

EVERYDAY

FEBRUARY 1996

PRACTICAL

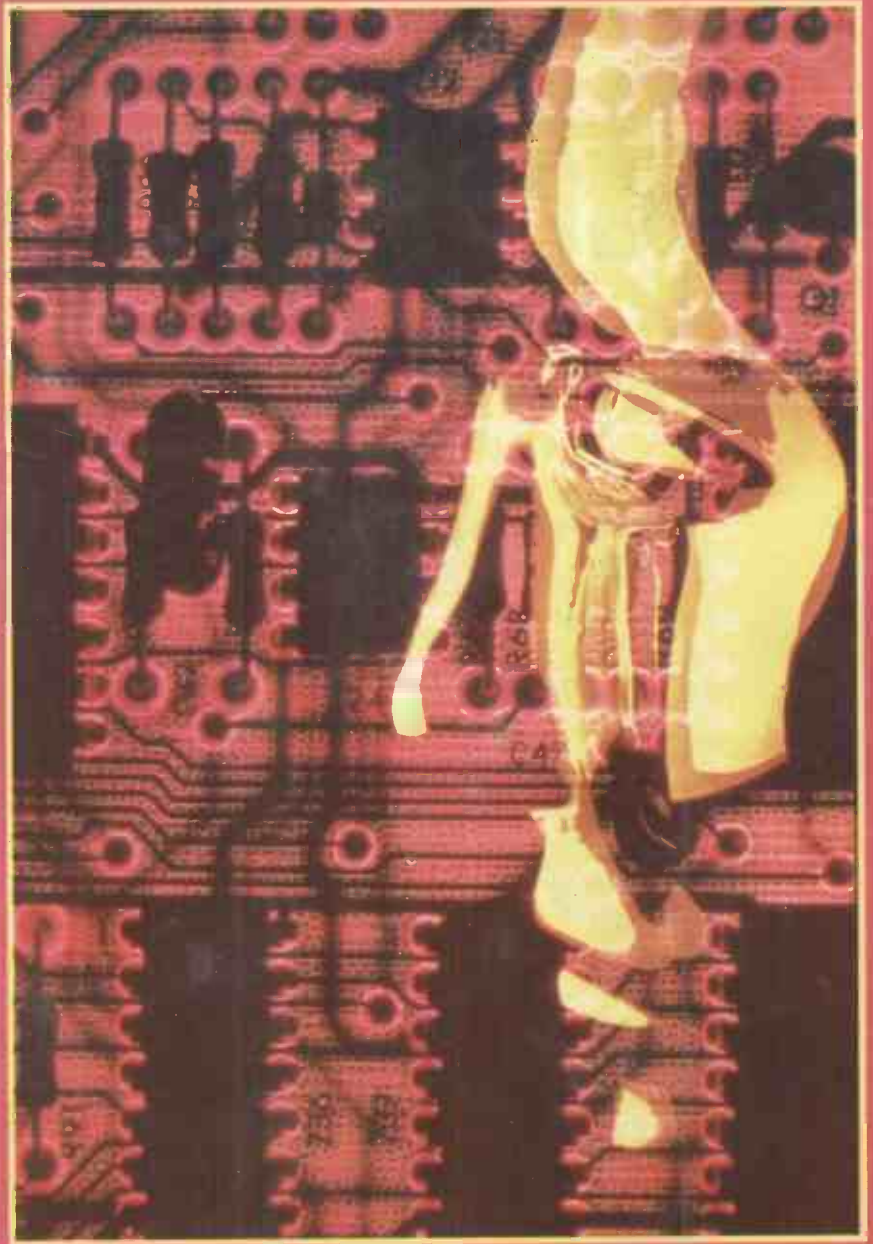
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PROGRAMMER**
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ON A BUDGET**
A practical approach

**THE No. 1 INDEPENDENT
MAGAZINE FOR
ELECTRONICS TECHNOLOGY
& COMPUTER PROJECTS**



SURVEILLANCE TELESCOPE Superb Russian zoom telescope adjustable from 15x to 60x complete with metal tripod (impossible to use without this on the higher settings) 66mm lens, leather carrying case £149 ref BAR69

RADIATION DETECTOR SYSTEM Designed to be wall mounted and connected into a PC, ideal for remote monitoring, whole building coverage etc. Complete with detector, cable and software. £19.95 ref BAR75.

WIRELESS VIDEO BUG KIT Transmits video and audio signals from a miniature CCTV camera (included) to any standard television! All the components including a PP3 battery will fit into a cigarette packet with the lens requiring a hole about 3mm diameter. Supplied with telescopic aerial but a piece of wire about 4' long will still give a range of up to 100 metres. A single PP3 will probably give less than 1 hours use. £99 REF EP79. (Probably not licensable!)

