how we got here." However, the pace of technological development since the birth of the integrated circuit poses particular problems in the case of reconfigurable logic, because there is no consistent terminology that has survived the ravages of time. To permit the presentation of a consistent view, the solution offered by *Bebop* is to adopt the following terminology[6]:

| | |
|---|---|
| Configurable hardware | A product whose function may be customized once or a very few times. |
| Reconfigurable hardware | A product whose function may be customized many times. |
| Remotely reconfigurable hardware | A product whose function may be customized remotely, by telephone or radio, while remaining resident in the system. |
| Dynamically reconfigurable hardware | A product whose function may be customized "on-the-fly" while remaining resident in the system. |
| Virtual hardware | An extension of dynamically reconfigurable |

*1 Ha! I pluck my chest hairs threateningly in their general direction.*
*2 By comparison, the term "software" refers to intangible programs, or sequences of instructions, that are executed by hardware. Additionally, the term "firmware" refers to programs that are hard-coded into non-volatile memory devices, while "vapourware" refers to either hardware or software that exist only in the minds of the people who are trying to sell them to you.*
*3 Programmable logic devices were introduced in Chapter 16.*
*4 PROMs may be regarded as being programmable logic devices or as memory devices depending on the applications for which they are being used.*
*5 Memory devices were introduced in Chapters 15 and 16.*
*6 The terminology presented here differs to some extent from current industry standards, which only tend to reflect the technology of the day (or flavour of the month).*

And so, armed with our trusty definitions, it only remains for us to gird up our loins and delve into the ramifications of hardware whose very reason for being can be transmogrified by an idle whim.

## Configurable Hardware

A classic example of a product whose function may only be customized once is provided by a car radio, of which there may be several versions: a cheap, no-frills little number for the cost-conscious buyer, a mid-range model for the young man about town, and an ultra-flash, no-holds-barred version for the powerful business executive who also delights in thrusting his gold Rolex under your nose. But, little do they know that it is not unusual for all of these variations to be constructed on identical circuit boards, which can be configured by adding or removing certain components and modifying certain switches or jumpers. In fact, on some occasions, the only major difference between the different models is the quality of their cases and the number of buttons and dials that they support. From the viewpoint of the manufacturer, the circuit boards used in these radios are configurable but, from the perspective of the user, their function is cast in stone.

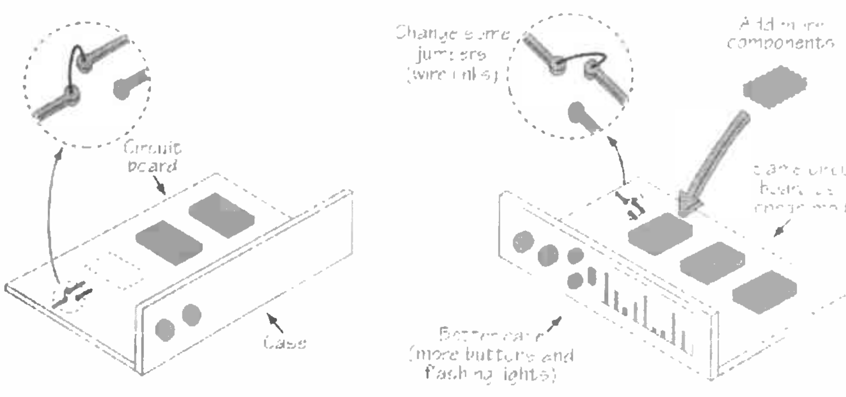



**Figure 21.1: Configurable hardware: car radios**

A similar example that may be a little closer to home revolves around digital wrist watches. One down-side of the electronics era is the inevitability of being cornered by someone who insists on regaling you with the 1,001 details you didn't want to know about his new digital watch that can simultaneously display the current time in Tokyo, Paris, London, New York, and Moscow, play sixteen immediately annoying tunes, and has a calculator rivaling the control panel of the space shuttle thrown in for good measure. By some strange quirk of fate, this almost invariably occurs on those days when the timepiece you are sporting arrived in the form of a free gift at the bottom of a box of cornflakes. But there is no need to lower your head in shame, because it is not beyond the bounds of possibility that both of these instruments contain identical integrated circuits! In the case of the simpler model, a hard-wired voltage level applied to one of the device's pins instructs it to pretend to be "cheap and cheerful." Once again, the major difference between the two models is the quality of their cases and . . . the price tag.

A final example of configurable products that is too good not to share revolves around a number of well-known computer manufacturers who used to offer a choice between the fast, deluxe, and expensive version of a machine, or the slower, somewhat cheaper model. However, unbeknownst to the innocent purchaser, the only difference between the two models was a simple switch on the main circuit board. Depending on the position of this switch, the system's clock either ran at full speed or was "slugged" to half its normal operating frequency. When the owners of one of the slower systems decided that they just had to upgrade, large amounts of money would change hands and, after appropriate sacrifices had been offered to the Gods, the computer engineer would (eventually) arrive. After making a ceremony of preparing to exchange the circuit boards, the engineer would suddenly leap to his feet, point excitedly out of the window, and cry "Good grief! What's that?" Then, while everybody's backs were turned, he would flick the switch and have the board halfway back into the system before anybody knew what was happening. And there are those who would say that electronics is dull and boring!

## Reconfigurable Hardware

Hardware that is simply configurable is obviously limited, because everything that the product can do has to be designed into its base configuration, which has to encompass all possible variants. One technique for producing a product whose function may be extended beyond its original design objectives is to base that product on devices that can be reprogrammed. For example, a PROM could be employed in the role of a hardware truth table (Figure 21.2).

Similarly, a PLA could be used to implement a state machine that performs a certain sequence of operations, or, based on the inputs presented to it, a PAL device could be used to implement Boolean equations and to generate appropriate outputs. In all of these cases, the functions of the truth table, state machine, or Boolean equations could be modified by simply exchanging the programmable device with an upgraded version.

Another technique would be to use non-volatile memory devices to store firmware programs for use by a microprocessor or a microcontroller. An example could be a set of instructions used by a microprocessor to play a tune such as the National Anthem on a musical door chime. Different versions of the PROM could be used to allow the product to be marketed in different countries (hopefully with the correct anthem). Additionally, in the case of those countries that count revolution as a national sport, the product could be easily reconfigured to reflect the "tune of the day."

The non-volatile memory examples introduced above could use PROM, EPROM, $E^2$PROM, or FLASH devices; similarly, the programmable logic device examples could employ PLD, EPLD, $E^2$PLD or FLASH-PLD components. In all of these cases, from a board-level perspective, the board itself would be classified as reconfigurable. However, from a device-level viewpoint, PROMs would fall into the

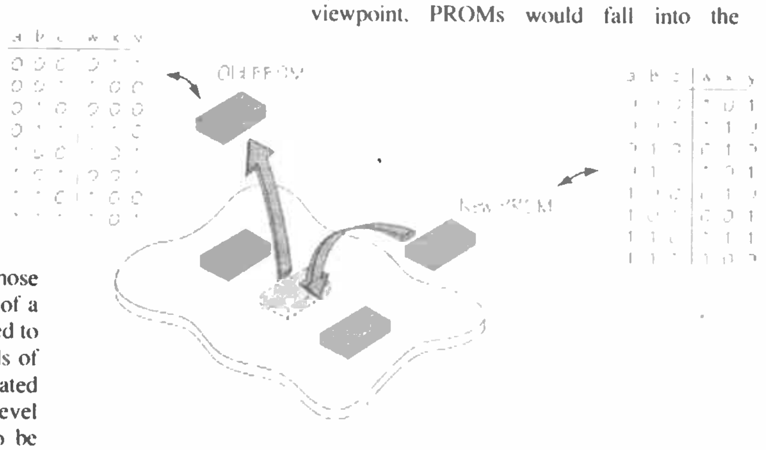


**Figure 21.2: Reconfigurable hardware: PROM as a hardware truth table**

category of *configurable*, while their more sophisticated cousins, EPROM, $E^2$PROM and FLASH would be categorised as *reconfigurable* (similarly in the case of PLDs versus EPLDs, $E^2$PLDs, and FLASH-PLDs). Additionally, $E^2$-based and FLASH-based components may be referred to as *in-system programmable* (ISP), because they can be reprogrammed while remaining resident on the circuit board.

## Dynamically Reconfigurable Hardware

The advent of SRAM-based FPGAs in the late 1980s and early 1990s presented a new capability to the electronics fraternity: dynamically reconfigurable hardware, which means designs that can be reconfigured "on-the-fly."

FPGAs contain a large number of diverse logic gates and registers, which can be connected together in widely different ways to achieve a desired function. SRAM-based variants augment the capabilities of standard FPGAs by allowing new configuration data to be down-loaded into the device by the main system in a fraction

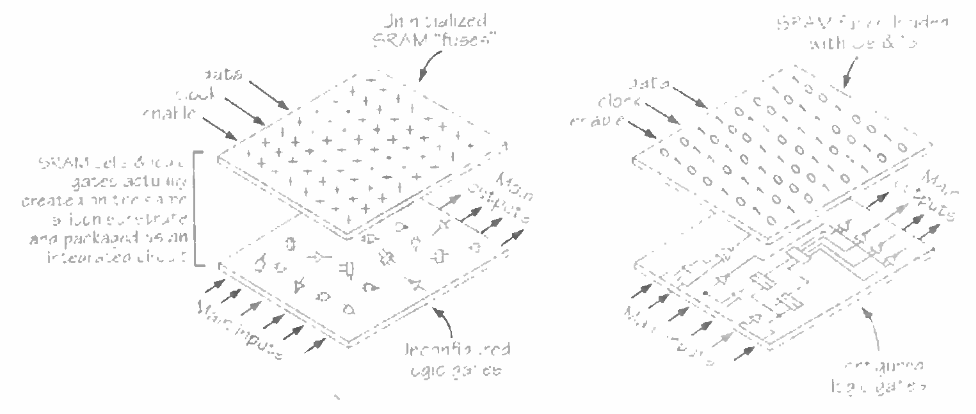


**Figure 21.3: Dynamically reconfigurable hardware: SRAM-based FPGAs**

chip modules. Additionally, within the foreseeable future, ultra-large-scale ASIC devices will become available, which combine microprocessor cores, blocks of memory, and communication functions with embedded FPGA-style and FPID-style functions.

## Virtual Hardware

The main limitation with the majority of SRAM-based FPGAs is that it is necessary to load the entire device. Apart from anything else, it is usually necessary to halt the operation of the entire circuit board while these devices are being reconfigured. Additionally, the contents of any registers in the FPGAs are irretrievably lost during the process.

of a second. In the case of these devices, a few of the external pins are dedicated to the task of loading the data, including an *enable* control and *clock* and *data* inputs. When the *enable* control is placed in its active state, edges on the *clock* are used to load the device's SRAM with a stream of 0s and 1s which are presented to the serial *data* input. Although all of the logic gates and SRAM cells are created on the surface of a single piece of silicon substrate, it may be useful to visualize the device as comprising two distinct strata: the logic gates and the programmable SRAM "switches."

The versatility of these devices opens the floodgates to a wealth of possibilities. For example, the creation of circuit boards whose interfaces can be configured to meet a variety of communications protocols, or devices acting as *digital signal processors (DSPs)*, whose core algorithms can be modified to process data in a variety of ways. As alternative protocols become available or improved algorithms are invented, the patterns that are used to configure the FPGAs can be modified to take full advantage of these new developments.

However, the true power of these devices, which are referred to as *in-circuit reconfigurable (ICR)*, resides in their ability to be reconfigured on-the-fly. For example, when a system is first turned on, it might configure all of the FPGAs to perform diagnostic functions, both on themselves and on the circuit board. After the diagnostic checks have been completed, the system can dynamically reconfigure the FPGAs to fulfill the main function of the design.

Another example is illustrated by the Tomahawk cruise missile, which uses one technique to control itself while flying over water and another while soaring over land. When the Tomahawk crosses the boundary from water to land or vice versa, it causes its FPGAs to be dynamically reconfigured, changing from water-navigation mode to land-navigation mode in a fraction of a second.[7]

## Dynamically Reconfigurable Interconnect

Wonderful as all of the above is, even these techniques only scratch the surface of the possibilities offered by today's emerging technologies. Designers would ideally like to create board-level products that can be reconfigured to perform radically improved, or completely different functions from the ones that they were originally designed for. The solution is to be able to dynamically configure the board-level connections between devices.

A new breed of devices offer just this capability: *field-programmable interconnect devices (FPIDs)*, which may also be known as *field-programmable interconnect chips (FPICs)*[8]. These devices, which are used to connect logic devices together, can be dynamically reconfigured in the same way as standard SRAM-based FPGAs. Because each FPID may have around 1,000 pins, only a few such devices are typically required on a circuit board:

In fact, the concepts discussed here are not limited to board-level implementations. Any of the technologies discussed thus far may also be implemented in hybrids and multi-

To address these issues, a new generation of FPGAs were introduced around the beginning of 1994. In addition to supporting the dynamic reconfiguration of selected portions of the internal logic, these devices also feature:

a) No disruption to the device's inputs and outputs.

b) No disruption to the system-level clocking.

c) The continued operation of any portions of the device that are not undergoing reconfiguration.

d) No disruption to the contents of internal registers during reconfiguration, even in the area being reconfigured.

The latter point is of particular interest, because it allows one instantiation of a function to hand over data to the next function. For example, a group of registers may initially be configured to act as a binary counter. Then, at some time determined by the main system, the same registers may be reconfigured to operate as a linear feedback shift register (LFSR)[9], whose seed value is determined by the final contents of the counter before it was reconfigured.

Although these devices are evolutionary in terms of technology, they are *revolutionary* in terms of the potential they offer. To reflect their new capabilities, appellations such as *virtual hardware*, *adaptive hardware* and *Cache Logic*[10] are beginning to emerge. Because it appears likely that this nomenclature may quickly work its way into mainstream usage, it is appropriate to take a few moments to explain the roots of these terms.

---

*7 Of course, some of us might take the view that it is inherently unwise to have an armed cruise missile "bombing" around the sky in a mindless state while it reprograms its own brain!*
*8 FPIC is a trademark of Aptix Corporation.*
*9 Linear feedback shift registers (LFSRS) are introduced in detail in Appendix F.*
*10 Cache Logic is a trademark of Atmel Corporation, San Jose, CA, USA, to whom thanks are due for the information that they provided at such short notice.*

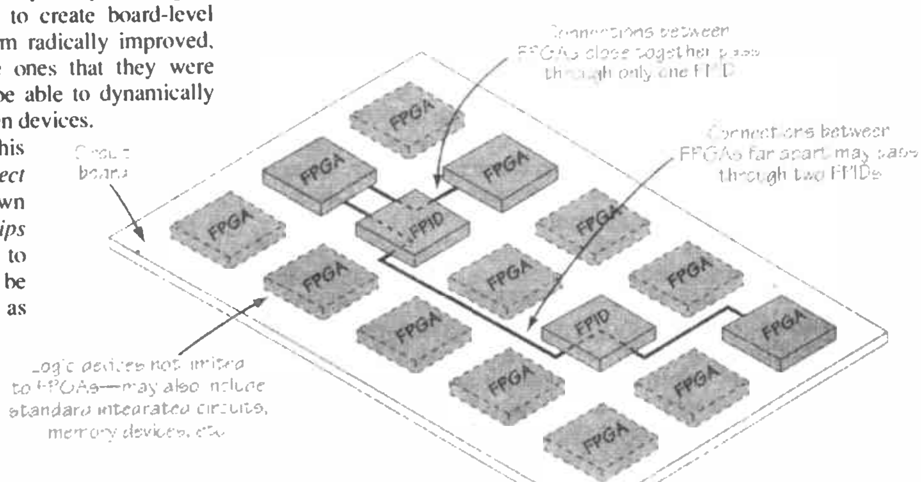



**Figure 21.4: Dynamically reconfigurable interconnect: SRAM-based FPIDs**

The phrase "*virtual hardware*" is derived from its software equivalent, "*virtual memory*", and both are used to imply something that is not really there. In the case of virtual memory, the computer's operating system pretends that it has access to more memory than is actually available. For example, a program running on the computer may require ten Mbytes to store its data, but the computer may have only five Mbytes of memory available. To get around this problem, whenever the program attempts to access a memory location that does not physically exist, the operating system performs a sleight-of-hand and exchanges some of the contents in the memory with data on the hard disk. Although this practice, known as swapping, tends to slow things down, it does allow the program to perform its task, without having to wait while someone runs down to the store to buy some more memory chips.

Similarly, the phrase "*Cache Logic*" is derived from its similarity to the concept of "*Cache Memory*", in which high-speed, expensive SRAM is used to store active data[11], while the bulk of the data resides in slower, lower-cost memory devices such as DRAM.

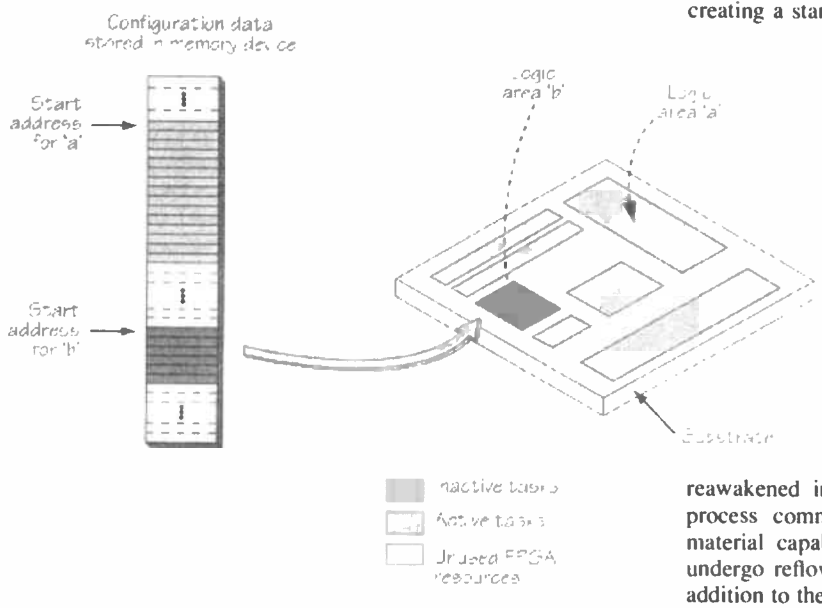



**Figure 21.5: Virtual hardware**

In fact, the concepts behind virtual hardware are actually quite easy to understand. Each large macro-function in a device is usually formed by the combination of a number of smaller micro-functions such as counters, shift registers, and multiplexers. Two things become apparent when a group of macro-functions are divided into their respective micro-functions. First, functionality overlaps, and an element such as a counter may be used several times in different places. Second, there is a substantial amount of *functional latency*, which means that, at any given time, only a portion of the microfunctions are active. To put this another way, relatively few micro-functions are in use during any given clock cycle. Thus, the ability to dynamically reconfigure individual portions of a virtual hardware device means that a relatively small amount of logic can be used to implement a number of different macro-functions.