CCTV CAMERA MODULES 46X70X29mm, 30 grams, 12v 100mA. Auto electronic shutter, 3.6mm F2 lens, CCIR, 512x492 pixels, video output is 1v p-p (75 ohm). Works directly into a scart or video input on a tv or video. IR sensitive. £79.95 ref EF137.

IR LAMP KIT Suitable for the above camera enables the camera to be used in total darkness! £5.99 ref EF138.

TANDATA TD1400 VIEWDATA Complete system comprising modem, infra red remote keyboard, psu, UHF and RGB output, phone lead, RS232 output, composite output. £9.95 ref BAR33.

MAGNETIC CARD READERS (Swipes) £9.95 Cased with flyleads, designed to read standard credit cards! they have 3 wires coming out of the head so they may write as well? complete with control electronics PCB. Just £9.95 ref BAR31

PANORAMIC CAMERA OFFER Takes double width photographs using standard 35mm film. Use in horizontal or vertical mode. Complete with strap £7.99 ref BAR1

COIN OPERATED TIMER KIT Complete with coin slot mechanism, adjustable time delay, relay output, put a coin slot on anything you like! TV's, videos, fridges, drinks cupboards, HiFi, takes 50p's and £1 coins. DC operated, price just £7.99 ref BAR27.

ZENITH 900 X MAGNIFICATION MICROSCOPE Zoom, metal construction, built in light, shrimp farm, group viewing screen, lots of accessories. £29 ref ANAYLT.

LUBITEL 166U Twin lens Russian 2 1/4" sq reflex camera supplied with two free rolls of colour film, flip up magnifier, 3 element f4.5 lens. £19.99 ref BAR36.

AA NICAD PACK Pack of 4 tagged AA nicads £2.99 ref BAR34

PLASMA SCREENS 222x310mm, no data hence £4.99 ref BAR67

NIGHTSIGHTS Model TZS4 with infra red illuminator, views up to 75 metres in full darkness in infrared mode, 150mm range, 45mm lens, 13 degree angle of view, focussing range 1.5m to infinity. 2 AA batteries required. 950g weight. £210 ref BAR61. 1 years warranty

FILIN-1 150mm range, 15 degree angle of view, focussing 10m-infinity, £179 ref BAR62. A separate infra red light is available at £30 ref BAR63.

WHITENIGHTSIGHTS Excellent professional night sight, small, hand held with camouflaged carrying case £325. 1 years warranty.

MEGA AIR MOVERS 375 cubic feet per min, 240v 200 watt, 2,800 rpm, reversible, 7"x7" UK made, new, Aluminium, current list price about £180 ours? £29.95 ref BAR35.

LIQUID CRYSTAL DISPLAYS Bargain prices, 16 character 2 line, 65x14mm £1.99 ref SM1612A

16 character 2 line, 99x24mm £2.99 ref SM1623A

20 character 2 line, 83x19mm £3.99 ref SM2020A

16 character 4 line, 62x25mm £5.99 ref SMC1640A

TAL-110MM NEWTONIAN REFLECTOR TELESCOPE Russian. Superb astronomical 'scope, everything you need for some serious star gazing up to 169x magnification. Send or fax for further details £249 ref TAL-1

GOT AN EXPENSIVE BIKE? You need one of our bottle alarms, they look like a standard water bottle, but open the top, insert a key to activate a motion sensor alarm built inside. Fits all standard bottle carriers, supplied with two keys. SALE PRICE £7.99 REF SA32.

GOT AN EXPENSIVE ANYTHING? You need one of our cased vibration alarms, keyswitch operated, fully cased just fit it to anything from videos to caravans, provides a years protection from 1 PP3 battery, UK made. SALE PRICE £4.99 REF SA33.

DAMAGED ANSWER PHONES These are probably beyond repair so just £4.99 each. BT response 200 machines. REF SA30.

COMMODORE GAMES CONSOLES Just a few of these left to clear at £5 ref SA31. Condition unknown.

COMPUTER DISC CLEAROUT We are left with a lot of software packs that need clearing so we are selling at disc value only! 50 discs for £4, that's just 8p each! (our choice of discs) £4 ref EP66

IBM PS2 MODEL 160Z CASE AND POWER SUPPLY Complete with fan etc and 200 watt power supply. £9.95 ref EP67

DELL PC POWER SUPPLIES 145 watt, +5, -5, +12, -12, 150x150x85mm complete with switch, flyleads and IEC socket. SALE PRICE £9.99 ref EP55

1.44 DISC DRIVES Standard PC 3.5" drives but returns so they will need attention SALE PRICE £4.99 ref EP68

1.2 DISC DRIVES Standard 5.25" drives but returns so they will need attention SALE PRICE £4.99 ref EP69

PP3 NICAD S Unused but some storage marks. £4.99 ref EP52

DELL PC POWER SUPPLIES (Customer returns) Standard PC psu's complete with fly leads, case and fan, pack of two psus SALE PRICE £5 FOR TWO! ref EP61

GA S HOBBS AND OVENS Brand new gas appliances, perfect for small flats etc. Basic 3 burner hob SALE PRICE £24.99 ref EP72. Basic small built in oven SALE PRICE £79 ref EP73

BITS AND BOBS We have a quantity of cased modems, multiplexers etc different specs but ideal strippers. £4 each ref EP63

RED EYE SECURITY PROTECTOR 1,000 watt outdoor PIR switch SALE PRICE £9.99 ref EP57

ENERGY BANK KIT 100 6"x6" 6v 100mA panels, 100 diodes, connection details etc. £69.95 ref EF12.

PASTEL ACCOUNTS SOFTWARE, does everything for all sizes of businesses, includes wordprocessor, report writer, windowing, networkable up to 10 stations, multiple cash books etc. 200 page comprehensive manual. 90 days free technical support (0345-326003 try before you buy) Current retail price is £129, SALE PRICE £9.95 ref SA12. SAVE £120!!!

WOLVERHAMPTON BRANCH NOW OPEN AT WORCESTER ST W'HAMPTON TEL 01902 22039

MINI MICRO FANS 12V 1.5" sq SALE PRICE £2. Ref SA13.

REUSEABLE HEAT PACKS Ideal for fishermen, outdoor enthusiasts elderly or infirm, warming food, drinks etc, defrosting pipes etc. reusable up to 10 times, lasts for up to 8 hours per go, 2,000wh energy, gets up to 90 degC. SALE PRICE £9.95 REF SA29

12V 2AMP LAPTOP psu's 110x55x40mm (includes standard IEC socket) and 2m lead with plug. 100-240V IP. £8.99 REF SA15.

PC CONTROLLED 4 CHANNEL TIMER Control (on/off times etc) up to 4 items (8A 240v each) with this kit. Complete with Software, relays, PCB etc. £25.99 Ref 95/26

COMPLETE PC 300 WATT UPS SYSTEM Top of the range UPS system providing protection for your computer system and valuable software against mains power fluctuations and cuts. New and boxed, UK made Provides up to 5 mins running time! In the event of complete power failure to allow you to run your system down correctly. SALE PRICE just £89.00.

SOLAR PATH LIGHTS Low energy walklights powered by the sun! built in PIR so they work when you walk past. Includes solar panel & rechargeable bat. SALE PRICE £19.95 REF EP62

BIG BROTHER PSU Cased PSU, 6v 2A output. 2m o/p lead, 1.5m input lead, UK made, 220v. SALE PRICE £4.99 REF EP7



Check out our
WEB SITE

<http://www.pavilion.co.uk/bull-electrical>

RACAL MODEM BONANZA! 1 Racal MPS1223 1200/75 modem, telephone lead, mains lead, manual and comms software, the cheapest way into the net! all this for just £13 ref DEC13.

4.6mw LASER POINTER. BRAND NEW MODEL NOW IN STOCK! supplied in fully built form (looks like a nice pen) complete with handy pocket clip (which also acts as the on/off switch.) About 60 metres range! Runs on 2 AAA batteries. Produces thin red beam ideal for levels, gun sights, experiments etc. just £39.95 ref DEC49 TRADE PRICE £28 MIN 10 PIECES

BULL TENS UNIT Fully built and tested TENS (Transcutaneous Electrical Nerve Stimulation) unit, complete with electrodes and full instructions. TENS is used for the relief of pain etc in up to 70% of sufferers. Drug free pain relief, safe and easy to use, can be used in conjunction with analgesics etc. £49 Ref TEN/1

COMPUTER RS232 TERMINALS. (LIBERTY) Excellent quality modem units, (like wyse 50, s) 2xRS232, 20 function keys, 50 thro to 38,400 baud, menu driven port, screen, cursor, and keyboard setup menus (18 menus) £29 REF NOV4.

RUSSIAN MONOCULARS Amazing 20 times magnification, coated lenses, carrying case and shoulder strap. £29.95 REF BAR73

PC PAL VGA to TV CONVERTER Converts a colour TV into a basic VGA screen. Complete with built in psu, lead and s/ware. Ideal for laptops or a cheap upgrade. Supplied in kit form for home assembly. SALE PRICE £25 REF SA34

EMERGENCY LIGHTING UNIT Complete unit with 2 double bulb floodlights, built in charger and auto switch. Fully cased. 6v 8Ah lead acid req'd. (secondhand) £4 ref MAG4P11.