By tracking the occurrence and usage of each micro-function, then consolidating functionality and eliminating redundancy, virtual hardware devices can perform far more complex tasks than they would appear to have logic gates available. For example, in a complex function requiring 10,000 equivalent gates, only 2,000 gates may be active at any one time. Thus, by storing, or caching, the functions implemented by the extra 8,000 gates, a small, inexpensive 2,000-gate device can be used to replace a larger, more expensive 10,000-gate component:

In fact, it is even possible to "compile" new design variations in real-time, which may be thought of as dynamically creating subroutines in hardware! Hence the phrase "*adaptive hardware*" referred to above.

## *Three-Dimensional Molded Interconnect*

For many years designers have wished for the ability to create robust three-dimensional (3-D) circuit boards for use with products such as hand-held cellular telephones, radios, and calculators. In addition to providing the interconnect, these 3-D circuit boards would also act as the product's package (from another point of view, designers want to be able to create a 3-D product package that also acts as the interconnect). In addition to reducing the product's size and weight, there can also be significant benefits in terms of cost and manufacturability.

A number of processes to create 3-D circuit boards have emerged over the years, but none have gained any significant level of commercial acceptance. One hopeful contender involved creating a standard two-dimensional (2-D) circuit board and then molding it into a 3-D shape. This process achieved some acceptance for simple product packages, such as those for power supplies, with limited aesthetic requirements. However, the process is not suitable for products that require an aesthetic appeal and ergonomic shapes involving complex surfaces.

Another technique involved the prefabrication of tracks on the inside surface of a mold. The process of injecting plastic into the mold caused the tracks to become an integral part of the packaging. But this process had its own problems – not the least, creating the interconnects on the 3-D surface of the mold in the first place.

However, a new development in 3-D photo-imaging technology in the early 1990s has reawakened interest in the injection molding technique[12]. The process commences with the injection molding of a plastic material capable of withstanding high enough temperatures to undergo reflow-soldering or vapor-phase soldering processes. In addition to the physical shape of the product, it is also possible to mold in features such as holes, ribs, recesses, standoffs, and chamfered edges. These features offer substantial savings compared to their equivalent drilling, routing, and grinding operations, and also reduce part counts and labour.

---

*11 In this context, "active data" refers to data or instructions that a program is currently using, or which the operating system believes that the program will want to use in the immediate future.*
*12 Thanks to Faldering Design Services, Hamden, CT, USA, for the information on this process.*

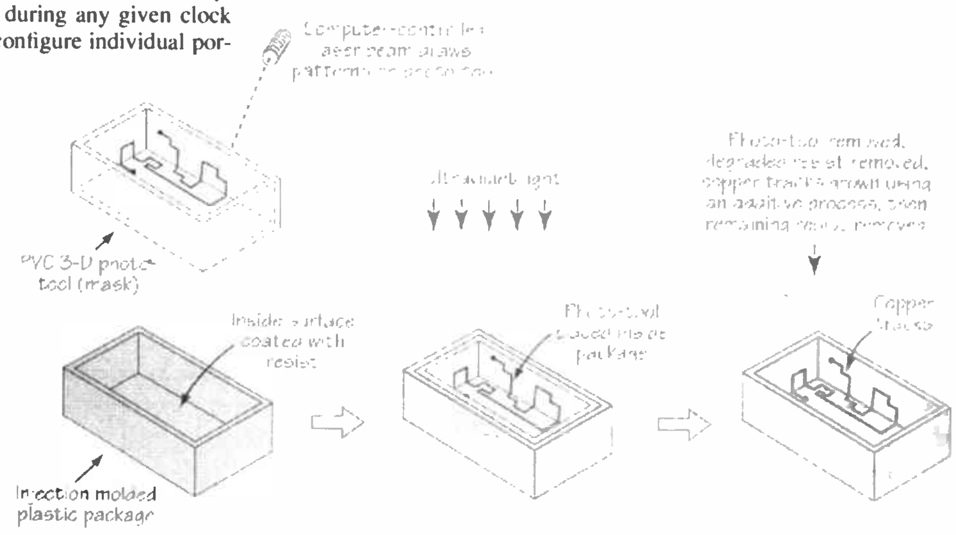



**Figure 21.6: Three-dimensional molded interconnect**

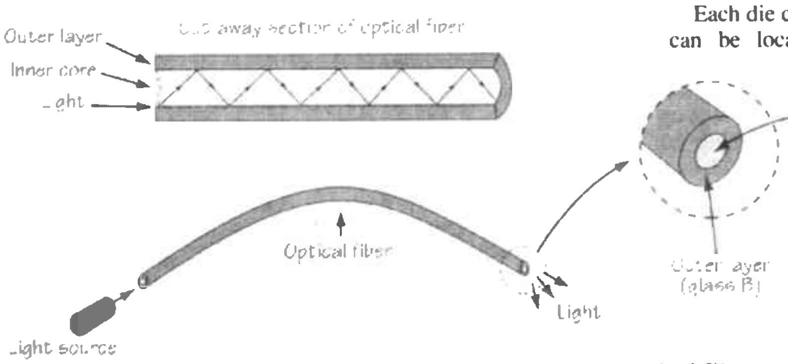



**Figure 21.7: Light propagating through an optical fiber**

A 3-D photo-tool, or mask, is formed by molding a PVC-based material to conform exactly to the contours of the plastic part. Next, a computer-controlled laser is used to draw an image of the desired circuit onto the photo-tool.

The remainder of the process is very similar to that for a standard circuit board, and can therefore leverage off existing technology. The surface of the plastic is covered by a special resist, the photo-tool is inserted, the whole assembly is exposed to ultraviolet light, the degraded resist is removed, and copper tracks are grown using an additive process.

One of the major problems with the process at this time is the lack of appropriate computer-aided design tools. Existing tools are geared to standard 2-D circuit boards and do not have the ability to transform 2-D designs into a 3-D space. Sadly, there is not yet a large enough market potential to cause this position to change. However, this technology is still in its infant stage and, with sufficient market interest, the requisite electromechanical toolsets will become available.

## *Optical Interconnect*

Electronics systems exhibit ever-increasing requirements to process ever-increasing quantities of data at ever-increasing speeds. Interconnection technologies based on conducting wires are fast becoming the bottleneck that limits the performance of electronic systems.

To relieve this communications bottleneck, a wide variety of optoelectronic interconnection techniques are undergoing evaluation. In addition to the extremely fast propagation of data[13], optical interconnects offer greater signal isolation, reduced sensitivity to electromagnetic interference, and a far higher bandwidth than do conducting wires.

## *Fibre-Optic Interconnect*

The fibres used in fibre-optic systems are constructed from two different forms of glass (or other materials) with different refractive indices. These fibres, which are finer than a human hair, can be bent into weird and wonderful shapes without breaking. When light is injected into one end of the fibre, it repeatedly bounces off the interface between the two glasses, undergoing almost total internal reflection with minimal loss, until it re-emerges at the other end:

Experimental systems using fibre-optic interconnect have been evaluated at all levels of a system – for example, to link bare die in a multichip module:

The transmitting device employs a surface-emitting laser-diode, which is constructed along with the transistors and other components on the integrated circuit's substrate. The receiving device uses a photo-transistor to convert the incoming light back into an electrical signal.

Each die can support numerous transmitters and receivers, which can be located anywhere on the surface of their substrates. However, there are several problems with this implementation, including the difficulty of attaching multiple fibres, the difficulties associated with repair and rework (replacing a defective die), and the physical space occupied by the fibres. Although the individual fibres are extremely thin, multichip modules may require many thousands of connections. Additionally, in this form, each optical fibre can only be used to connect an individual transmitter to an individual receiver.

At the board level, a variation of discrete wired technology[14] has been developed, in which optical fibres are ultrasonically bonded into the surface of a board. When combined with chip-on-board techniques, this process offers significant potential for the future. In fact, due to the way in which the optical fibres are connected to the die, it is possible for an individual transmitter to be connected to multiple receivers. Unfortunately, the techniques used to achieve this may not be disclosed here, because the author has been sworn to secrecy using arcane oaths and strange handshakes, and an Englishman's word is his bond!

Last, but not least, optical fibres may be used to provide intra-board connections, which may be referred to as *optical backplanes*. Once again, discrete wire technology, modified to accommodate optical fibres, may be employed to create backplanes. Alternatively, the boards may be mounted in a rack without an actual backplane, and groups of optical fibres may be connected into special couplers.

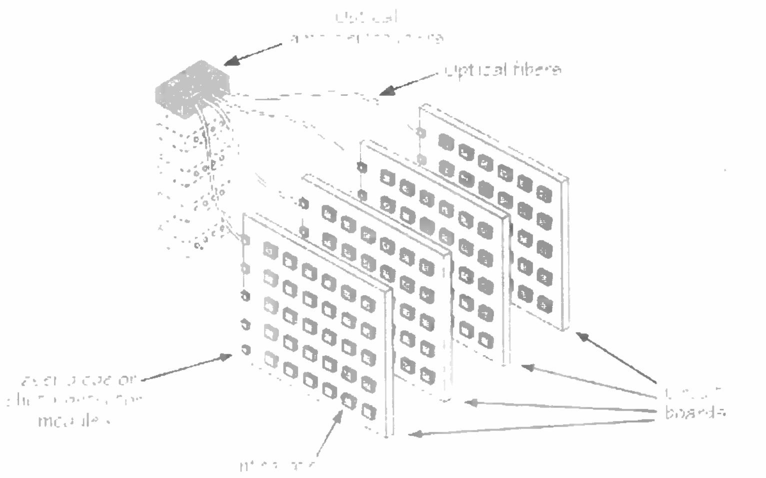


**Figure 21.9: Fiber-optic interconnect: optical backplanes**

Each optical fibre from a transmitter is connected into a coupler, which amplifies the optical signal and can re-transmit it to multiple receivers. This form of backplane offers great latitude in regard to the proximity of the boards. In fact, boards connected in this way can be separated by as much as tens of metres.

## *Free-Space Interconnect*

With the free-space technique, a laser-diode transmitter communicates directly with a photo-transistor receiver without employing an optical fibre. Consider a free-space technique used to link bare die mounted on the substrate of a multichip module as in Fig.21.10.

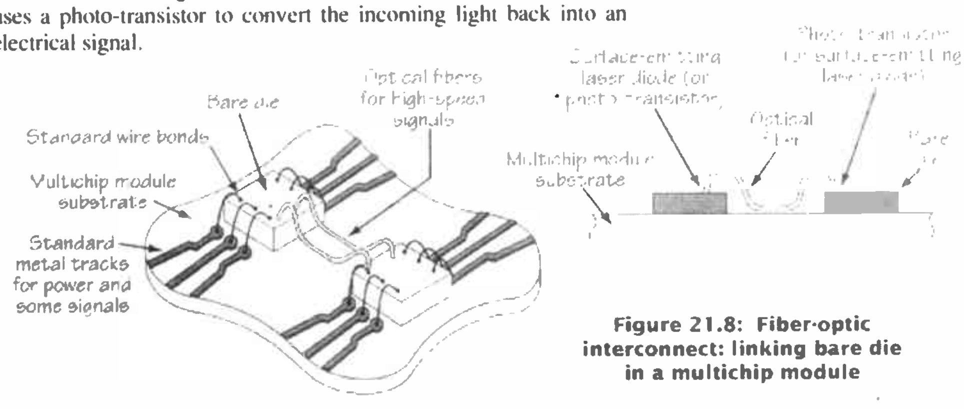



**Figure 21.8: Fiber-optic interconnect: linking bare die in a multichip module**

*13 Light travels at 299,792,458 meters per second in a vacuum; thus, a beam of light would take only approximately 2.6 seconds to make a round trip from the earth to the moon and back again!*
*14 Discrete wired technology was introduced in Chapter 18.*

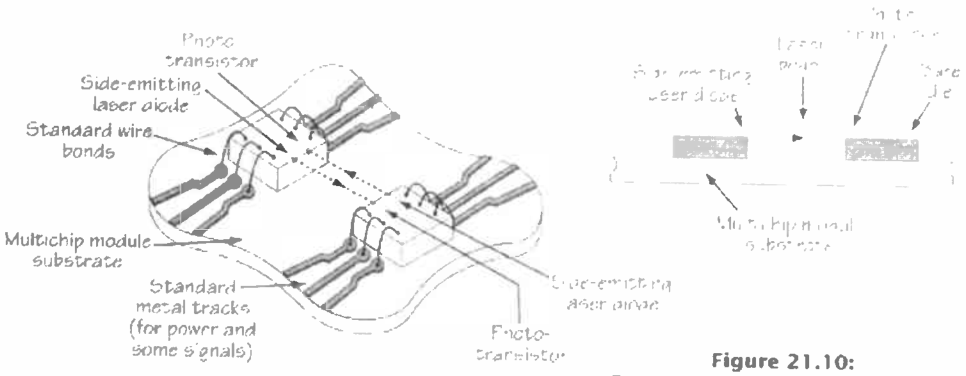



**Figure 21.10: Free-space interconnect: linking bare die in a multichip module**

In this case, the transmitters are constructed as side-emitting laser diodes along the upper edges of the die; similarly with the photo-transistors on the receivers. Each die may contain multiple transmitters and receivers. The free-space technique removes some of the problems associated with its fibre-optic equivalent: there are no fibres to attach and replacing a defective die is easier.

However, as for optical fibres, each transmitter can still only be used to connect to an individual receiver. Additionally, the free-space technique has its own unique problems: the alignment of the devices is critical and there are *thermal tracking* issues. When a laser-diode is turned on, it rapidly cycles from ambient temperature to several hundred degrees Celsius. The heat generated by an individual laser-diode does not greatly affect the die, because each diode is so small. But the cumulative effect of hundreds of such diodes does affect the die, causing it to expand and therefore disturbing the alignment of the transmitter-receiver pairs.

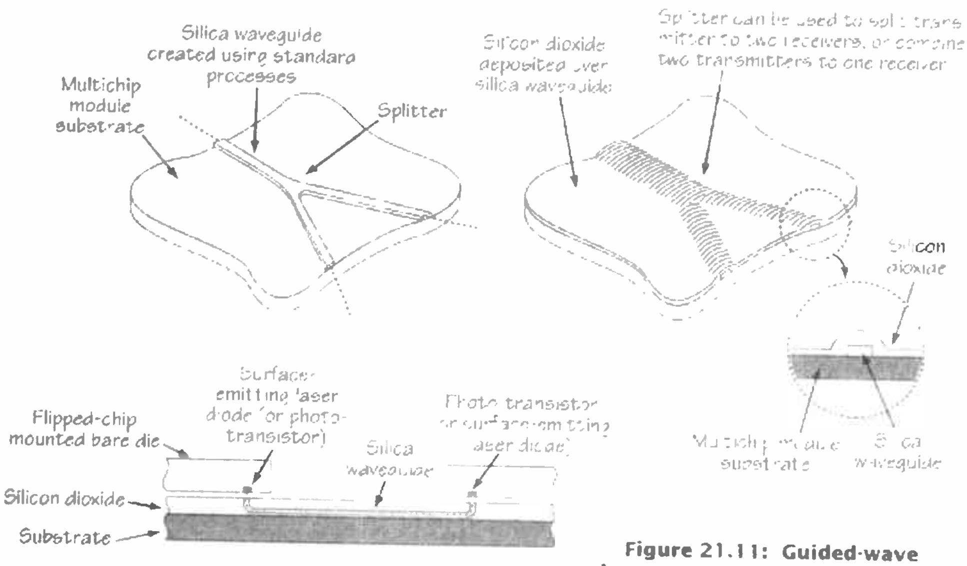



**Figure 21.11: Guided-wave interconnect: silica waveguides**

A somewhat more significant consideration is that, unless the system is constructed as an array of identical die, each die has to be fabricated with unique arrangements of transmitters to interface to its surrounding die. This is not unlike an extremely complex jigsaw, and is probably the key deficiency that will prevent this technique from maturing into a commercially viable proposition.

## Guided-Wave Interconnect

Another form of optical interconnect that is receiving significant interest is that of guided-wave, whereby optical waveguides are fabricated directly on the substrate of a multichip module. These waveguides can be created using variations on standard optolithographic thin-film processes. One such process involves the creation of silica waveguides,[15] see Fig.21.11.

Using a flipped-chip mounting technique, the surface-emitting laser-diodes and photo-transistors on the component-side of the die are pointed down towards the substrate. One major advantage of the waveguide technique is that the waveguides can be constructed with splitters, thereby allowing a number of transmitters to drive a number of receivers. On the down-side, it is very difficult to route one waveguide over another, because the crossover point tends to act like a splitter and allows light from the waveguides to "leak" into each other.

An alternative form of waveguide technology, *photo-imagable polyimide interconnect*, which was announced towards the tail-end of 1993, is of particular interest in the case of multichip modules of type MCM-D. As you may recall from Chapter 20, MCM-D devices are "*. . . ceramic, glass, or metal substrates that are covered with a layer of dielectric material such as polyimide. The dielectric coat is used to modify the substrate's capacitive characteristics and tracks are created on the surface of the dielectric using thin-film processes.*"

When exposed to light passed through an appropriate mask, a layer of photo-imagable polyimide can be imprinted with patterns in a similar way to exposing a photograph. After being developed, the polyimide contains low-loss optical waveguides bounded by relatively opaque reflective surfaces (Figure 21.12).

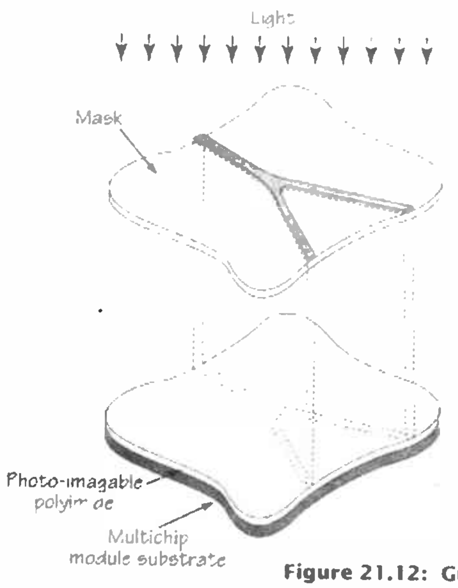
Apart from its inherent simplicity, one of the beauties of this technique is that both the exposed and unexposed areas of polyimide have almost identical dielectric constants. Thus, in addition to leveraging off existing technology, the polyimide waveguides have relatively little impact on any thin-film metallisation tracking layers that may be laid over them.

This technique is currently finding its major audience in designers of multichip modules, but it is also being investigated as a technique for multilayer circuit boards. Future circuit boards could therefore be fabricated as a mixture of traditional copper interconnect and very high speed optical interconnect.

## Holographic Interconnect

Unfortunately, all of the optical interconnection technologies introduced above have their own unique problems and limitations. The technique that shows most potential is

*15 Thanks for the information on silica waveguides go to Dr. Terry Young of the GEC-Marconi Research Centre, Chelmsford, Essex, with apologies for all the extremely technical details that were omitted here.*



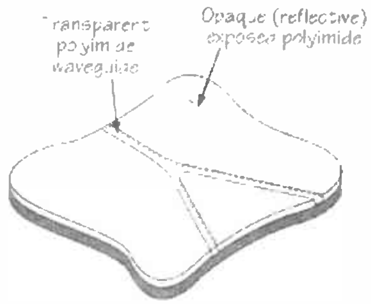




**Figure 21.12: Guided-wave interconnect: photo-imagable polyimide waveguides**

that of guided-waves, but even this has the problem of routing waveguides over each other. Additionally, both waveguides and optical fibres share a common shortcoming, the fact that the light tends to bounce around an awful lot. In fact, the light bounces around so much that it actually travels approximately four to six times the straight-line distance between the transmitter and the receiver.

Quite apart from these concerns, it is doubtful if any of the above techniques will be capable of dealing with the sheer number of interconnection paths that will be required. A new contender that is rising to the challenge is holographic interconnect. Using the term "*holographic*" in this context may at first seem a little strange, because *holography* is traditionally considered to be a method of obtaining three-dimensional images known as *holograms* (from the Greek: *holos* meaning "whole" and *gram* meaning "message"). However, the term holographic is appropriate, because this form of interconnect is actually based on a three-dimensional image.

In the case of holographic interconnect for a multichip module, the process commences with an extremely thin slice of quartz, into which sophisticated patterns are cut using a laser. The quartz slice is then mounted approximately 1mm above the die, and a face-surface mirror[16] is mounted approximately 2cm above the quartz:

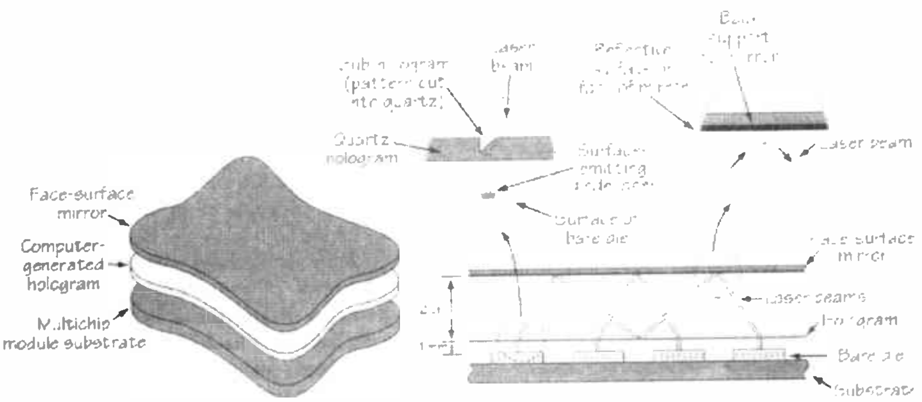



**Figure 21.13: Holographic interconnect: multichip module**

When a surface-emitting laser-diode on one of the die is turned on, it transmits a laser beam straight up into one of the patterns in the quartz. This pattern causes the laser beam to be deflected so that it bounces backwards and forwards between the face-surface mirror and the quartz. When the laser hits the point on the quartz directly above a photo-transistor on the receiving die, another pattern cut into the quartz causes it to be deflected back through the quartz and down into the receiver.

Note that the patterns cut into the quartz in the illustration above are gross simplifications. Additionally, there are typically two patterns cut into the quartz over the receiver, one on each side of the slice. The pattern on the upper side of the slice captures the laser beam and deflects it into the slice, and the pattern on the lower side then captures it again and redirects it out of the slice down onto the receiver. These patterns also perform the same function as a lens, focusing the beam precisely onto the receiver.

The angles of the patterns cut into the quartz are precisely calculated, as are the number of reflections between the face-surface mirror and the quartz, thereby ensuring that each laser beam exactly hits the target for which it is intended and no other. All of these calculations are performed by a computer, and the laser used to cut the three-dimensional patterns into the quartz is also controlled by a computer. Thus, the slice of quartz is referred to a *computer-generated hologram (CGH)*, and the individual patterns above each transmitter and receiver are known as sub-holograms.

In fact, the laser beam actually undergoes relatively few reflections between the face-surface mirror and the quartz; far fewer than an equivalent beam transmitted through a waveguide or an optical fibre. Thus, the time taken for a signal to propagate from a transmitter to a receiver, known as the *time-of-flight*, is actually close to that for free-space interconnect. But the clever part is still to come. The sub-hologram above a laser-diode can be created in such a way that it splits the laser beam into sub-beams, each of which can target a different receiver:

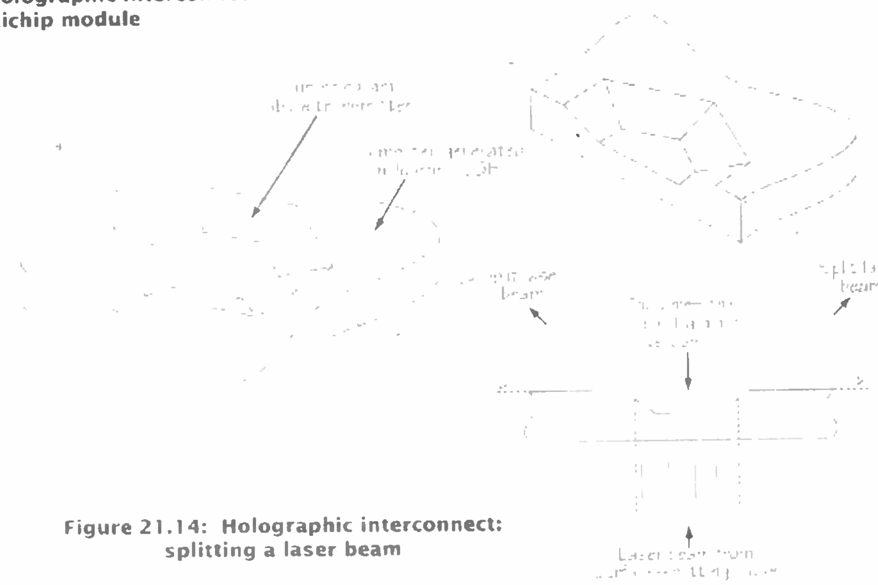


**Figure 21.14: Holographic interconnect: splitting a laser beam**

For the sake of clarity, the previous illustration shows a hexagonal sub-hologram with equal angles between the vertices, and equal angles of incidence for each face. However, the angles between the vertices can vary, and each face can have a different angle of incidence. Furthermore, the sub-holograms above receivers can be correspondingly complex, and capable of receiving signals from multiple transmitters.

Finally, in addition to multichip module applications, holographic interconnect is also undergoing evaluation as a possible backplane technology for the interconnection of circuit boards. These backplanes, known as *holobackplanes*, offer an additional, amazingly powerful capability. it is technically feasible to create multiple holograms in the backplane's equivalent of the quartz slice. Thus, by moving the holographic slice a fraction of a millimeter in a direction parallel to the face-surface mirror, the interconnection pattern could be reconfigured and a completely new set of board-to-board interconnects could be established. The mind boggles!

*16 The term "face-surface" refers to the fact that the reflective coating is located on the face of the mirror, and not behind it as would be the case in a mirror you look into when you shave or apply your makeup (or both, depending on how liberated you are).*

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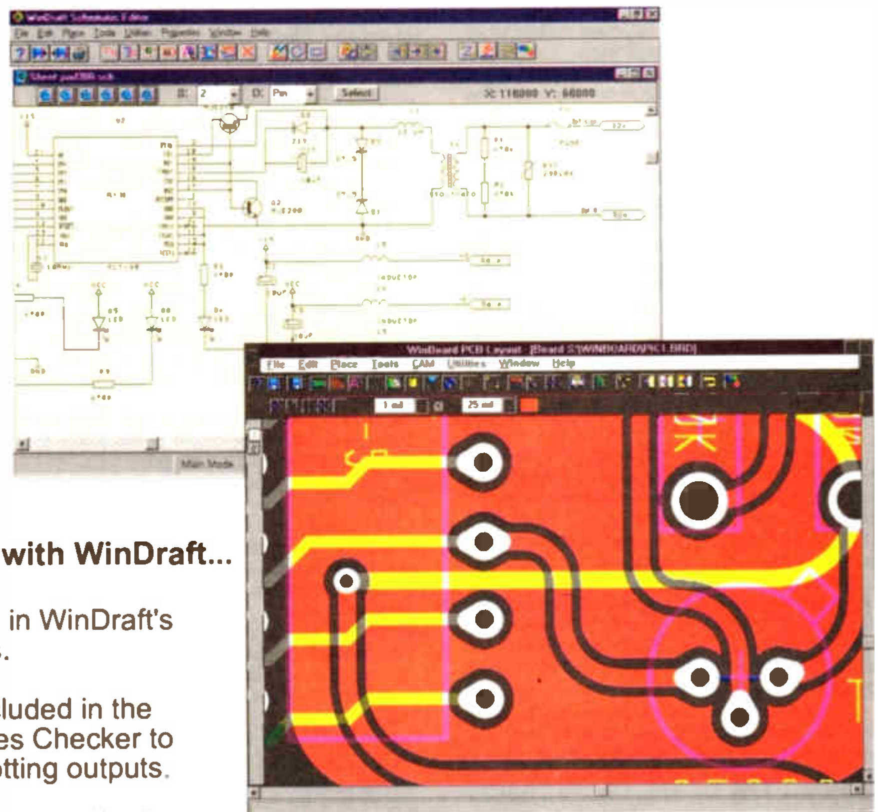

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# READOUT

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

## POWER EARTHING

*Something of a stir was created by some comments made in* Circuit Surgery *of October '97 (*Back Down to Earth*). The following letter typically represents the views expressed by a number of readers; it is followed by a reply from Alan Winstanley.*

Dear EPE,

You seem to state that the power companies in the UK are distributing power to our houses via one live conductor and an earth connection *at our houses*, which returns power current to an earth at the sub-station transformer.

Unless I have been misinformed for a lifetime (I am recently retired), that is not the case. The normal return of power is via the neutral conductor to the star point of the sub-transformer. The star point is earthed directly or indirectly, and it is only fault currents from our own live installation conductors that travel via our installation earth to that star point.

I suggest that AW is over-simplifying the protection: a read of the IEE regulations and guides to them shows this. I know that articles such as *CS* need to be short and pithy, but the earthing explanation did not seem to come over well. For your information, I enclose some relevant extracts from the guide to the 15th edition of the IEE regulations.

**I.J. Goldfinch, Stevenage**

*Thank you for your comments and the data relating to mains earthing, which I read with interest. Several readers have either written or phoned to express their opinions on the validity of the* Circuit Surgery *item, and clearly there is quite a lot of interest in this topic.*

*One problem is that qualified and experienced engineers don't seem to relate to a very simplistic approach which it is necessary to adopt sometimes, and as you rightly say, space was severely restricted in that issue which limited the depth to which I could go.*

*In the few paragraphs I could spare, there was no scope at all to discuss delta/star networks, 3-phase supplies, sub-stations or any of the other techniques associated with electricity distribution. I felt that, in any case, it would not be appropriate in a micro-electronics magazine to become too involved with the mains-side unless I came up with some in-depth and definitive answers. This would have taken far too much space and would have created as many questions as it answered.*

*However, I did choose my words more carefully than some readers probably believe, and I dealt with the regional/national scale rather than the local scale (delivery of the supply to the domestic fuseboard, for example, where the earth is hard-wired to neutral).*

*Furthermore, I was pretty clear on the point I wanted to make and I actually asked a qualified engineer from my local electricity board to comment on the proposed text. He replied that there was nothing wrong in what I intended to write, so I proceeded on that basis as a follow up to an earlier* Surgery *article (which somebody said had not fully answered the original question).*

*One interesting point caught my eye in the literature you kindly sent: "the earth can be considered to be a vast conductor which is set at zero potential". This begs the question: why use copper wire instead of this earth "conductor"?*

*Whilst I may be guilty of a woolly statement or two, all I can say is that readers have replied to these points each by writing several pages of A4 text, along with IEE Regulations galore, to explain the technicalities involved!*

*It occurs to me that a separate feature article with photos etc. may act to tidy up this topic, so I'll ask to see what can be done. I have been invited on a tour of a power station and my local electricity board would like to help out, so this may develop further.*

*Many thanks for your interest in the column, and to all those who have commented on this issue.*

**Alan Winstanley**

## PICS, PRAISES AND REBUKES

Dear EPE,

Glad to see *Readout* is back as it enables me to sing the praises of at least two of your advertisers: Engineering Services of Rotherham, and Lennard Research of Newcastle upon Tyne. Both companies gave me personal attention by sending hand-written letters and information to enable me to program the PIC16C84 via my BBC "B" computer.

By singing their praises, I suppose this means a smack on the wrist for you – you should have supplied the relevant info!

I was able to write a suite of programs on my Beeb within a few days (am I the only one still with a Beeb?)

Also, regarding Dr Michael Sharp's letter (*Readout* Nov '97), I am not familiar with his Amstrad but assume it's IBM-compatible. This raises the point I've made to you before – that the free software is not for us who do not own an IBM type PC.

Can you, therefore, print a hex-dump of the listing and the configuration or/and make available photocopies of the listings?

**I. Scott-Young, Bulwell, Notts**

*We know that many of our advertisers recognise that personal attention helps to keep customers happy and loyal. Offering help for a vintage computer problem really deserves applause.*

*For us, though, as much as we would like to help all readers who want to program PICs with computers other than PC-compatibles, there are enormous logistical problems. For example, for which computers other than PCs should we cater? The legacy from the past is great: Beebs, PETs, Fat 40s, C64s, Sinclairs, Acorns, Archimedes, Apples, Dragons, Tangerines, UK101s, and so on – the list is extensive, and some of you can probably add to it.*

*How could we possibly provide info on programming PICs from these older machines? We can't – for several reasons. First, our knowledge is not all-embracing – we are simply not familiar with programming many of the machines just listed (or not listed). It would not be practical to seek out those who do and get them to provide the info, and it would cost too much to do so anyway, as there are too few readers who would benefit from it. Whilst we are sure you would like us to do things for purely altruistic reasons, there aren't enough hours in the day, and we've all got families, friends and pets who need us (we believe!).*

*Besides which, if there is any moral obligation to cater for non-standard computers, then the PIC manufacturers should make the necessary information available.*

*Not even supplying photocopies of the listings would be practical for us. My recent* EPE Time Machine *had over 1000 commands occupying 1200 text lines. At about 60 lines per printout page, at least 20 pages would be needed for the source code listing. A hex dump would need a conversion process to be written and run in order to produce a file suitable for outputting to a printer – the object code (.OBJ) cannot be listed directly since the values can be any from 0 to 255, most of which do not correspond to alphanumeric characters.*

*As it turned out, even supplying all our PIC files on a 5·25-inch disk to Michael Sharp for his Amstrad 1640 turned out to be problematic. I had overlooked the fact that our 3·5-inch disks hold more than can go onto a single 5·25-inch disk, consequently I had to split our files into three batches, each on a separate 5·25-inch. And then the copying time was excessive due to the computer's slowness in copying from hard-disk to floppies.*

*So, very sorry folks, but we cannot offer help with PIC programming for machines other than PC-compatibles having 3·5-inch disk drives. However, readers who want to use their non-standard machines for PIC programming, might consider putting a classified ad in our pages, asking if other readers can help. Readers who are willing to help can tell us for possible* Readout *publication, or advertise the fact in the classifieds.*

*But, there remains in mind the nagging question: why don't ill-equipped readers get a PC-compatible computer? Whilst new ones start at about £1000 (and even that's not expensive for what you get), there are many second-hand bargains to be had inexpensively. Many companies sell-off good machines when they upgrade to the latest version.*

*In this way, I was able to buy a 4-year old Compaq for £25 from the company my wife works for – they were replacing about 40 machines in one go. It's a perfectly good machine, although somewhat slow compared to my Dell Pentium. (I did have to buy a new mouse, though, for another £25!) Read the computer magazines for info and adverts about second-hand machines (but closely examine any machine before buying it).*

*Let your old incompatible computers go into retirement – more recent machines can do far more for you than perhaps you realise.*

*Incidentally, thank you Michael Sharp for the postcard showing Rugby before the transmitters were built!*

## AN END TO GW-BASIC

Dear EPE,

Re Tony Hiener's query regarding exiting from GW-BASIC (*Readout* Nov. '97) – before I retired I used several GW-BASIC programs and always added these lines at the end:

```
900 INPUT " Another run ? Y/N ";R$
910 IF R$ = "Y" OR R$ = "y" THEN 10
950 INPUT " Finished with BASIC ? Y/N ";F$
960 IF R$ = "Y" OR R$ = "y" THEN SYSTEM
1000 STOP
```

Presumably, these would also work with QuickBASIC.