SWINGFIRE GUIDED MISSILE WIRE 4,200 metre reel of ultra thin 4 core insulated cable, 28lbs breaking strain, less than 1mm thick! Ideal alarms, intercoms, dolls house's etc. £13.99 ref EP51

ELECTRIC CAR WINDOW DE-ICERS Complete with cable, plug etc SALE PRICE JUST £4.99 REF SA28

ASTEC SWITCHED MODE PSUBM41012 Gives +5 @ 3.75A, +12 @ 1.5A, -12 @ 4A. 230/110, cased, BM41012. £5.99 ref AUG6P3.

AUTO SUNCHARGER 155x300mm solar panel with diode and 3 metre lead fitted with a cigar plug. 12v 2watt. £9.99 REF SA25.

TOP QUALITY CENTRIFUGAL MAINS MOTORS SALE PRICE £2 FOR JUST £2.60 REF SA38

ECLATRON FLASH TUBE As used in police car flashing lights, etc, full spec supplied, 60-100 flashes a min. £8.99 REF SA15.

24v AC 96WATT Cased power supply. New. £9.99 REF SA40

MILITARY SPEC GEIGER COUNTERS Unused an straight from Her Majesty's forces. SALE PRICE £44 REF SA16

MICRODRIVE STRIPPERS Small cased tape drives ideal for stripping, lots of useful goodies including a smart case, and lots of components. SALE PRICE JUST £4.99 FOR FIVE REF SA26

SOLAR POWER LAB SPECIAL You get TWO 6"x6" 6v 130mA solar cells, 4 LED's, wire, buzzer, switch plus 1 relay or motor. Superb value kit SALE PRICE JUST £4.99 REF SA27

RGB/CGA/EGA/TTL COLOUR MONITORS 12" in good condition. Back adorned metal case. SALE PRICE £49 REF SA16

PLUG IN ACORNSU 19v AC 14w, £2.99 REF MAG3P10

POWER SUPPLY fully cased with mains and o/p leads 17v DC 900mA output. Bargain price £5.99 ref MAG6P9

ACORN ARCHMEDES PSU +5v @ 4.4A. on/off sw uncased, *SOME OF OUR PRODUCTS MAY BE UNLICENSABLE IN THE UK

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selectable mains input, 145x100x45mm £3.99 REF MAG7P2

13.8V 1.9A PSU cased with leads. Just £9.99 REF MAG10P3

200 WATT INVERTER Converts 10-15v DC into either 110v or 240v AC. Fully cased 115x36x156mm, complete with heavy duty power lead, cigar plug, AC outlet socket. Auto overload shutdown, auto short circuit shut down, auto input over voltage shutdown, auto input under voltage shut down (with audible alarm), auto temp control, unit shuts down if overheated and sounds audible alarm. Fused reversed polarity protected, output frequency within 2%, voltage within 10%. A well built unit at an kept price. Just £64.99 ref AUG65.

UNIVERSAL SPEED CONTROLLER KIT Designed by us for the C6 motor but ok for any 12v motor up to 30A. Complete with PCB etc. A heat sink may be required. £17.00 REF: MAG17

COMPUTER COMMUNICATIONS PACK Kit contains 100m of 6 core cable, 100 cable clips, 2 line drivers with RS232 interfaces and all connectors etc. Ideal low cost method of communicating between PCs over a long distance. Complete kit £8.99.

VIEWDATA SYSTEMS made by Phillips. complete with internal 1200/75 modem, keyboard, psu etc. RGB and composite outputs, menu driven, autodialler etc. SALE PRICE £12.99 REF SA18

AIR RIFLES. 22As used by the Chinese army for training purposes, so there is a lot about! £39.95 Ref EF78. 500 pellets £1.60 ref EF80.

PLUG IN POWER SUPPLY SALE FROM £1.60 Plugs in to 13A socket with output lead. Three types available. 9vdc 150mA £1.50 ref SA19, 9vdc 200mA £2.00 ref SA20, 6.5vdc 500mA £2 ref SA21.

VIDEO SENDER UNIT. Transmits both audio and video signals from either a video camera, videorecorder, TV or Computer etc to any standard TV set in a 100' range! (tune TV to a spare channel) 12V DC op. Price is £15 REF: MAG15 12v psu is £5 extra REF: MAG5P2

***FM CORDLESS MICROPHONE** Small hand held unit with a 500' range! 2 transmit power levels. Reqs PP3 9v battery. Tuneable to any FM receiver. Price is £15 REF: MAG15P1

***MINIATURE RADIO TRANSCENERS** A pair of walkie talkies with a range up to 2km in open country. Units measure 22x52x155mm. Including cases and earpieces. 2xPP3 req'd. £30.00 pr. REF: MAG30

***FM TRANSMITTER KIT** housed in a standard working 13A adapter! the bug runs directly off the mains so lasts forever why pay £700? or price is £15 REF: EF62 (kit) Transmits to any FM radio.