**R.L.A. Latham, Stafford, Staffs**

*Thanks, Tony, obviously very useful when running a completed and debugged GW-BASIC program. I expect, though, that when developing a program and wish to exit back to DOS before its complete, you still use the command SYSTEM on its own.*

*In fact, with QuickBASIC, the SYSTEM command does not achieve the same result. If called, you certainly return to the DOS screen, but it shows the statement "Press any key to continue". Pressing a key then brings you back into QuickBASIC's editing mode. Not even pressing CTRL/BREAK while in DOS gets round this.*

*Normally to exit from QuickBASIC editing mode, you call down a menu panel using ALT followed by f (for File mode) and then followed by x to exit. If the current program has been altered and not saved, the option to save is automatically prompted/reminded following the x.*

*There are advanced ways by which to exit to DOS from within a program, but these are less simple than the above.*

## HOW QBASIC?

Dear EPE,

I was rather startled to come across the remark "QBasic (also known as Quick-Basic)" in *Readout* Nov '97, as there are considerable differences in concept and detail between the two languages.

QuickBASIC was sold as a much enhanced version of BASIC with a 220-word instruction set. The programming and very comprehensive file-handling system are implemented via Windows-type menus accessed by mouse or the arrows keys.

Most BASIC versions are "interpreted", meaning that each time a BASIC word is met in the program, it has to be looked up in the word list to find the machine-code to execute the instruction.

However, QuickBASIC introduces the "trick" of interpreting the BASIC code words into pseudo machine-code when the program is entered, so producing a "compiled" program which will run much faster – hence *Quick*BASIC.

QBasic is a simplified version of QuickBASIC, remaining as an interpreted and, hence, slower running language. Programming is again handled via Windows-type displays, but with simpler menus for file handling. Also, a particularly convenient system for entering and calling sub-routines is included.

For my present pre-occupation with writing programs to run a model railway via a Maplin I/O interface, speed is not an issue, and I find QBasic much the easier language to use, and it's "free"(!) for many users such as myself, being incorporated into DOS-5 upwards and Windows 95 (and others?).

QuickBASIC has now been replaced by Visual-BASIC, a much more complex (and expensive!) version, incorporating facilities for creating Windows-type programs.

**T.B. Owen, Aberystwyth, Ceredigion**

*Thank you for putting me right on these niceties. It seems, however, that it is common mis-practice to use the names interchangeably, and this will probably become increasingly common.*

*For one thing, the directory under which my QuickBASIC is held is named QBASIC (the full name wouldn't fit into the measly eight characters that DOS allows, even if I wanted to use it). Secondly, it is quicker to say and write QBasic than the full name even when the latter in fact applies. Amongst others, I am also guilty of just using the term QB when in general conversation, this not only being an even quicker way of saying it, but is also in keeping with the keyboard command to enter the program from DOS.*

*All the programs I have written, including those with machine code routines and mouse control, run on my QBasic 1.1 as well as with QuickBASIC, with the proviso that QBasic is supplied with a text file of the commands. In other words, a QuickBASIC file intended for QBasic as well must be saved as "Text – Readable by Other Programs", rather than as "QuickBASIC – Fast Load and Save".*

*Just as a further point of good order, the style of spelling is shown on my screen as QuickBASIC (version 4.50), although (as has been seen) I am also capable of mis-typing it as Quick-Basic on the* Readout *page! According to their program screens, QBasic and GW-BASIC are the correct styles; I can't vouch for Visual-BASIC's correct style.*

## PINNING IT DOWN

Dear EPE,

With reference to the reply by JB to your (edited) version of my letter (*Pin Board Wizard, Readout* July '97), there appears to be an emergency, presumably created by my not having said the positioning of the holes for the pins on the PBs (pin boards) are formed by metal drills of a suitable diameter and not by digging them out with a spade. Tin is relatively soft and not as suitable as iron for spade blades.

You may care to know that PBs were used in about 1947 in a new type of feedback amplifier I produced and patented, and which was used for transmitting TV signals between London and Birmingham in the 3MHz to 7MHz band, probably before JB was born.

I get a lot of fun out of such devices and am sad at the implication by JB that the UK is no longer developing devices but, in my modest way, reject thoughts that this was because I left the UK in 1960.

Your readers may not appreciate my relief in knowing that I have been passed as reasonably sane by JB, operating in his role as a psychiatrist, "physician first heal thyself".

In my letter I merely asked that you present the case for PBs fairly so that your readers can make judgement on the case for PBs, a request that, for obvious reasons, has been rejected by JB. All the claims I made for the advantages of PBs over PCBs are demonstrably true, indeed I was decent enough not to mention that PBs are far more rugged and robust, easier to modify, and have longer lives because it is not possible to remove all the corrosive materials used in PCB manufacture.

With the red herring of stripboard, introduced by JB, I suggest that they have many of the disadvantages of PCBs and few of the advantages of PBs. It would appear that Indian Fakirs have far more knowledge than JB of the importance of component layout at higher frequencies. My Cockney sense of humour suggests that in place of PCBs, *EPE* should supply PBs with the wire connections between the mounting posts, the so-called ground wiring completed, if in fact this wiring causes the troubles stated by JB, which I very much doubt.

Kind regards with mountains of fun – hilarity?

**Freddie Clifford, Wetton, South Africa**

*Greetings Freddie, I'd been hoping you would reply, although it's taken you longer than expected – isn't your subscription copy arriving by airmail? If so, I suspect that at the time I key-in this reply, you may not have seen George Short's letter defending you in* Readout *Sept '97 (*Ruffled Feathers*), which includes a partial acceptance on my part of the role pinned boards can play in electronics prototyping, based, indeed, on personal experience. When you've seen that letter and reply, I'd be pleased to hear from you again.*

*Here in the office, when your original letter arrived, we were divided as to whether or not you were pulling our legs. Editor/MD Mike Kenward replied to you by mail in seriousness. I have to admit that I was not sure, but felt on balance that you had written in humour (is there* really *a surplus of brass pins available due to changes in South African shoe-making techniques?).*

*I also acknowledged that any technology should be selected to suit the conditions in which it is to be used, hence my aside reference to spades and tin roofs. In the early '60s, I worked in many parts of West Africa, from Sierra Leone to Nigeria. I recall that the ubiquitous corrugated metal sheet was put to many uses there, not just for roofing (the so-called tin-roof). I have even seen it used as a rudimentary spade, with a bit of make-shift reinforcing (the illicit diamond miners in Sierra Leone used crafty techniques to avoid detection). As I said, if something can do a similar job to something else, then use it.*

*What I had not appreciated is the extent to which you appear to have used the pin board constructional technique (I still can't fully visualise it). If you have a photograph of something you designed around pin boards and productively used in the past, send us a copy for possible publication; we will return it to you.*

*Truly nice to hear from you; it's all in good fun and* Readout *needs periodic light-heartedness as well as informative discussion (in this instance, we seem to have both – high frequency Fakirs, indeed, really!).*

*Incidentally, your reference to my seeming youthfulness is graciously accepted – the reality is greatly different. Perhaps being involved in an exciting technology keeps one young at heart! As to my sanity, though? Well, many gave that up as a lost cause years ago!*

## WATER DESCALING

Dear EPE,

I had hoped that the *PIC Water Descaler* article (Oct '97) might contain information on how these devices work, or at least reference to any published research.

As things stand, these descalers seem to be related to plastic pyramids that are supposed to sharpen razor blades put under them, or copper bracelets that are supposed to cure arthritis. Since my father had an electric descaler installed over 45 years ago, they are not "new" so something must be written somewhere. (It didn't have any affect and my father had it removed after six months.)

In a recent *Daily Mail* feature *Answers to Correspondents*, there were three replies to the question of how they work, varying from "they don't" to "don't know" and (from a manufacturer!) "they do but I don't know how".

However, some time ago I built a descaler using an analogue VCO and this has reduced the scale deposits around my kitchen sink (its sole purpose as I have an ion exchange water softener). The coil configuration is two open-ended windings, exactly as used by three of the most widely advertised devices on the market, and thus not requiring a high current output. I note that Mark Stuart's design uses a single coil with a current of over 200mA and wonder if there is any evidence that this is more effective?

**Barry J. Taylor, Rickmansworth, Herts**

*Unfortunately, we are unable to find any information on how or why water descalers work. If anyone comes up with a reasonable article on the subject we would be pleased to consider it for publication.*

*It's too early to have had response from readers on the effectiveness of Mark Stuart's design, but we hope to hear in due course. A number of readers have commented very favourably on the effectiveness of the earlier design from Andy Flind.*

*We would comment, of course, that when "fringe" subjects crop up (such as electronic descaling, Kirlian photography, ghost-voice recording and the like) then it is not incumbent on the reader who produces an experimental device related to that subject to "prove" how or why it works. As long as there is enough circumstantial or hear-say evidence that the device will work under some conditions, even if those conditions are not known, surely we do not deserve censure for publishing it?*

*Nor do we necessarily expect contributors to research the background to the subject for which they have designed something. If this were so, some prolific contributors (like yourself) would spend much of their time in reference libraries. Background information is interesting, but not essential.*

*In the case of water descalers, there are many claims that an alternating electrical field can reduce the scaling. So far as is known, no manufacturer of such devices has yet been prosecuted under the Trades Descriptions Act. The frequencies at which their equipment is designed to operate can be (and has been) easily established. Therefore, if anyone designs a circuit based on similar principles and those principles are not patented, then we feel at liberty to publish the design, providing it meets the other criteria that we take into account before accepting projects for publication.*

*It's interesting, Barry, that you have conflicting evidence on the subject, via your father and your sink! To what do you attribute his failure and your success?*

*Readers, we want to hear from you about your knowledge or experience of water descalers.*

*Incidentally, I once promised Editor Mike that I would one day design a Kirlian camera for* EPE, *and one day I shall. The techniques for Kirlian photography are well established (high potentials causing strange images of nearby objects to appear on photosensitive materials), but the reasons for it working remain controversial. Would anyone care to offer me background information or sources on this "fringe" technology?*

## PARROTS!

Dear EPE,

In your *Micro Pest Scarer* of July '97, it was not mentioned as to what is the effective range of the scarer and whether it will scare off birds. Please give the range and examples or bird pests it scares – I am mainly interested in scaring off parrots.

**Azam, Pakistan, via the Net.**

*The unit should be effective over about three to four metres but we have not tested it as a bird scarer and have no idea if it will have any effect on parrots!*

*Constructional Project*

# MINI ORGAN

MICHAEL McLOUGHLIN

*The tuned accuracy of this tiny music maker is in-built and, astonishingly, it needs no adjustment!*

ANYONE making a musical instrument collides at once with the problem of accuracy. Musicians will complain if the frequency of a note differs by more than about one per cent from its correct value. This rule appears to exclude the use of resistor/capacitor (RC) oscillators, unless everything is made adjustable.

As a test, the writer bought a junior kit based on RC oscillation, but when it was assembled the notes were found to be up to 43 per cent out. To obtain proper accuracy, electronic keyboards have tended to rely on crystals, backed by large scale integration (LSI) processor chips.

Of course, one per cent resistors have been available for years, but recently one per cent capacitors have also appeared on the retail market. This transforms the situation.

It now seems possible to make a genuine one per cent musical instrument, based on RC oscillation, without adjustable components. Tuning is unnecessary.

The crystal will continue to be preferred for anything complex, but the simplest instrument can now be made without it. For this Mini Organ design, the author aimed at producing just a basic keyboard, where only one note can be played at a time.

Numerous tunes can be picked out on such an instrument. More important is the help that it can give to a singer. Many people can sing, but most perform badly: an instrument of this sort will find that elusive note, and enable anyone to reach the end of the verse.

Ability to read music is not essential: you just experiment until you tap out the tune. Teams, supporters, or party groups anywhere might appoint a director of singing: when things flounder, he could produce this little instrument from his pocket.

## INTERVALS

If a sound has constant frequency, musicians call it a note. Music is made by stepping from one note to another. That step is called the *interval*: for example the interval from frequency $f$ to $2f$ is called an *octave*. The ear can recognise the octave for what it is – a doubling or halving of the frequency – whatever the starting note $f$, and whether it goes up or down ($2f$ to $f/2$).

To summarise, a definite interval is produced by a definite multiplier, and for the octave, the multiplier is two.

Sound two notes at random, and they will probably produce a discord. But choose any frequency $f$ and compare it with $3/2 \times f$. The multiplier is 3/2 and you hear a beautiful concord, called the *fifth*. Being greater than one and less than two, this multiplier divides the $f$ to $2f$ octave.

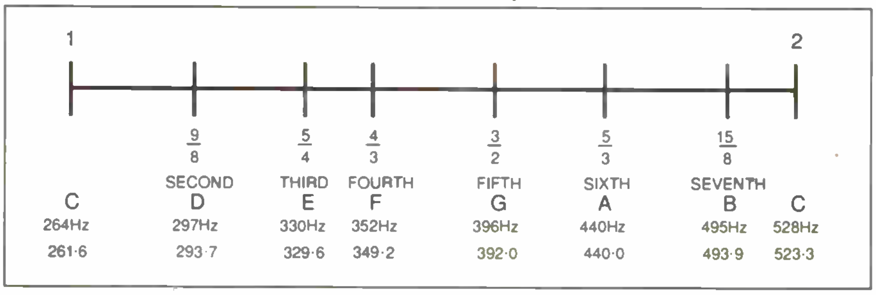


*Fig. 1. Note frequency multipliers.*

Other fractions will also work: the multipliers 4/3, 5/4 and 5/3 divide the octave in a pleasing way. But that list cannot be extended: fractions involving integers greater than five produce less pleasing results. Whatever we do inside our heads to identify a concord, it works much better when small integers are involved.

The multipliers have been laid out to scale in Fig.1.

## FREQUENCIES

The starting frequency (top left) in Fig.1 is labelled as *1*. But what starting frequency does that *1* stand for?

By International agreement, it has been decided that $A$ = 440Hz. Divide by 5/3 to obtain $C$, and then use the multipliers shown to check the first line of frequencies given. These frequencies are whole numbers and exact, and they are called the *Just Intonation* (*juste = accurate*).

Tone-tone-semitone, tone-tone-tone-semitone. That describes the top line of Fig.1. But each of the tones is two semitones, by definition. So there are 12 semitones in an octave. Since each semitone step is a multiplier, you could call it $m$, and insist that $m^{12}$ = 2: taking the twelfth root of 2 gives $m$ = 1·059(463094 . . . ) which is about 1·06.

This letter $m$ is the multiplier needed to go up a semitone: it adds almost six per cent to the existing frequency.

Starting again from $A$ = 440Hz and using the precise figure for $m$, the frequencies in the last line of Fig.1 can now be checked. These are called the *Well-Tempered Scale*, and all (except for $A$) are infinite non-recurring decimals. But the two scales are different!

The basic reason for the difference is that the fractions that give perfect concord are not spaced absolutely uniformly. The tempered scale represents a decision to adjust all semitones to be absolutely identical intervals (multipliers).

After two centuries of argument, musicians everywhere have now accepted the well-tempered scale. On keyboard instruments, it makes matching to other octaves practical, and the departures from true concord involved (close to one per cent in five of the eight notes) are well nigh imperceptible.

So, we are entitled to draw an important conclusion: whatever they say, musicians *do* tolerate errors up to about one per cent, and they do so as matter of course.

Further, we must go with the flow, and accept the frequencies of the tempered scale.

So, to summarise the detail in Fig.1, the line starts with *1* and ends with *2*: these figures represent *f* and *2f*. The multipliers are plotted along the line. *Third* and *Fourth* etc. refer to the position on the plot. These names are also used for the interval, from *1* up to the point concerned.

The letters shown can also be used for the notes. Start from *1* and go up a fifth (×3/2): going up a further third (×5/4) or down a further fourth (÷4/5) produces the *Seventh* and *Second*, and justifies their insertion.

The larger steps, such as *C* to *D* are almost equal, and are called *tones*. The two steps of about half this size are called *semitones*. To show this clearly the scale in Fig.1 is logarithmic, so that equal distances represent equal multipliers, and therefore equal musical intervals.

The tempered frequencies are those which the Mini Organ has been designed to produce. An oscillator that will generate them is shown in Fig.2.


## RC OSCILLATOR

To understand the circuit in Fig.2, first suppose that one of the switches (S1 to S8) is pressed: if the voltage at *P* is high, then *X* is raised somewhat, but in time *Y* will rise above it, driving *P* low. But *P* low means *X* is lowered somewhat, and in time *Y* will fall below it, and so the cycle repeats, generating an oscillating waveform at *P*.

The keyboard resistor chain, R1 to R7, sets the frequency scale, and it deserves close attention. The basic problem is that we cannot have *exactly* the resistors we need. The chain can only be approximate.

It would be possible to rely on a parallel chain of resistors, "hanging" from *P*. But there is only a finite number of resistor values to choose from, and the series arrangement offers eight times the fineness of adjustment, because the resistors to be added are eight times smaller.

## RESISTOR VALUES

The resistor values shown are from the E24 series, and 820kΩ is the starting value that defines the upper *C* note. To go down the first semitone to reach the note *B*, the frequency must be divided by *m* (as previously defined).

Thus, the decay time for the capacitor voltage must be multiplied by *m*. So the 820kΩ must be multiplied by *m*, to get 868·8kΩ, and this could be arranged by adding 48·8kΩ in series with it. The best E24 fit is 47kΩ (and it produces a −0·21 per cent error).

Continuing to multiply by *m* or $m^2$, and then choosing the best fit from E24 resistors gives the sequence shown for R1 to R7. The largest error on any note in the chain turns out to be 0·22 per cent, which is well inside the one per cent total error allowable.

Ideally each resistor in the E24 series should be 1·1006(94171...) times its predecessor, so that 24 such steps will cover a decade. But the resistance values allocated to the E24 series contain departures of more than four per cent from this ideal progression.

The result of these wobbles is that replacing the 820kΩ with another starting resistor gives significantly different errors when the new chain is deduced. The worst starter is 110kΩ (or 11kΩ, or 1k1Ω, etc.) the maximum error it produces in the chain is 0·75 per cent.

For most starting values, the maximum error found is around 0·5 per cent, but 820kΩ (or 82kΩ or 8k2Ω, etc.) at 0·22 per cent is the optimum choice.

After the resistor chain, choose the capacitor (C1). Then it is possible to calculate the step voltage required at *X* to produce upper *C* correctly. Using the value of 4n7F shown, the feedback resistors (R9 to R11) required to generate this step are also as shown (see later).

## OSCILLATOR OP.AMP

The type CA3130 op.amp used as IC1 in the oscillator circuit has the advantage that its output voltage runs virtually to the supply rails, which means that variations in supply voltage should not affect the frequency.

A compensation capacitor is usually connected to the CA3130, but the author had the good fortune to pull this out accidentally, when the circuit was still on the breadboard. Mysterious errors of five per cent in the upper frequencies promptly disappeared, and the circuit performed properly.

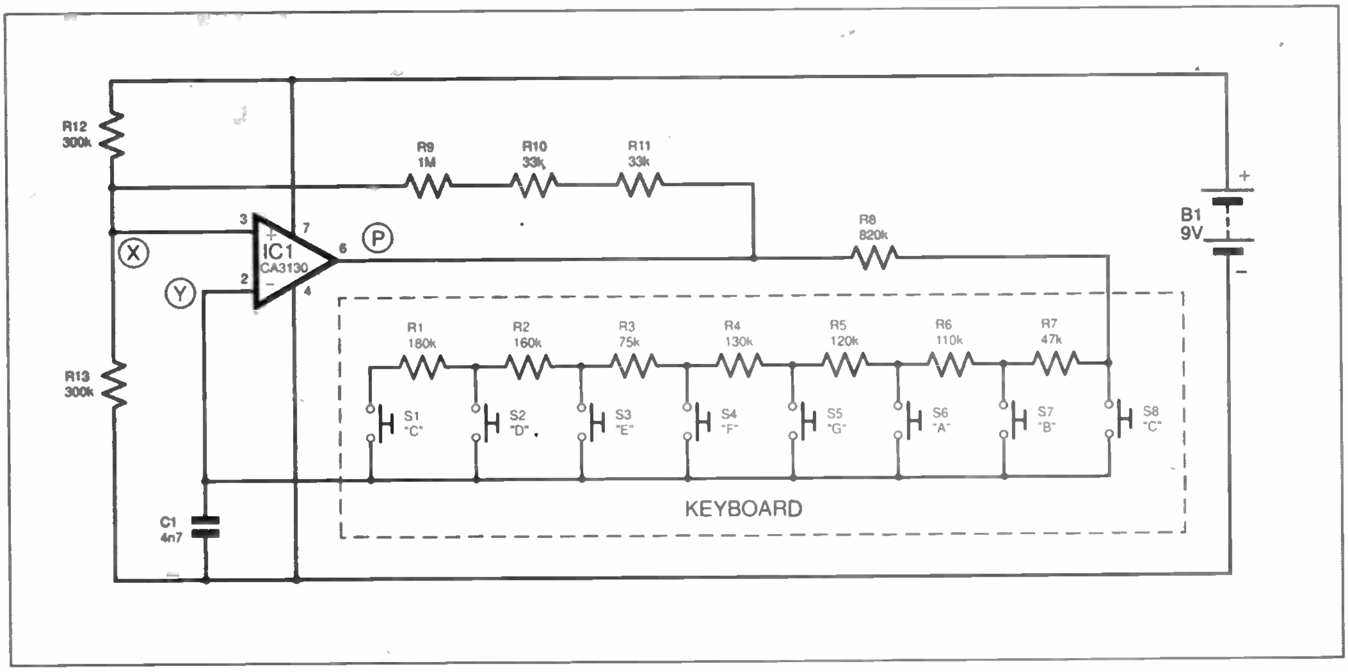


*Fig.2. Op-Amp Multivibrator with switched feedback for frequency variation.*

Compensation restricts the rate at which the output can slew, and that has proportionately more effect on the square wave at higher frequencies, delaying the charging of the timing capacitor and so lowering the frequency.

Whilst compensation is obligatory to ensure stability in most negative feedback arrangements, in this design IC1 is only active during positive feedback. In other words, it is acting as a comparator. So the omission of compensation is legitimate.

## SEMITONE AND OCTAVE SWITCHES

Using a pushbutton switch to add a 270pF capacitor in parallel with the 4n7F timing capacitor would reduce any note frequency by six per cent, which is a semitone. Alternatively, adding another 4n7F in parallel would drop any note by an octave.

But these suggestions conflict with each other. Once the octave is lowered, twice the 270pF is required to produce a drop of a semitone.

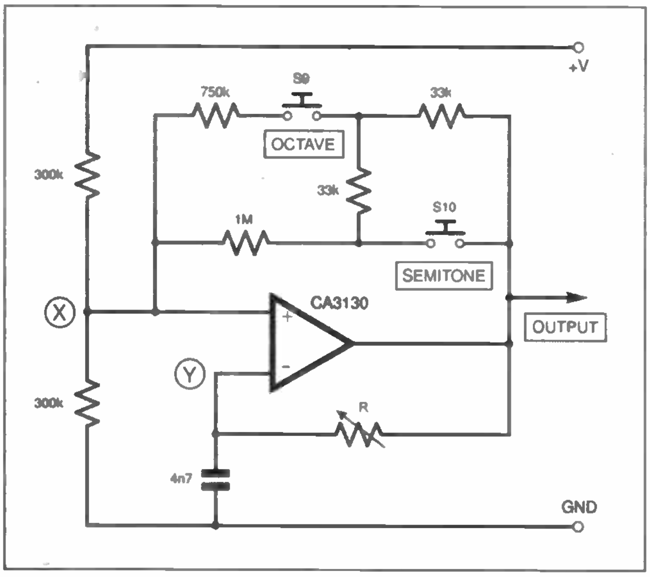

*Fig.3. Semitone and Octave Network.*

An alternative is to produce the semitone drop by adjusting the feedback resistors, and this would work properly whether or not a second 4n7F was in use to reduce the octave.

This suggests a bolder move: dispense with extra capacitors altogether, and replace the feedback resistors by a network, which uses two pushbutton switches to offer the four different values of feedback that are required; see Fig.3.

When neither switch (S9 and S10) is pushed, the circuit resembles that of Fig.2. Pressing the semitone switch (S10) increases the feedback slightly, increasing the step at *X*. Frequency falls a little, as the voltage at *Y* now has to "travel" further.

The octave switch (S9) has a much more drastic effect. If it is held pressed, the semitone switch allows greater change in current than it did before, and an accurate semitone is again generated.

## COMPUTATION

There is some evidence that one per cent resistors tend to be more accurate than one per cent capacitors. This suggests that generation of semitone and octave is best done by the resistor network: it will cause less error than adding capacitors. It is also a much cheekier thing to do!

However, the system now needs to be analysed again as a whole on a computer, trying every reasonable value of resistor and capacitor, to discover the components that give minimum overall error.

Using QBasic, the author's 486DX computer took over 30 minutes to find the optimum components, now shown together in the complete circuit diagram for the Mini Organ, as depicted in Fig.4.

## FINAL CIRCUIT

The circuit of Fig.2 has an irritating quirk. If point *Y* is high when the last pushbutton is released, then *Y* sinks slowly over some tens of seconds, and an unexpected final click is heard when *Y* finally sinks below the voltage on *X*. So the keyboard of Fig.2 has been "inverted" in Fig.4 (switches S1 to S8 "on top").

This arrangement permits the addition of resistors R1 and R2. When a switch (S1 to S8) is pressed, these resistors are just a small extra load on the op-amp. But when all switches S1 to S8 are open they define a mid-rail potential, towards which the timing capacitor decays, and no delayed click is produced.

The power amplifier, IC2, provides a low impedance output, which is needed to damp speaker resonances.

The square wave output produces a sound midway between an organ and bagpipes, which can be softened by adding capacitors C4 and/or C5. Space has been left for both, but you may install either or neither. The author preferred to include just C5, to give the slightly rough sound of the traditional organ.

## POWER CONSCIOUS

To avoid battery waste, an auto power-off circuit has been included. The circuit is switched on by pressing switch S11. This causes transistor TR2 to turn on, so turning on TR1 to allow power to reach the rest of the circuit.

If no note is sounded for a couple of minutes, the charge on capacitor C11 fades, and the circuit is switched off by the joint action of TR1 and TR2. Light emitting diode (l.e.d.) D4 shows when the circuit is on.

In the interests of oscillator stability, advantage was taken of the class B output circuit around IC2. On the positive half of the signal cycle the battery is heavily loaded, and it may lose 1V, or rather more than that as it ages. But on the negative half-cycle the battery is not loaded, and its voltage recovers almost completely.

Diode D1 in the positive rail ensures that only the recovered voltage powers the oscillator, limiting the effects of battery ageing.

**Table 1. Prototype frequency performance**

| Note | Target | Measured | Error (Hz) |
|---|---|---|---|
| High C | 523·3 | 521·8 | −1·5 |
| B | 493·9 | 493·5 | −0·4 |
| A | 440 | 438·0 | −2·0 |
| G | 392·0 | 390·3 | −1·7 |
| F | 349·2 | 349·0 | −0·2 |
| E | 329·6 | 329·0 | −0·6 |
| D | 293·7 | 293·1 | −0·6 |
| Low C | 261·6 | 261·5 | −0·1 |
| Semi HC | 493·9 | 493·2 | −0·7 |
| Oct HC | 261·6 | 262·0 | +0·4 |
| Oct LC | 130·8 | 130·8 | 0·0 |

Semi HC = semitone and High C
Oct HC = Octave and High C pressed
Oct LC = Octave and Low C pressed

## TARGET VALUES

The network in Fig.4 does not quite produce the four target values that are required, but the largest of its four errors is only 0·18 per cent. This must be added to the 0·22 per cent mismatch found in the resistor chain, to give a maximum note mismatch of 0·4 per cent, which is still well under the one per cent target aimed at.

So far, no allowance has been made for the tolerance error that might be found in the components themselves. It is already clear that one per cent components are required: five per cent errors would blow away the above results.

In fact, most of the errors are likely to be a good deal less than one per cent, and they are unlikely to conspire to go in the same direction. So there is a good chance of remaining within the one per cent overall margin allowed, even when the one per cent tolerance errors are added.

The 10μV differential input voltages that might occur with the CA3130 have almost no effect: they slow one half of the cycle slightly, but speed the other half equally. The best test is to construct the instrument, and to measure its errors.

Table 1 shows the results achieved with the prototype.

## CONSTRUCTION

The case chosen is of minimum depth, so that the instrument can be carried in a pocket. The speaker must not exceed 38mm diameter or 17mm depth. The electrolytic capacitors should be low-profile types, height not exceeding 7mm, and the remaining capacitors should be kept small as well. Resistors are 0.25W size.

The circuit is assembled on stripboard, layout details for which are shown in Fig.5.

Stripboard is easy to cut, if it is clamped to a good edge, copper side uppermost, and then cut with a hacksaw held almost parallel to the board. Note that part of one edge is removed, and two corners are trimmed. Handle these tasks with particular care.

Tidy the cut edges with steady strokes of a file. Then make the breaks (cuts) in the track as shown, using a standard stripboard cutting tool.

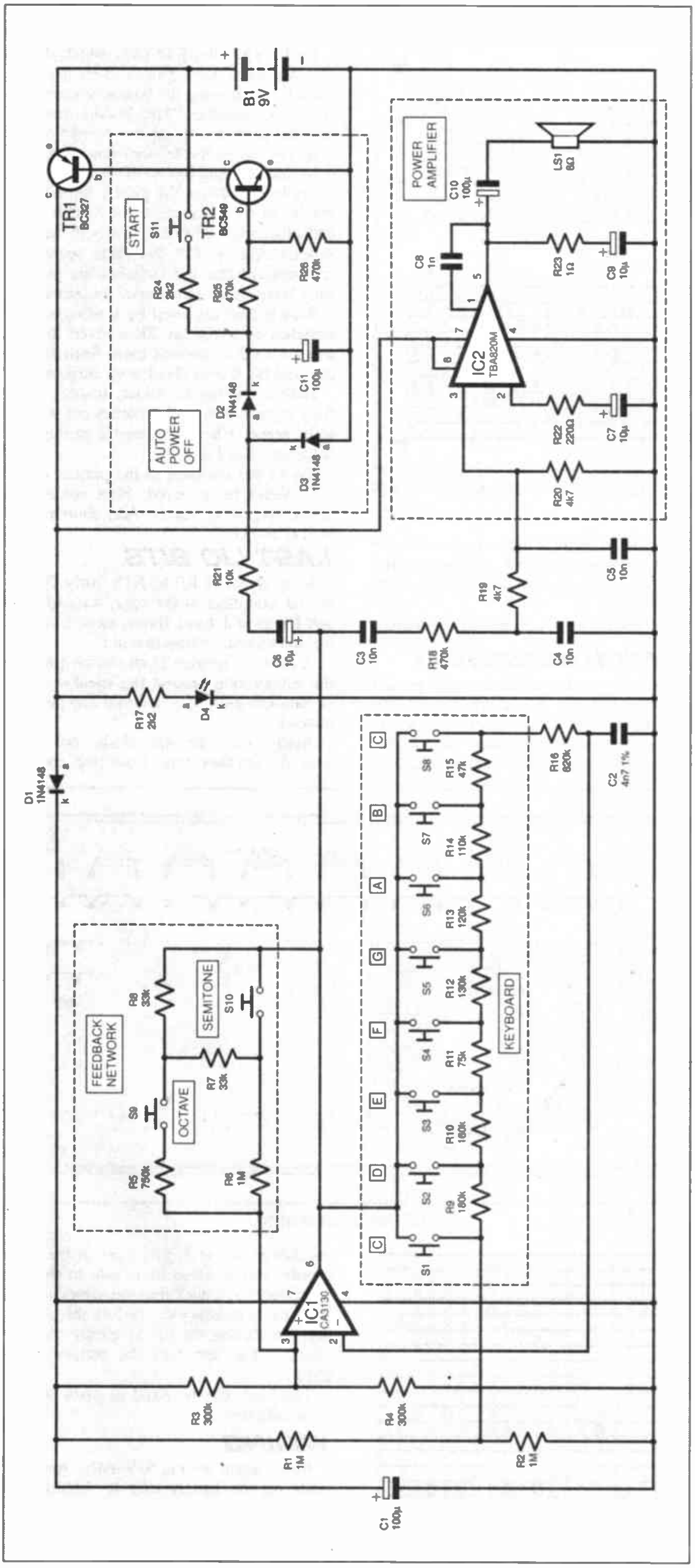


*Fig.4. Mini-Organ final circuit.*

## COMPONENTS

**Resistors**

| | |
|---|---|
| R1, R2 | 1M (2 off) |
| R3, R4 | 300k (2 off) 1% |
| R5 | 750k 1% |
| R6 | 1M 1% |
| R7, R8 | 33k (2 off) 1% |
| R9 | 180k 1% |
| R10 | 160k 1% |
| R11 | 75k 1% |
| R12 | 130k 1% |
| R13 | 120k 1% |
| R14 | 110k 1% |
| R15 | 47k 1% |
| R16 | 820k 1% |
| R17, R24 | 2k2 (2 off) |
| R18, R25, R26 | 470k (3 off) |
| R19, R20 | 4k7 (2 off) |
| R21 | 10k |
| R22 | 220Ω |
| R23 | 1Ω |

All resistors 0·25W 5%, unless stated

See SHOP TALK Page

**Capacitors**

| | |
|---|---|
| C1, C10, C11 | 100µ min. radial elect. 16V (3 off) |
| C2 | 4n7 1% polystyrene |
| C3 to C5 | 10n min. polyester (3 off) |
| C6, C7, C9 | 10µ min. radial elect. 16V (3 off) |
| C8 | 1n polystyrene |

**Semiconductors**

| | |
|---|---|
| D1 to D3 | 1N4148 (3 off) |
| D4 | red l.e.d. 5mm high brightness |
| TR1 | BC327 *pnp* transistor |
| TR2 | BC549 *npn* transistor |
| IC1 | CA3130 op.amp |
| IC2 | TBA 820M power op.amp |

**Miscellaneous**

| | |
|---|---|
| B1 | PP3 9V battery |
| LS1 | 8Ω speaker 38mm dia. × 17mm deep |
| S1 to S11 | push-to-make switch, 5mm × 5mm grid (11 off) |

Stripboard, 0·1 inch pitch, 10 rows × 41 holes (see text); battery clip; 8-pin d.i.l. socket (2 off); speaker cloth (see text); plastic case 111mm × 57mm × 22mm; solder pins, single sided (13 off); connecting wire, solder, etc.

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Solder the 13 links in position first, then assemble in order of resistors, diodes, i.c. sockets, terminal pins, capacitors C3, C4, C5 and C8 (you can omit C4 or C5 or both, as discussed earlier). Next, insert the transistors and remaining capacitors.

Finally, make the solder link that joins pins 6 and 7 under the socket for IC2. Omit it, and there will be no output!

## DRILLING THE LID

The lid of the case carries the resistor chain, all pushbutton switches, the l.e.d. and speaker, plus resistors R7 and R8. Accurate location of the components is required, if everything is to fit.

Preparing the lid is definitely a challenge. However, the work becomes quite easy if an additional piece of stripboard is used as a jig, as in Fig.6.

The piece of stripboard used will not be damaged and it can be larger than that

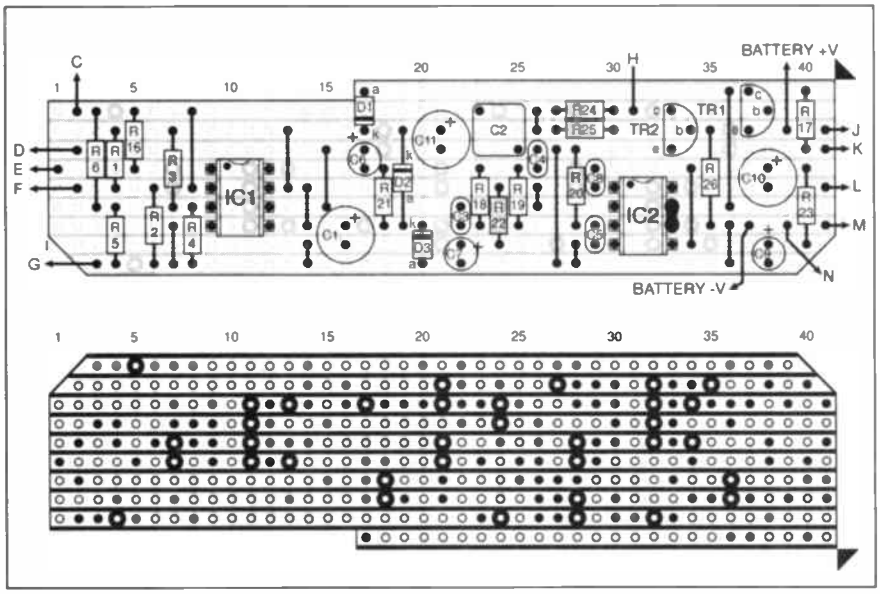



*Fig.5. Component layout on the stripboard, and trackside view showing the track breaks required.*

shown. Lay the stripboard with copper tracks uppermost. Then use a marker pen to ring the holes shown, to guide the 1mm drill. Only the relative position of the marked holes is important.