***FM BUG BUILT AND TESTED** superior design to kit. Supplied to detective agencies. 9v battery req'd. £14 REF: MAG14

TALKING COINBOX STRIPPER COMPLETE WITH COIN SLOT MECHANISMS originally made to retail at £79 each, these units are designed to convert an ordinary phone into a payphone. The units have the locks missing and sometimes broken hinges. However they can be adapted for their original use or used for something else?? SALE PRICE JUST £2.50 REF SA23

GAT AIR PISTOL PACK Complete with pistol, darts and pellets £12.95 REF EF82B extra pellets (500) £4.50 ref EF80.

6"x12" AMORPHOUS SOLAR PANEL 12v 155x310mm 130mA. SALE PRICE £4.99 REF SA24.

FIBRE OPTIC CABLE BUMPER PACK 10 metres for £4.99 ref MAG5P13 ideal for experimenters! 30m for £12.99 ref MAG13P1

MIXED GOODIES BOX OF MIXED COMPONENTS WEIGHING 2 KILOS YOURS FOR JUST £5.99

4X28 TELESCOPIC SIGHTS Suitable for all air rifles, ground lenses, good light gathering properties. £19.95 ref R/7.

RATTLE BACKS Interesting things these, small piece of solid perspex like material that if you try to spin it on the desk it only spins one way! in fact if you spin it the 'wrong' way it stops of its own accord and goes back the other way! £1.99 ref GI/J01.

GYROSCOPES Remember these? well we have found a company that still manufactures these popular scientific toys, perfect gift or for educational use etc. £6 ref EP70

HYPOTHERMIA SPACE BLANKET 215x150cm aluminised foil blanket, reflects more than 90% of body heat. Also suitable for the construction of two way mirrors! £3.99 each ref OL/L041.

LENSTATIC RANGER COMPASS Oil filled capsule, strong metal case, large luminous points. Sight line with magnifying viewer. 50mm dia, 86gm. £10.99 ref O/K604.

RECHARGE ORDINARY BATTERIES UP TO 10 TIMES! With the Battery Wizard! Uses the latest pulse wave charge system to charge all popular brands of ordinary batteries AAA, AA, C, D, four at a time! Led system shows when batteries are charged, automatically rejects unsuitable cells, complete with mains adaptor. BS approved. Price is £21.95 ref EP31.

TALKING WATCH Yes, it actually tells you the time at the press of a button. Also features a voice alarm that wakes you up and tells you what the time is! Lithium cell included. £7.99 ref EP26.

PHOTOGRAPHIC RADAR TRAPS CAN COST YOU YOUR LICENCE! The new multiband 2000 radar detector can prevent even the most responsible of drivers from losing their licence! Adjustable audible alarm with 8 flashing leds gives instant warning of radar zones. Detects X, K, and Ka bands, 3 mile range, 'over the hill' 'around bends' and 'rear trap' facilities. micro size just 4.25"x2.5"x.75". Can pay for itself in just one day! £79.95 ref EP3.

SANYO NICAD PACKS 120mmx14mm 4, 8v 270 mA suitable for cordless phones etc. Pack of 2 just £5 ref EP78.

3" DISCS As used on older Amstrad machines, Spectrum plus 3's etc £3 each ref BAR400.

STEREO MICROSCOPES BACK IN STOCK Russian, 200x complete with lenses, lights, filters etc very comprehensive microscope that would normally be around the £700 mark, our price is just £299 (full money back guarantee) full details in catalogue. Ref 95/300.

SOLAR POWERED CAR VENTILATOR Simply fits along the top of the glass in a side window and provides a constant supply of fresh air in hot sunny conditions! keeps your car cool in summer. £19.95 ref s/vent.

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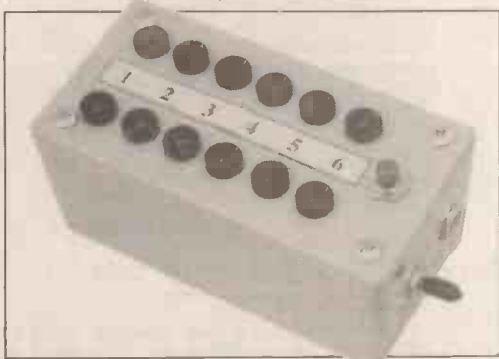
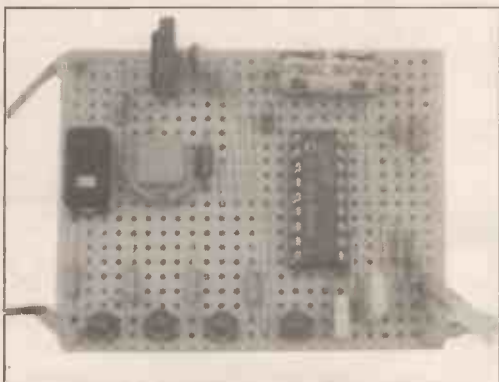
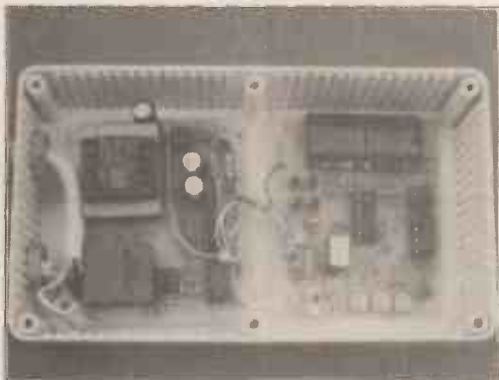
- SIMPLE PIC16C84 PROGRAMMER** by Derren Crome **102**
Use your PC to program the EEPROM version of the PIC microcontroller family
- MAINS SIGNALLING UNIT - 2** by Andy Flind **111**
Two add-on units to use with last month's controller: a transformerless 12V Capacitive PSU, and a Two-Tone Alarm
- PIC-ELECTRIC METER** by John Becker **122**
Know how much each electrical appliance is adding to your bill
- VARI-SPEED DICE** by Max Horsey **136**
There's no cheating fate when the chips are down! A *Teach-In '96* project
- ANALOGUE FREQUENCY METER** by Andy Flind **152**
Good test gear doesn't always need to be digital, there are ample uses for simple analogue units

Series

- TEACH-IN '96 - A Guide to Modular Circuit Design - 4** **128**
by Max Horsey
Showing how simple modules can be used as the building blocks for larger designs. Astables and a decade counter/chaser, plus l.e.d. series resistance
- INTERFACE** by Robert Penfold **140**
More about computer-controlling model railways - automatic signal response
- CIRCUIT SURGERY** by Alan Winstanley **144**
Auto battery back-up, cycle l.e.d. flashers; Ni-Cads - yet more!
- TECHNIQUES - ACTUALLY DOING IT** by Robert Penfold **149**
Obtaining components; semiconductor numbering; transistor pinouts; logical type numbers and reliability
- AMATEUR RADIO** by Tony Smith G4FAI **164**
Morse - no change!; RSGB annual report; schools links strengthened; crash course for teachers; satellite launch arranged

Features

- EDITORIAL** **101**
- FOX REPORT** by Barry Fox **108**
The Theremin revival, and some interesting bits about its history
- MAKING YOUR OWN P.C.B.s** by Andy Flind **114**
It's easy to do with a minimal amount of equipment and outlay!
- INNOVATIONS** **118**
Everyday news from the world of electronics
- NEW TECHNOLOGY UPDATE** by Ian Poole **120**
Bipolar transistors can have current advantages over f.e.t.s. and a new system fabricates r.f. coils into cell phone chips
- SHOPTALK** with David Barrington **121**
Component buying for EPE projects
- OHM SWEET OHM** by Max Fidling **133**
Despite technology, when it comes to chocky bics, it can still be bonhomie and bonmoggy in the Fidling winter-wonder workshop
- ELECTRONICS VIDEOS** **134**
Our range of educational videos
- BACK ISSUES** Did you miss these? **142**
- DIRECT BOOK SERVICE** **159**
A wide range of technical books available by mail order
- PRINTED CIRCUIT BOARD SERVICE** **162**
PCBs for EPE projects
- ADVERTISERS INDEX** **168**



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Our March '96 Issue will be published on Friday, 2nd February 1996. See page 91 for details.

Everyday Practical Electronics, February 1996

Readers Services • Editorial and Advertisement Departments 101

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Order as HIGRADE 286 **ONLY £149.00** (E)
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Optional Fitted extras: VGA graphics card	£29.00
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FLOPPY DISK DRIVES 3 1/2" - 8"

5 1/4" from £22.95 - 3 1/2" from £24.95

Massive purchases of standard 5 1/4" and 3 1/2" drives enables us to present prime product at industry beating low prices! All units (unless stated) are BRAND NEW or removed from often brand new equipment and are fully tested, aligned and shipped to you with a 90 day guarantee and operate from standard voltages and are of standard size. All are IBM-PC compatible (if 3 1/2" supported on your PC).