Take the lid of the box and lay it face upwards. Note the slightly curved profile of the edges. Measuring from the outer profile of the edge, use a pencil to mark point *A* exactly 9mm from its two adjacent edges.

Use the stripboard track-break tool or similar to make an indent at *A*, and follow through with a 1mm drill. Press an old-fashioned brass drawing pin into hole *A* from below. Sometimes a modern drawing pin has teeth near the tip, and these can be an obstacle.

Find hole *A* on the jig, and locate it very positively and with copper side upwards on the drawing pin at hole *A* on the lid. Adjust the lower edge of the lid by eye, so that it runs exactly parallel to the rows of holes in the board, and drill through the jig at hole *B*, to produce hole *B* in the lid.

Insert a second drawing pin at *B* from below, to lock the jig and lid at *B*. Position jig and lid on a flat backing board, so that both pins are truly trapped. Keeping them under observation, drill all the other holes that are marked on the jig, except those nearest to *A* and *B*. To drill these, move the pins elsewhere, to avoid fouling the drill.

Four holes in the jig define the speaker aperture. Drill these four, and a succession of intermediate holes on the perimeter of that aperture. With a little more work the centre can now be cleared, and the aperture tidied. But treat its narrow edge with some respect!

Drill out the l.e.d. hole to 5mm diameter.

## SWITCH MOUNTING

The pins on the switches only project 1mm beyond the plastic of the lid. To create more room for soldering, use a track-break tool on the underside of the lid, to countersink each of the 1mm diameter holes. Remove material gently, until the full diameter of the track-break tool is engaged.

Each switch has four pins, which divide into two pairs. Each pair is internally connected, and pressing the button connects the two pairs together. The button must be oriented correctly, to achieve correct operation. The flat on its the outer ring is there to help, and it should face to the right.

Soldering causes the plastic material of the lid to melt and seize the switch pins, and any errors of orientation will require serious surgery. For the same reason, it is important that the switches are pushed fully home at the moment of soldering.

This is best achieved by loading all the switches on to the lid. Then invert the lid, using a card to prevent them from falling out, and lay it on a clean work surface.

Before starting to solder, inspect carefully to ensure that all switches are pushed fully home. Check frequently during the soldering. See Fig.7.

To fix the switches in the plastic, every pin should be soldered. First solder the connecting wire, via *D*. Add short pieces at *J*, *H* and *G*.

## LAST LID BITS

Keep resistors R9 to R15 fairly flat on the lid, and clear of the edge. Resistors R7 and R8 should stand 10mm away from the lid, to facilitate connection at *C*.

A piece of speaker cloth can be glued to the rubber ring around the speaker cone, or handkerchief-style material can be used instead.

Apply glue to the cloth, but only over the speaker ring. Place the covered speaker as in Fig.7, just clear of the edge profile, and as close as is safe to the left hand buttons. Check that the view into the aperture is satisfactory. Before the glue is dry, try closing the lid, to ensure that the speaker does not foul the battery (with clip).

The l.e.d. can be fixed in place with a clear adhesive.

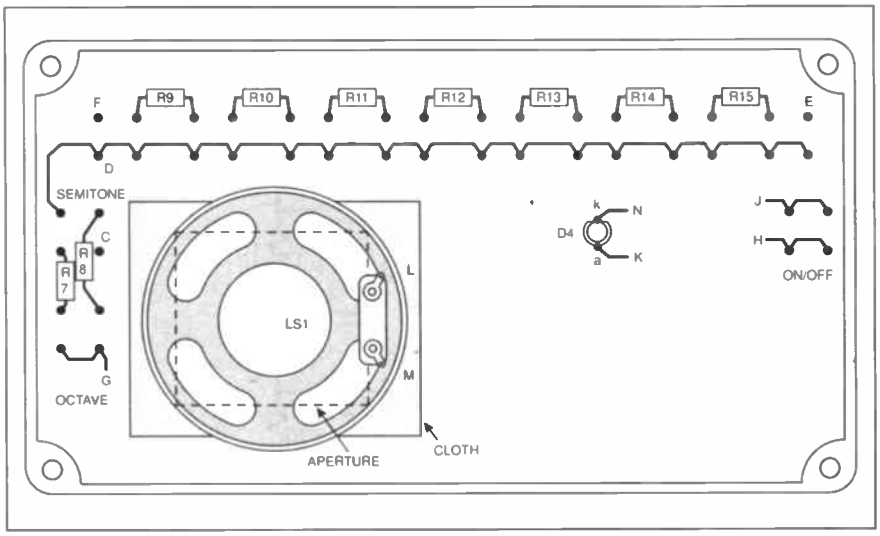



*Fig.7. Inside view of lid.*

## WIRING

Refer again to Fig.5. Firstly, trim the leads on the battery clip to 40mm, and solder them at the pins indicated. Find pins CDEFG on the left of the stripboard, and pins HJKLMN towards the right. Pins with the same letters are marked in Fig.7: connect C to C and so on.

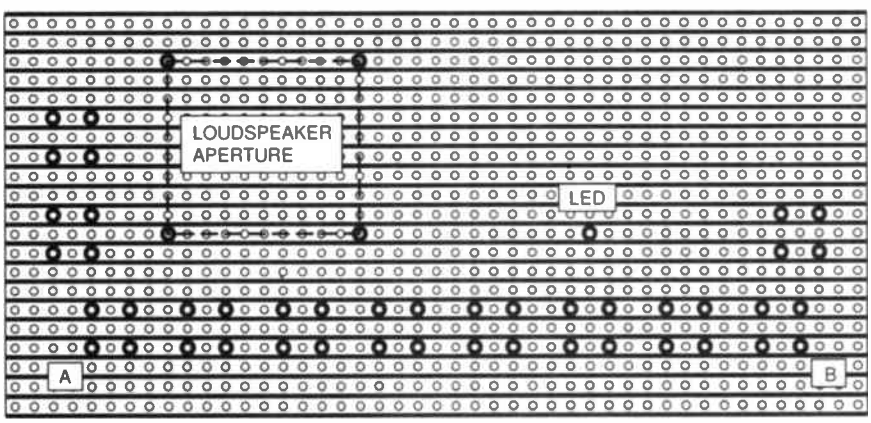
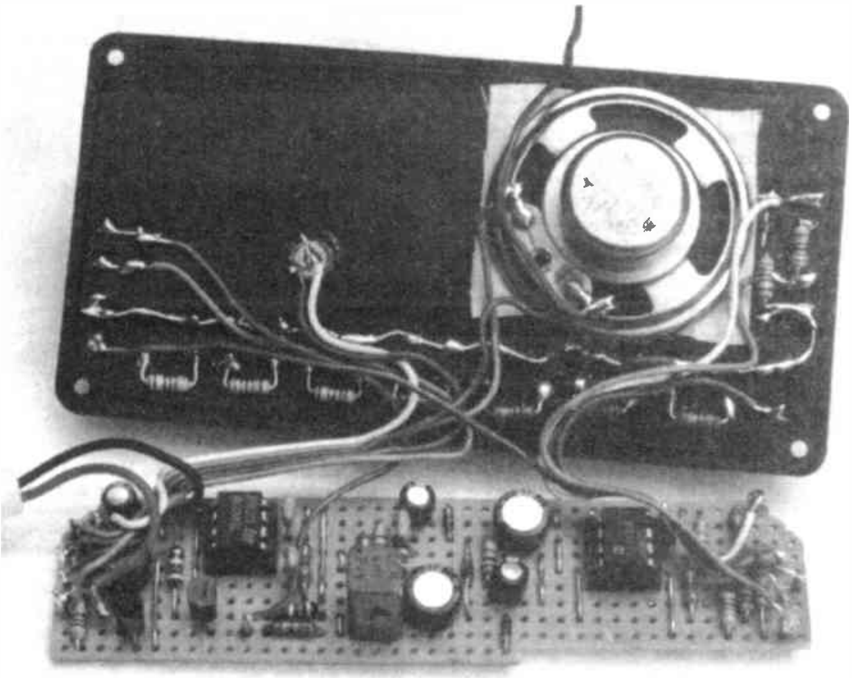



*Fig.6. Stripboard jig for use when drilling lid.*



Flexible wire must be used, to allow the lid to shut easily. The author used a piece of coloured ribbon cable at each end of the stripboard. When deciding on length of the leads and their separation, bear in mind that there is room for the ribbons to run backwards and forwards along the line of the two i.c.s.

Neither ribbon, though, should use more than half the available run, and it should fold into this space as the box is closed. If these leads are excessively long, they are more difficult to pack into the space available. If they are too short, it is difficult to control the folding when the box is closed. The photograph should act as a guide.

If you wish, drill a 3mm hole in the rear just behind the speaker, and bring out a pair of wires from the speaker terminals. The pair should terminate in a terminal block, to protect IC2. Output voltage is 1V peak, and it will drive a power amplifier, to produce a rock-steady organ note. Alternatively, these leads will drive a frequency meter, to test the instrument.

## TESTING

Before closing the box, connect the battery, in series with a current meter. There should be no current until the On switch is pushed, when a standing current of around 11mA should flow. This should increase to about 44mA when a note is sounded. Within three minutes of play finishing, the l.e.d. should slowly extinguish.

When closing the box, watch the 4n7 capacitor C2: there is no headroom above it for any leads, but there is plenty of room on the i.c. side. If the lid bows upwards, you have something trapped somewhere. Or, perhaps, there are some long "tails" under the stripboard – trim them off.

Note that before the prototype box could be closed, the author had to clear the screw holes in its base, using a 2mm drill.

It is not necessary to fix the stripboard or the battery inside the box.

## ACCURACY

When tested with a frequency meter, the prototype gave the results shown earlier in Table 1. The figures are on the startling side: the maximum error found was under 0·5 per cent! A piano chosen at random would not be that accurate.

By trying three other timing capacitors and choosing the worst of them, it was possible to double the maximum error, to 1·1 per cent. The extra error caused by capacitor tolerance affects all notes equally, so it does not alter the relative tuning: as a result it is too small to be perceived, even by someone gifted with "perfect pitch".

Musicians who have tried this instrument have played happily for some time, and without commenting on the tuning.

Three demonstration tunes are offered in the Musical Appendix panel.

## MODIFICATIONS

This design could be expanded in a number of directions. Capacitors C4 and C5 could be connected to switches, to allow change of tone. If mechanical skills are in evidence, piano-like keys could be arranged to operate strong microswitches, which would provide the springs needed to restore the keys.

Where mathematical skills are available, the black notes of the keyboard could be added; and/or the octave facility could be dropped, with the lower octave generated by continuing the resistor chain instead. The method of calculation has been indicated earlier. □

## MUSICAL APPENDIX

Here are some tunes to try. When playing, hold the finger forward, its fleshy underside should do the work. Lengthen any note. ^C refers to the upper C button.

*Speed, bonnie boat, like a bird upon wing; Onwards, the sailors cry;*
C D C F F F G A G ^C A G A D D C

*Carry the lad that was born to be king, Over the sea to Skye.*
C D C F F F G A G ^C A G A D D F

The second tune uses the semitone: C̲ means Semitone switch + C
CCDC̲CD EEFEDC DCC̲C; GGGGFĒ FFFFED EFEDCEFG AFEDC

*Frere Jacques* uses the octave: *g* means Octave button + G:

CDEC CDEC EFG EFG GAGFEC GAGFEC CgC CgC

When a note cannot be reached, the octave lower can be played.
Play ▸D as D, but sing it an octave higher:

GGGAGGD EDEGGG ; GGGAGGD EDEGGG
▸D ↑CBABAG EDEG̲GG; DDEG̲GGA –▸D ↑CBAG ↑CG

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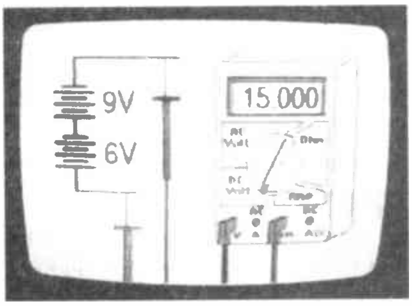


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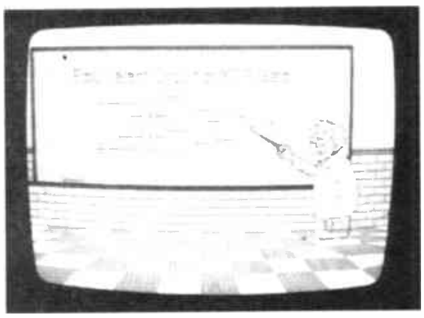

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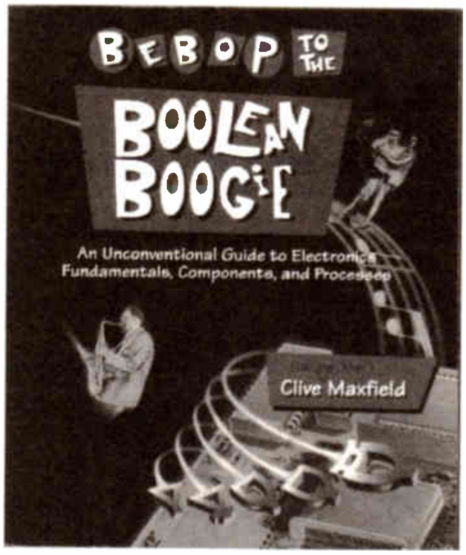


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The Foreword by Pete Waddell,
Editor, *Printed Circuit Design*, reads:

My first exposure to the unique writing style of Clive (call me Max) Maxfield was a magazine article that he co-wrote with an associate. The article was technically brilliant (he paid me to say that) and very informative, but it was the short biography at the end of the piece that I enjoyed the most. I say enjoyed the most because, as you will soon learn, Max does not necessarily follow the herd or dance to the same drummer as the masses. Trade journals have a reputation for being informative and educational but also as dry as West Texas real estate.

Anyway, Max's personally submitted biography not only included a message from his mom, but also made mention of the fact that he (Max) is taller than his co-author, who just happened to be his boss at the time. Now to some people this may seem irrelevant, but to our readers (and Max's boss), these kind of things – trivial as they may seem to the uninitiated – are what helps us to maintain our off-grid sense of the world. Max has become, for better or worse, a part of that alternate life experience.

So now it's a couple of years later, and Max has asked me to write a few words by way of introduction. Personally, I think that the title of this tome alone (hmmm, a movie?) should provide some input as to what you can expect. But, for those who require a bit more: be forewarned, dear reader, you will probably learn far more than you could hope to expect from *Bebop to the Boolean Boogie*, just because of the unique approach Max has to technical material. The author will guide you from the basics through a minefield of potentially boring theoretical mish-mash, to a Nirvana of understanding. You will not suffer that fate familiar to every reader: re-reading paragraphs over and over wondering what in the world the author was trying to say. For a limey, Max shoots amazingly well and from the hip, but in a way that will keep you interested and amused. If you are not vigilant, you may not only learn something, but you may even enjoy the process. The only further advice I can give is to "expect the unexpected."

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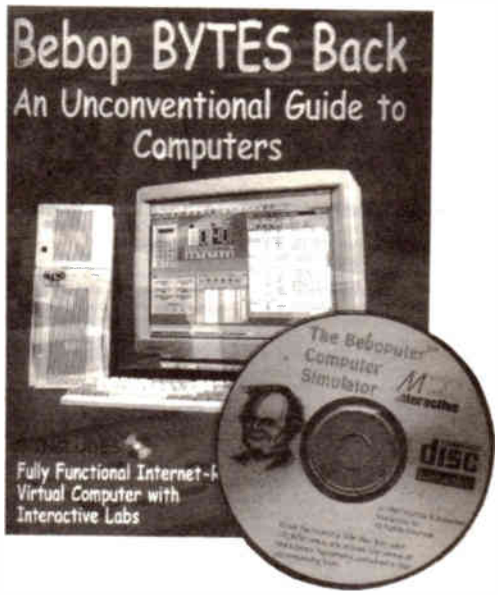


The Foreword by Lee Felsenstein reads:

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This book will admit you to the company of people who have deep knowlege of computer technology. It is only a beginning (there is no end), and there are many possible directions for you to go.

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| *EPE Met Office – Sensor/Rainfall/Vane | | 963/965 | £11.33 |
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| Light-Operated Switch | | 966 | £6.37 |
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# SURFING THE INTERNET

# NET WORK

## ALAN WINSTANLEY

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It is now possible to order a subscription (or renew an existing one), order printed circuit boards for our constructional projects, and also check the availability of Back Issues and order any requirements, all by logging on to our Secure Server. Payment is made by credit card (Mastercard or VISA) and you are asked to enter the details on a simple on-line order form. After hitting the "Mail" button you will then receive a brief acknowledgement confirming that your request is safely on its way.

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### Beating the Junkmailer

A few topical points of interest this month, starting again with my least favourite subject – unsolicited commercial E-mail (UCE). My junk mail box stands at 277 items, of which perhaps the tackiest of all (and from an English marketeer at that), is a recent Diana, Princess of Wales T-shirt offer, with proceeds said to be going to the Memorial Fund.

In the hours immediately following the death in Paris of the Princess of Wales, a UK discussion group sprang up, but soon an American spammer filled the fledgling discussion group with grotesque image files, thereby bringing many subscribers' newsfeeds to a crawl (not to mention the distress this would have caused to many ordinary citizens) as they blithely posted scores of .JPG images.

The only way to prevent your newsfeed from being unduly loaded with rubbish is really to fetch the "headers" only to begin with, mark any items of possible interest and then dial-in again to download them. It is interesting to note that spammers avoid many of the *comp.infosystems* and *sci.electronics* newsgroups (for example) by a wide margin, perhaps because they know that they would aggravate a number of qualified users who would be capable of exacting a revenge?

One such defence (partially, anyway) against unsolicited commercial E-mail is built into the latest version of *Turnpike (V3.04)* for Windows, the British-designed Internet mail and off-line newsreader software (**www.turnpike.com**). I have been running *V3.04* and although it's a bit quirky, I must say that I am generally very impressed with this latest in a long string of upgrades.

Demon Internet Services claim to be the country's largest ISP. They use SMTP (Simple Mail Transfer Protocol) as its standard mail delivery system, which is more flexible than a standard POP3 mailbox in some respects, less so in others. One problem Demon customers have is that they may not necessarily have any control over the receipt of mail: Demon delivers SMTP mail automatically, whenever their customers connect, and they will unfailingly deliver it, junk and all.

However, a new "Reject Message" feature within *Turnpike V3.04* will generate a "Delivery Failed" Delivery Notification Status message, which will be sent back to the junkmailer, and which then gives the appearance of the UCE mail having bounced (even if it was actually delivered). It is reckoned that sending any form of "Remove me from your mailing list" message indicates to E-mail marketeers that your address is still active (and therefore still a prime target): but the Reject Message means they will have no idea whether the E-mail address is still active or not.

At worst, an incapable spammer might try to reject your Rejection! "This is unwise," says Turnpike's Richard Clayton, "since if they had 25 million addresses, they would probably try to send out again another five million rejected Rejections, which they'll get back again to reject. Few people set up systems so incompetently, and (according to the RFC's, incorrectly). They certainly don't do it twice!" he mused. In the meantime, I've just received another four UCE messages.

### MSIE 4.0

*Microsoft Internet Explorer Version 4* finally broke cover at the end of September, after which the official Demon download site serving out this mammoth upgrade in the UK had a temporary dizzy spell. It is interesting to reflect that Demon decided early on that they would issue the Windows 95 Version 4 on CD-ROM and mailshot it to their dial-in customers, to "save them lots of time downloading IE4 from our servers", as Demon's Managing Director Cliff Stanford put it.

I do commend Demon Internet Services for producing the upgrade disk together with a glossy magazine, but it is surely a sign that there is still a long way to go in terms of bandwidth before it becomes feasible to distribute large-scale software using the medium of the Internet. Currently, unless you are on an academic or commercial network, fetching *MSIE 4.0* by FTP is like trying to drain a reservoir with a hosepipe. (The upgrade files total some 36MB on the Demon CD ROM.)

Contrast this with the marketing ethos of, say, Xara Ltd., who market some brilliant little web graphics effects packages via their web site (**www.xara.com**); Xara – a British software house famed for its fast and powerful 32-bit graphics software – make a deliberate point of distributing handy web graphics utilities (*Xara Webster* and *Xara 3D*) which are compact and easy to use, and which don't take months to learn to master (or download). The Internet was probably made for Xara.

Definitely, anyone attempting a file transfer as ambitious as *Microsoft Internet Explorer 4.0* should use good FTP software (e.g. *WS_FTP Pro*) which will enable them to "recover" or carry on from where it left off if the transfer hangs halfway through, otherwise you are faced with fetching the whole lot again. In practice, everyone will wait until *MSIE 4.0* appears on the cover disk of their favourite computer magazine. Or at least they ought to. Why hurry?

### Latest Links

Remember that *Net Work* is a good way of sharing favourite electronics-related URLs with your fellow readers – let me know your preferred sites! Note that the following URLs commence with **http://** unless otherwise stated, and are ready-made for you on our web site.

Advanced readers or those in higher education might like to try the demo version of *Basic Stamp II Windows 95* front end at **www.dontronics.com/bswfe.html** (a site generally worth exploring). Steve Nunn suggests **gnv.fdt.net/~redscho/** containing information about the correct use of Ni-Cads, of interest to radio-control hobbyists (also see the "NiCad" files on our FTP site in the **pub/docs** subdirec tory).

My *Surgery* co-writer Ian Bell suggests a couple of Java-enabled MOS transistor and CMOS gate simulators: try **www-elec.enst.fr/java/mos-beta/test.html** and **www-elec.enst.fr/java/skip-beta/test.html**. Don Lancaster is a well-known American writer, you will find lots of electronics design material on his site at **www.tinaja.com**. (*Adobe Acrobat* reader required.)

My E-mail address is **alan@epemag.demon.co.uk**.

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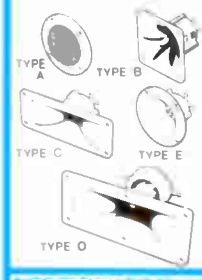


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**OMP/MF 200 Mos-Fet** Output power 200 watts R.M.S. into 4 ohms, frequency response 1Hz - 100KHz -3dB, Damping Factor >300, Slew Rate 50V/uS, T.H.D. typical 0.001%, Input Sensitivity 500mV, S.N.R. -110 dB. Size 300 x 155 x 100mm.
**PRICE £64.35 + £4.00 P&P**

**OMP/MF 300 Mos-Fet** Output power 300 watts R.M.S. into 4 ohms, frequency response 1Hz - 100KHz -3dB, Damping Factor >300, Slew Rate 60V/uS, T.H.D. typical 0.001%, Input Sensitivity 500mV, S.N.R. -110 dB. Size 330 x 175 x 100mm.
**PRICE £81.75 + £5.00 P&P**

**OMP/MF 450 Mos-Fet** Output power 450 watts R.M.S. into 4 ohms, frequency response 1Hz - 100KHz -3dB, Damping Factor >300, Slew Rate 75V/uS, T.H.D. typical 0.001%, Input Sensitivity 500mV, S.N.R. -110 dB, Fan Cooled, D.C. Loudspeaker Protection, 2 Second Anti-Thump Delay. Size 385 x 210 x 105mm.
**PRICE £132.85 + £5.00 P&P**

**OMP/MF 1000 Mos-Fet** Output power 1000 watts R.M.S. into 2 ohms, 725 watts R.M.S. into 4 ohms, frequency response 1Hz - 100KHz -3dB, Damping Factor >300, Slew Rate 75V/uS, T.H.D. typical 0.002%, Input Sensitivity 500mV, S.N.R. -110 dB, Fan Cooled, D.C. Loudspeaker Protection, 2 Second Anti-Thump Delay. Size 422 x 300 x 125mm.
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**NOTE: MOS-FET MODULES ARE AVAILABLE IN TWO VERSIONS: STANDARD - INPUT SENS 500mV, BAND WIDTH 100KHz. PEC (PROFESSIONAL EQUIPMENT COMPATIBLE) - INPUT SENS 775mV, BAND WIDTH 50KHz. ORDER STANDARD OR PEC.**

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# FORMULAE & NOTES

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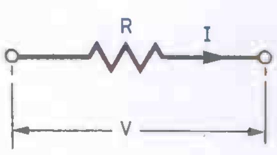
## OHM'S LAW




$V = IR$ V, volts

$I = \frac{V}{R}$ I, amperes

$R = \frac{V}{I}$ R, ohms

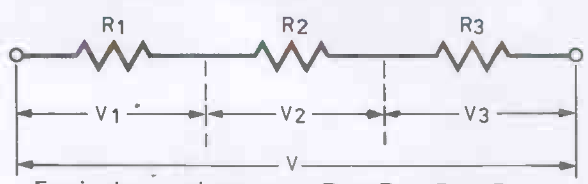
## QUANTITY


Quantity Q = current I (amperes) × time t (secs)
= It Coulombs

## MATHEMATICAL

Approximately equa
Greater than
Less than
Identical with
Proportional to
Increment
Therefore

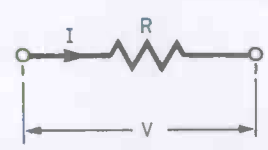
## RESISTORS IN SERIES




Equivalent resistance $R_E = R_1 + R_2 + R_3$

$V = V_1 + V_2 + V_3$

## POWER DISSIPATION




Power dissipated in R: $P = IV = I^2R = \frac{V^2}{R}$ watts

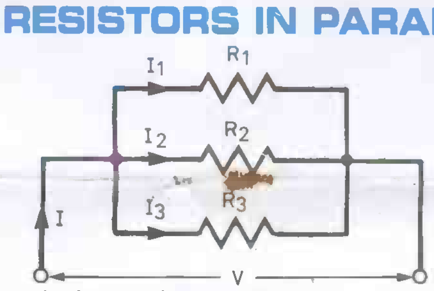
Heat developed in $R = I^2Rt = IVt = \frac{V^2t}{R}$ joules

1 watt is a rate of working of 1 joule per second. Multiply the joule heating by $2{\cdot}4 \times 10^{-4}$ to obtain the heat in kilocalories.

## MKS U

| | |
|---|---|
| Mass | M |
| Length | L |
| Velocity | v |
| Time | t |
| Angular velocity | ω |
| Energy | W |
| Power | P |
| Charge | Q |
| Current | I |
| E.M.F. | E |
| Resistance | R |
| Capacitance | C |
| Conductance | G |

## RESISTORS IN PARALLEL



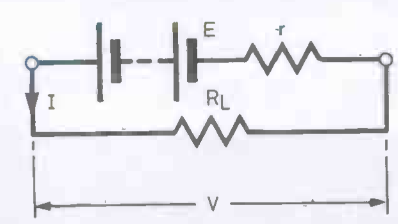

For equivalent resistance $R_E$:

$$\frac{1}{R_E} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

$$I = I_1 + I_2 + I_3$$

For two resistors only $R_E = \frac{R_1 \times R_2}{R_1 + R_2}$

## INTERNAL RESISTANCE




For a source of e.m.f. E volts and internal resistance r ohms:

Current $I = \frac{E}{R_L + r}$ amperes

$E = V + Ir = I(R_L + r)$ volts

P.D. across the load $V = E - Ir$ volts

Power in the load $P_L = \frac{E^2R_L}{(R_L + r)^2}$ watts

This power is greatest when $R_L = r$

## CAPACIT CONVERSIO

picofarads pF
nanofarads nF
microfarads µF

| | | |
|---|---|---|
| 0·0001µF | = | 0·1 |
| 0·001µF | = | 1 n |
| 0·01µF | = | 10 n |
| 0·1 µF | = | 100 n |
| 1 µF | = | 1000 n |

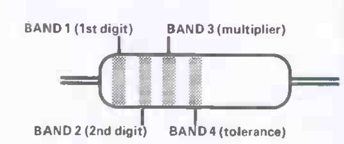
## CONDUCTANCE

Conductance $G = \frac{1}{\text{resistance}}$ Siemen

For resitors in parallel, equivalent conductance

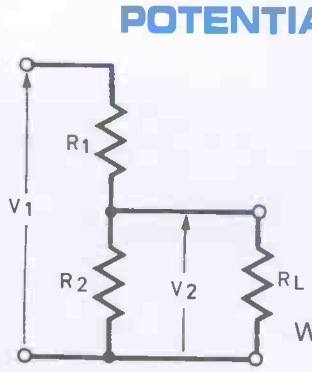
$G_E = G_1 + G_2 + G_3$ Siemen

## RESISTOR CO




| COLOUR | | |
|---|---|---|
| | 4 Band Codes | 1 |
| | 5 Band Codes | 1 |
| | Silver | – |
| | Gold | – |
| | Black | 0 |
| | Brown | 1 |
| | Red | 2 |
| | Orange | 3 |
| | Yellow | 4 |
| | Green | 5 |
| | Blue | 6 |
| | Violet | 7 |
| | Grey | 8 |
| | White | 9 |
| | None | – |

## POTENTIAL DIVIDER




For load resistor $R_L > 10R_2$

$$V_2 = \frac{R_2}{R_1 + R_2} \times V_1$$

For $R_L < 10R_2$

$$V_2 = \frac{R_E}{R_1 + R_E} \times V_1$$

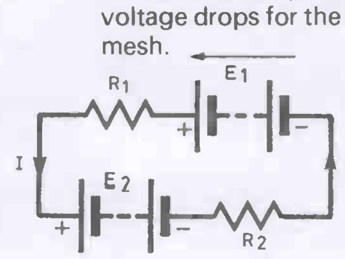
Where $R_E = \frac{R_L \times R_2}{R_L + R_2}$

## KIRCHHOFF'S LAWS

1 The current law: the algebraic sum of the currents meeting at any point in a network is zero.


$I_1 + I_3 = I_2$
or
$I_1 + I_3 - I_2 = 0$

2 The voltage law: in travelling round any closed mesh of a network, the algebraic sum of the e.m.f.'s acting in the mesh is equal to the algebraic sum of the IR voltage drops for the individual resistance in the mesh.




Working anticlockwise:

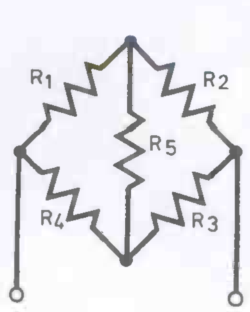
$IR_1 + IR_2 = E_1 - E_2$

Working clockwise:

$-IR_1 - IR_2 = E_2 - E_1$

If no sources are acting in the mesh, the algebraic sum of the IR voltage drops is zero

## WHEATSTONE BRIDGE




For balance (no current through $R_5$):

$\frac{R_1}{R_2} = \frac{R_4}{R_3}$ or $R_1R_3 = R_2R_4$

At balance:

$R_E = R_1 + R_2$ in parallel with $R_3 + R_4$

$$= \frac{(R_1 + R_2)\,(R_3 + R_4)}{R_1 + R_2 + R_3 + R_4}$$

WITH DECEMBER 1997.

# RONICS

http://www.epemag.wimborne.co.uk

Presented Free with *Everyday Practical Electronics*.
Material produced by Steve Knight.


## SYMBOLS

| | |
|---|---|
| to | $\simeq$ |
| | $>$ |
| | $<$ |
| | $\equiv$ |
| | $\propto$ |
| | $\delta$ or $\Delta$ |
| | $\therefore$ |

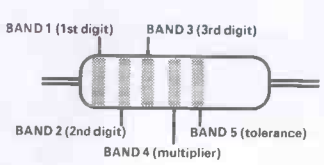
## NITS

kilogramme (kg)
metre(m)
metre/second (m/s)
second(s)
radian/second(r/s)
joule (J)
watt (W)
Coulomb (C)
ampere (A)
volt (V)
ohm (Ω)
Farad (F)
Siemen(S)

## ANCE ON TABLE

| | | |
|---|---|---|
| | = | $10^{-12}$ Farads |
| | = | $10^{-9}$ Farads |
| | = | $10^{-6}$ Farads |
| nF | = | 100 pF |
| F | = | 1000 pF |
| F | = | 10000 pF |
| F | = | 100000 pf |
| F | = | 1000000 pf |

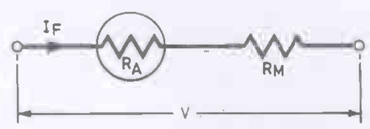
## LOUR CODE




| BAND NUMBER | | | |
|---|---|---|---|
| 2 | | 3 | 4 |
| 2 | 3 | 4 | 5 |
| | | 0·01 | 10% |
| | | 0·1 | 5% |
| 0 | 0 | 1 | |
| 1 | 1 | 10 | 1% |
| 2 | 2 | 100 | 2% |
| 3 | 3 | 1000 | |
| 4 | 4 | 10000 | |
| 5 | 5 | 100000 | |
| 6 | 6 | 1000000 | |
| 7 | 7 | | |
| 8 | 8 | | |
| 9 | 9 | | |
| | | | 20% |

## SERIES MULTIPLIERS

Used for extending voltage ranges

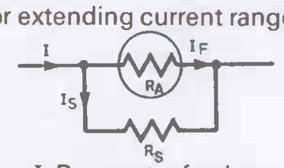



$$R_M = \frac{V}{I_F} - R_A \text{ ohms}$$

where $R_M$ = required multiplier resistance, ohms
$I_F$ = full scale deflection of existing meter, amperes
$R_A$ = resistance of meter, ohms
V = required voltage range on meter scale

## PARALLEL SHUNTS

Used for extending current ranges

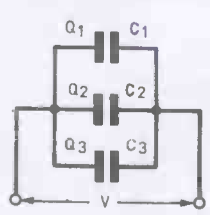



$$I = I_F + I_S$$

$$R_S = \frac{I_F R_A}{I_S} = \frac{\text{meter f.s.d. current}}{\text{shunt current}} \times R_A$$

where I is the required current range

## CAPACITORS IN PARALLEL

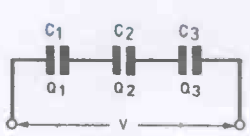



Equivalent capacitance:
$C_E = C_1 + C_2 + C_3$

Total stored charge:
$Q_E = Q_1 + Q_2 + Q_3$

Charge on $C_1 = Q_1 = C_1V$
Charge on $C_2 = Q_2 = C_2V$
Charge on $C_3 = Q_3 = C_3V$

## CAPACITORS IN SERIES



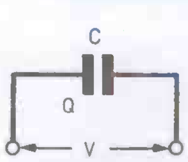

For equivalent capacitance $C_E$:

$$\frac{1}{C_E} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$$

Total stored charge $Q_E = Q_1 = Q_2 = Q_3$

For two capacitors only $C_E = \frac{C_1 \times C_2}{C_1 + C_2}$

## ENERGY STORED IN A CAPACITOR




C Farads
V volts
Q Coulombs

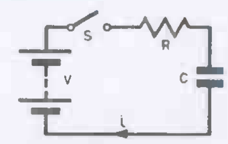
Charge on the capacitor $Q = CV$ Coulombs

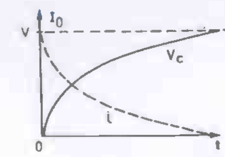
Energy stored $W = \frac{1}{2}CV^2$ joules

$= \frac{1}{2}QV$ joules

$= \frac{Q^2}{2C}$ joules

## CHARGE OF C THROUGH R




Switch S is closed at time t = 0

Initial current $I_o = \frac{V}{R}$

Current at any subsequent instant: $i = I_o \exp\left(-\frac{t}{CR}\right)$

Initial voltage across C at t = 0:

$V_c = 0$

Voltage across C at any subsequent instant:

$$V_c = V\left[1 - \exp\left(-\frac{t}{CR}\right)\right]$$

Time constant T = CR seconds; (C Farads, R ohms)
After a time t = CR seconds:
$V_c = 0{\cdot}63V$
$i = 0{\cdot}37I_o$

## INDUCED E.M.F.


Whenever a current i is switched on, switched off or changes in value in an inductance, L henries, the e.m.f. induced in the inductor

$e = -L \times$ rate of change of current i

$= -L\frac{di}{dt}$ volts

where $\frac{di}{dt}$ is amperes per second.

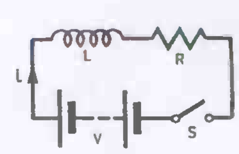
Lenz's Law: When a current is increasing, the induced e.m.f. is negative and opposes the supply voltage (the "back" e.m.f.).
When a current is decreasing, the induced e.m.f. is positive and acts in the same direction as the supply voltage.