3 1/2" Panasonic JU363/4 720K or equivalent	£24.95 (B)
3 1/2" Mitsubishi MF355C-L 1.4 Meg. Laptops only *	£36.95 (B)
3 1/2" Mitsubishi MF355C-D 1.4 Meg. Non laptop	£29.95 (B)
5 1/4" Teac FD-55GFR 1.2 Meg	£29.95 (B)
5 1/4" BRAND NEW Mitsubishi MF501B 360K	£22.95 (B)

* Data cable included in price.	£195.00 (E)
Shugart 800/801 8" SS refurbished & tested	£250.00 (E)
Shugart 851 8" double sided refurbished & tested	£275.00 (E)
Mitsubishi M2894-63 8" double sided NEW	£285.00 (E)
Mitsubishi M2896-63-02U 8" DS slimline NEW	£285.00 (E)

Dual 8" drives with 2 mbyte capacity housed in a smart case with built in power supply. Ideal as exterior drives! £499.00 (F)

HARD DISK DRIVES

End of line purchase scoop! Brand new NEC D2246 8" 85 Mbyte of hard disk storage! Full Industry standard SMD interface. Ultra hi speed data transfer and access time, replaces Fujitsu equivalent model. complete with manual. Only £299.00 (E)

3 1/2" FUJII FK-309-26 20mb MF1M I/F RFE	£59.95 (C)
3 1/2" CONNER CP3024 20 mb IDE I/F (or equiv.) RFE	£69.95 (C)
3 1/2" CONNER CP3044 40mb IDE I/F (or equiv.) RFE	£89.00 (C)
3 1/2" RODIME RO3057S 45mb SCSI I/F (Mac & Acorn)	£99.00 (C)
5 1/4" MINISCRIBE 3425 20mb MF1M I/F (or equiv.) RFE	£49.95 (C)
5 1/4" SEAGATE ST-238R 30 mb RLL I/F Return	£69.95 (C)
5 1/4" CDC 94205-51 40mb HH MF1M I/F RFE tested	£89.95 (C)
8" FUJITSU M2322K 160Mb SMD I/F RFE tested	£195.00 (E)

Hard disc controllers for MF1M, IDE, SCSI, RLL etc. from £16.95

THE AMAZING TELEBOX

Converts your colour monitor into a QUALITY COLOUR TV!!



TV SOUND
& VIDEO
TUNER!

The TELEBOX consists of an attractive fully cased mains powered unit, containing all electronics ready to plug into a host of video monitors made by makers such as MICROVITEC, ATARI, SANYO, SONY, COMMODORE, PHILIPS, TATUNG, AMSTRAD etc. The composite video output will also plug directly into most video recorders, allowing reception of TV channels not normally receivable on most television receivers* (TELEBOX MB). Push button controls on the front panel allow reception of 8 fully tuneable 'off air' UHF colour television channels. TELEBOX MB covers virtually all television frequencies VHF and UHF including the HYPERBAND as used by most cable TV operators. A composite video output is located on the rear panel for direct connection to most makes of monitor or desktop video systems. For complete compatibility - even for monitors without sound - an integral 4 watt audio amplifier and low level Hi Fi audio output are provided as standard.

TELEBOX ST for composite video input type monitors	£34.95
TELEBOX STL as ST but with integral speaker	£37.50
TELEBOX MB Multiband VHF-UHF-Cable- Hyperband Tuner	£69.95

*For overseas PAL versions state 5.5 or 6mhz sound specification.
*For cable / hyperband reception Telebox MB should be connected to cable type service. Shipping code on all Teleboxes is (B)