## ENERGY STORED IN A MAGNETIC FIELD

Work done in establishing a steady current I in an inductance, L henries; and the energy stored in the field:

$W = \frac{1}{2}LI^2$ joules

## CURRENT GROWTH IN AN INDUCTANCE

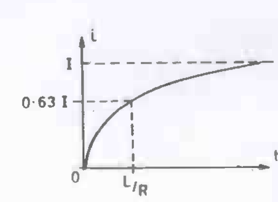



Switch S is closed at time t = 0

Final steady state current $I = \frac{V}{R}$

Current at any subsequent instant after t = 0:

$$i = I\left[1 - \exp\left(-\frac{Rt}{L}\right)\right]$$




Time constant $T = \frac{L}{R}$ seconds

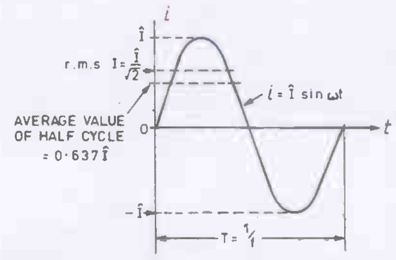
After a time $t = \frac{L}{R}$ seconds:
$i = 0{\cdot}63I$

## SINE WAVE CHARACTERISTICS

$i$ = instantaneous current
$\hat{I}$ = peak or maximum excursion
$I$ = Root mean square (r.m.s.) value
$f$ = frequency
$\omega$ = $2\pi f$, the angular velocity
$T$ = periodic time
$2\hat{I}$ = peak-to-peak value

$I = \dfrac{\hat{I}}{\sqrt{2}} = 0{\cdot}707\hat{I}$

$\hat{I} = \sqrt{2}I = 1{\cdot}414I$



Form factor $= \dfrac{\text{r.m.s. value}}{\text{average value}} = 1{\cdot}11$

These formulae refer equally to a voltage wave

## R.M.S. VALUES

R.m.s. value of a sinusoidal wave:

$$\frac{\hat{I}}{\sqrt{2}} \text{ or } \frac{\hat{V}}{\sqrt{2}} = 0{\cdot}707\hat{I} \text{ or } 0{\cdot}707\hat{V}$$

R.m.s. value of a.c. superimposed on d.c.:

$$I = \sqrt{I_{d.c.}^2 + \tfrac{1}{2}\hat{I}^2}$$

R.m.s. value of two sinusoidal currents of the same frequency and in phase:

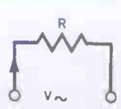
$$\frac{\hat{I}_1 + \hat{I}_2}{\sqrt{2}} = 0{\cdot}707(\hat{I}_1 + \hat{I}_2)$$

## POWER IN A.C. CIRCUITS

Apparent power = VI volt-amp (VA)
True power = apparent power × power factor
= VI × cos $\phi$ watts
where $\phi$ is the phase angle.

## PURELY RESISTIVE CIRCUIT

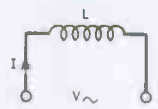
$$I = \frac{V}{R}$$



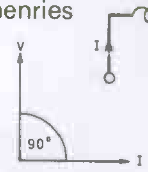
I and V are in phase; phase angle $\phi = 0°$

## PURELY INDUCTIVE CIRCUIT

Reactance $X_L = 2\pi fL$ ohms, L in henries



$I = \dfrac{V}{X_L}$; $V = IX_L$

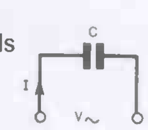


I lags V by 90° ($\pi/2$ radians)
Phase angle $\phi = 90°$ lagging

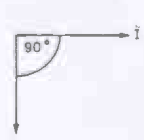
## PURELY CAPACITIVE CIRCUIT

Reactance $X_c = \dfrac{1}{2\pi fC}$ ohms, C in farads

$= \dfrac{10^6}{2\pi fC}$ ohms, C in $\mu$F



$I = \dfrac{V}{X_c}$; $V = IX_c$



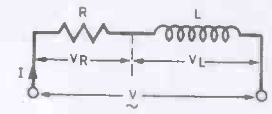
I leads V by 90° ($\pi/2$ radians)
Phase angle $\phi = 90°$ leading

## R AND L IN SERIES

Reference phasor for a series circuit = I

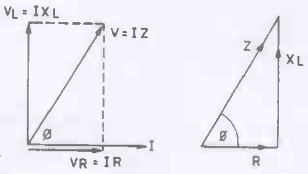
Circuit impedance

$|Z| = \sqrt{R^2 + X_L^2}$ ohms



$I = \dfrac{V}{|Z|}$

$V = \sqrt{V_R^2 + V_L^2}$



$\tan\phi = \dfrac{X_L}{R}$

$\cos\phi = \text{power factor} = \dfrac{R}{|Z|}$

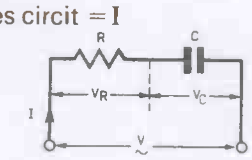
where $\phi$ is the phase angle of lag.

## R AND C IN SERIES

Reference phasor for a series circit = I

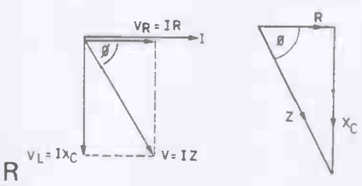
Circuit impedance

$|Z| = \sqrt{R^2 + X_c^2}$



$I = \dfrac{V}{|Z|}$

$V = \sqrt{V_R^2 + V_c^2}$



$\tan\phi = \dfrac{X_c}{R}$

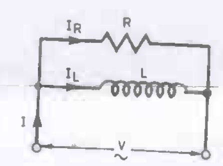
$\cos\phi = \text{power factor} = \dfrac{R}{|Z|}$

where $\phi$ is the phase angle of lead.

## R AND L IN PARALLEL

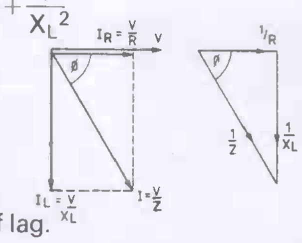
Reference phasor for a parallel circuit = V

$I_R = \dfrac{V}{R}$ is in phase with V



$I_L = \dfrac{V}{X_L}$ lags V by 90° ($\pi/2$ radian)

$I = \sqrt{I_R^2 + I_L^2}$; $\dfrac{1}{|Z|} = \sqrt{\dfrac{1}{R^2} + \dfrac{1}{X_L^2}}$



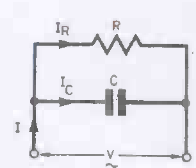
$\tan\phi = \dfrac{R}{X_L}$;

$\cos\phi = \text{power factor} = \dfrac{|Z|}{R}$

where $\phi$ is the phase angle of lag.

## R AND C IN PARALLEL

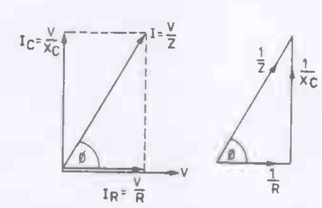
$I_R = \dfrac{V}{R}$ is in phase with V



$I_c = \dfrac{V}{X_c}$ leads V by 90° ($\pi/2$ radian)

$I = \sqrt{I_R^2 + I_c^2}$

$\dfrac{1}{|Z|} = \sqrt{\dfrac{1}{R^2} + \dfrac{1}{X_c^2}}$



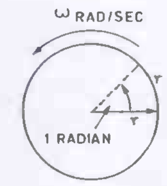
$\tan\phi = \dfrac{R}{X_c}$

$\cos\phi = \text{power factor} = \dfrac{|Z|}{R}$

where $\phi$ is the phase angle of lead.

## RADIAN MEASURES

The radian is defined as the angle subtended at the centre of a circle by an arc on the circumference equal in length to the radius of the circle. Since the circumference is $2\pi$ times the radius, there are $2\pi$ radians in a complete circle.
Hence $2\pi$ radians = 360°
or 1 radian = $360/2\pi = 57{\cdot}3°$.



The angular velocity of a rotating arm (or phasor) is expressed in rad/sec ($\omega$), hence

$\omega = 2\pi \times$ number of revolutions per second

$= 2\pi f$ rad/sec, where f is the frequency.

$90° = \dfrac{\pi}{2}$ rad, $180° = \pi$ rad, $270° = \dfrac{3\pi}{2}$ rad, $360° = 2\pi$ rad.

## TRIGONOMETRY

Pythagoras: Angle BCA is right-angled.
$(AB)^2 = (AC)^2 + (BC)^2$

Basic Identities:

$\sin\theta = \dfrac{\text{opposite}}{\text{hypotenuse}} = \dfrac{BC}{AB}$

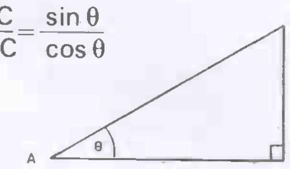
$\cos\theta = \dfrac{\text{adjacent}}{\text{hypotenuse}} = \dfrac{AC}{AB}$

$\tan\theta = \dfrac{\text{opposite}}{\text{adjacent}} = \dfrac{BC}{AC} = \dfrac{\sin\theta}{\cos\theta}$

$\sin^2\theta + \cos^2\theta = 1$

$1 + \tan^2\theta = \sec^2\theta$

$1 + \cot^2\theta = \text{cosec}^2\theta$



## LOGARITHMIC FORMS

$\log(AB) = \log A + \log B$

$\log\left[\dfrac{A}{B}\right] = \log A - \log B$

$\log A^n = n \log A$

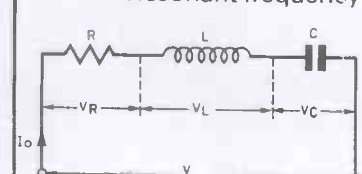
$\log_{10}A = \log_e A \times \log_{10}e = 0{\cdot}4343 \log_e A$

$\log_a b = \dfrac{1}{\log_b a}$

## SERIES RESONANCE

At resonance $X_L = X_c$ or $2\pi fL = \dfrac{1}{2\pi fC}$

Resonant frequency $f_o = \dfrac{1}{2\pi\sqrt{LC}}$ Hertz { L henries, C farads



$= \dfrac{10^6}{2\pi\sqrt{LC}}$ Hertz { L $\mu$H, C$\mu$F

At resonance $V_c = V_L$ (in magnitude but antiphase)
$= VQ_o$ where $Q_o$ is the resonant Q-factor

Resonant impedance $Z_o = R$ (purely resistive).
Applied V and resonant current $I_o$ are in phase;

$\phi = 0°$; power factor unity.

Resonant $I_o = \dfrac{V}{R}$ and is a **maximum.**

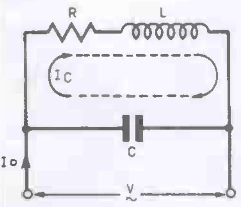
## PARALLEL RESONANCE

Resonant frequency $f_o = \frac{1}{2\pi}\sqrt{\frac{1}{LC} - \frac{R^2}{L^2}}$ Hertz

which, if $L^2 \gg R^2 \simeq \frac{1}{2\pi\sqrt{LC}}$ Hertz

Resonant impedance $Z_o = \frac{L}{CR}\,\Omega$ and is resistive.

Applied V and resonant current $I_o$ are in phase; $\phi = 0^o$; power factor unity




Resonant current

$I_o = \frac{VCR}{L}\,\Omega$ and is a **minimum.**

Circulating current

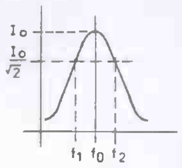
$I_c = I_o Q_o$ where $Q_o$ is the resonant Q-factor.

## SELECTIVITY

At resonance, voltage magnification or Q-factor

$Q = Q_o = \frac{\text{reactance of one kind}}{\text{total circuit resistance}}$

$= \frac{2\pi fL}{R} = \frac{1}{2\pi fCR} = \frac{1}{R}\sqrt{\frac{L}{C}}$




$f_1$ and $f_2$ are the half-power points (3dB down)

Bandwidth $= f_2 - f_1$

$Q_o = \frac{f_o}{f_2 - f_1}$

## THE TRANSFORMER

(a) Turns Ratio:
Voltage turns ratio $N = \frac{N_2}{N_1}$ and $V_2 = N \times V_1$

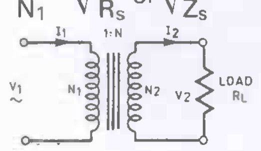
Neglecting losses $= \frac{V_2}{V_1} = \frac{N_2}{N_1} = \frac{I_1}{I_2}$

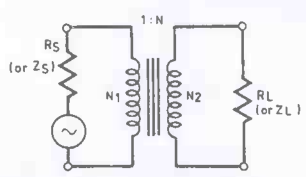
Secondary load current $I_2 = \frac{V_2}{R_L}$

Turns ratio = voltage ratio = $\frac{1}{\text{current ratio}}$

(b) Impedance Matching:
For maximum power transfer from source to load

$N = \frac{N_2}{N_1} = \sqrt{\frac{R_L}{R_s}}$ or $\sqrt{\frac{Z_L}{Z_s}}$



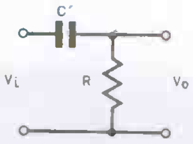




(c) Impedance Transformation
Input impedance seen at primary terminals

$Z_i = \left[\frac{N_1}{N_2}\right]^2 \cdot Z_s = \left[\frac{1}{N^2}\right] \cdot Z_s$

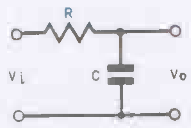
The transformer changes the modulus (the "size") of $Z_s$ but not the phase angle.

## PHASE ADVANCE NETWORK




$V_o$ leads $V_i$ by $\theta = \arctan \frac{1}{2\pi fCR}$

## PHASE RETARD NETWORK

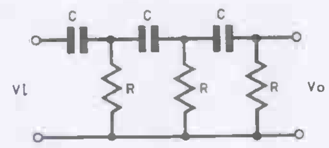



$V_o$ lags $V_i$ by $\theta = \arctan 2\pi fCR$

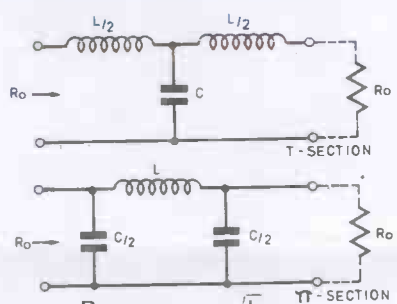
## 180° PHASE SHIFT NETWORK

$V_o$ lags $V_i$ by 180° ($\pi$ rad) at frequency

$f = \frac{1}{2\pi\sqrt{6}CR} = \frac{1}{15{\cdot}4CR}$ Hz




## LOW PASS FILTER




$L = \frac{R_o}{\pi f_c}$ $\quad R_o = \sqrt{\frac{L}{C}}$ ohms

$C = \frac{1}{\pi f_c R_o}$ $\quad f_c = \frac{1}{\pi\sqrt{LC}}$ Hz

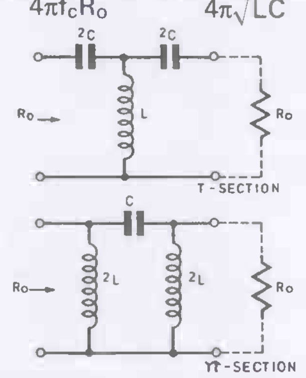
where $f_c$ = cut-off frequency,

$R_o$ = characteristic or design impedance.

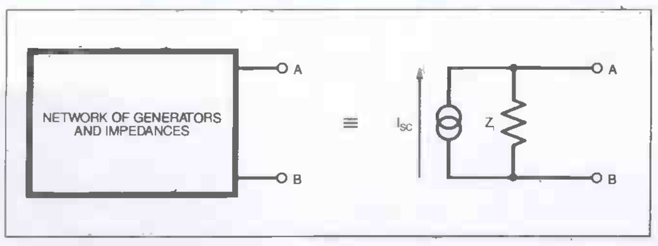
## HIGH PASS FILTER

$L = \frac{R_o}{4\pi f_c}$ $\quad R_o = \sqrt{\frac{L}{C}}$ ohms

$C = \frac{1}{4\pi f_c R_o}$ $\quad f_c = \frac{1}{4\pi\sqrt{LC}}$ Hz

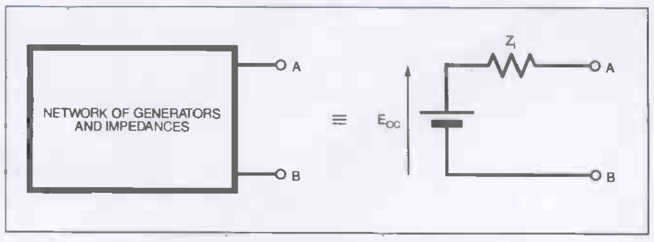



## NORTON'S THEOREM




Any two-terminal network of generators and impedances may be replaced by a single constant-current generator $I_{sc}$ in parallel with a single impedance $Z_i$ where $I_{sc}$ is the current that would flow in a short-circuit connected across the terminals A and B and $Z_i$ is the impedance seen at the terminals with all independent sources suppressed.

## THÈVENIN'S THEOREM




Any two-terminal network of generators and impedances may be replaced by a single voltage generator $E_{oc}$ in series with a single impedance $Z_i$ where $E_{oc}$ is the voltage measured between the terminals A and B with no load connected and $Z_i$ is the impedance seen at the terminals when all independent voltage sources have been suppressed or replaced by their internal impedances.

## T AND π SECTIONS

Characteristic impedance $Z_{oT}$

$= \sqrt{Z_1{}^2 + 2Z_1Z_2} = \sqrt{Z_{oc}Z_{sc}}$

For attenuation $N = V_o/V_i$

$Z_1 = Z_{oT}\left[\frac{N-1}{N+1}\right]$ ; $Z_2 = Z_{oT}\left[\frac{2N}{N^2-1}\right]$

Characteristic impedance $Z_{o\pi}$

$= \frac{Z_1 Z_2}{Z_{oT}}$

For attenuation $N = V_o/V_i$

$Z_2 = Z_{o\pi}\left[\frac{N+1}{N-1}\right]$ ; $Z_1 = Z_{o\pi}\left[\frac{N^2-1}{2N}\right]$

Where $Z_{oc}$ is the open circuit impedance and $Z_{sc}$ = short circuit impedance