FANS & BLOWERS

MITSUBISHI MMF-D6D12DL 60 x 25 mm 12v DC	£4.95 10 / £42
MITSUBISHI MMF-09B12DH 92 x 25 mm 12v DC	£5.95 10 / £53
PANCAKE 12-3.5 92 x 18 mm 12V DC	£7.95 10 / £69
EX-EQUIP 120 x 38mm AC fans - tested specify 110 or 240 v	£6.95
EX-EQUIP 80 x 38mm AC fans - tested specify 110 or 240 v	£5.95
VERO rack mount 1U x 19" fan tray specify 110 or 240v	£45.95 (B)
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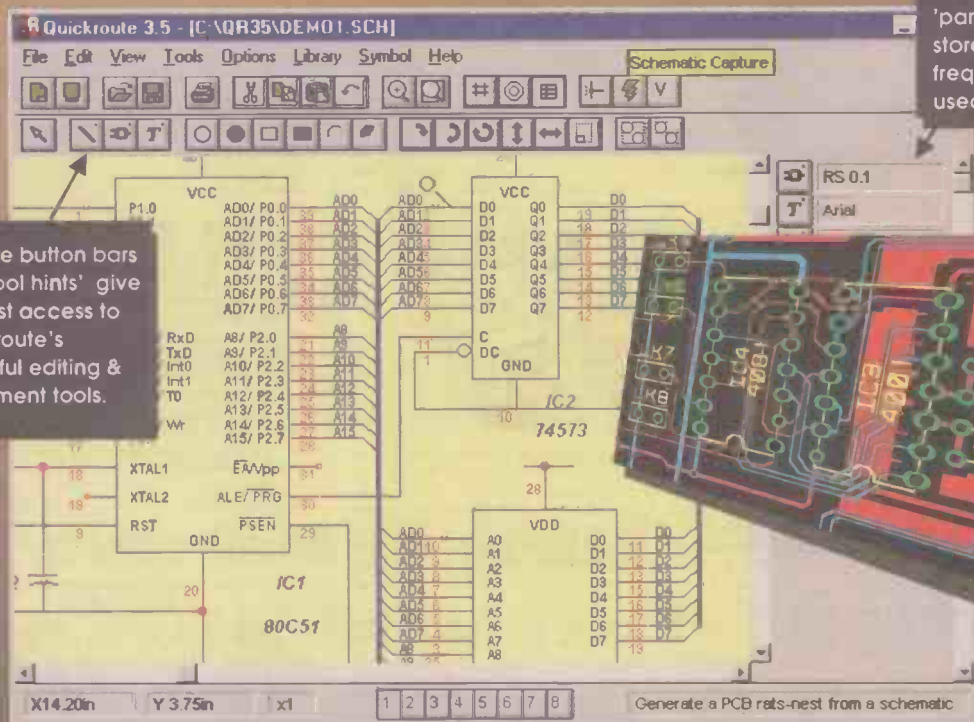
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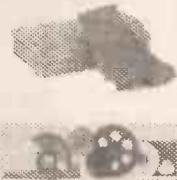
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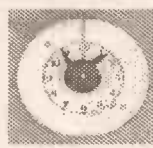
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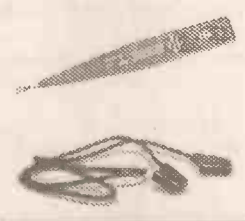
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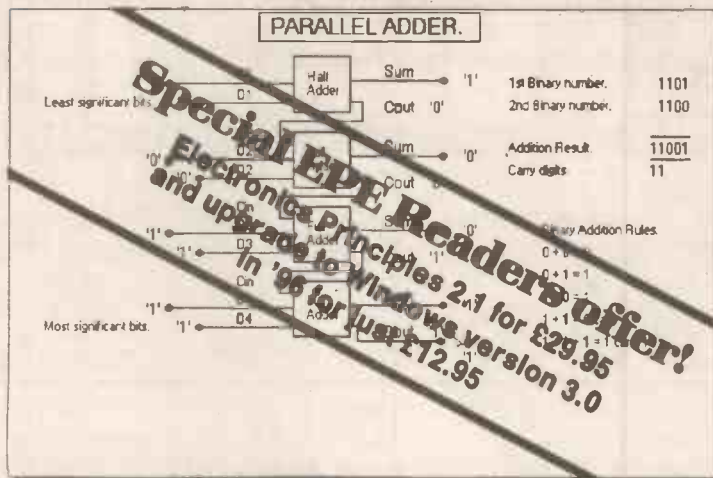
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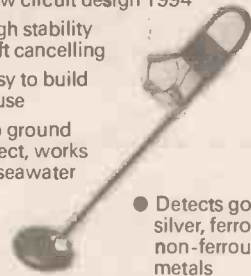
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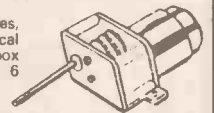
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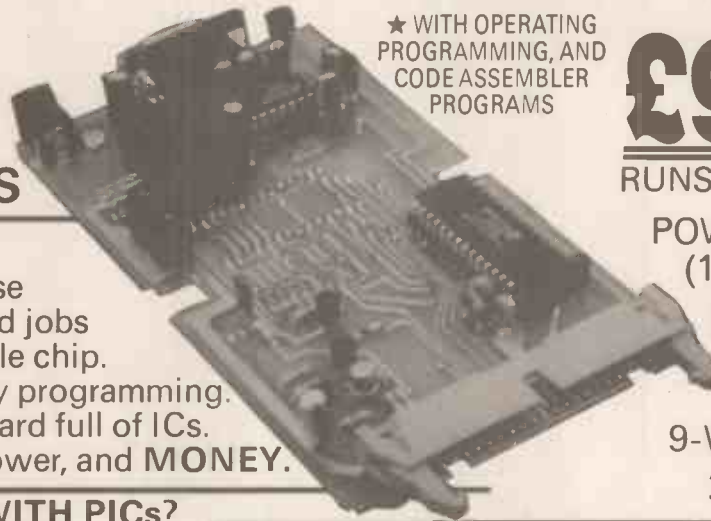
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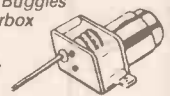
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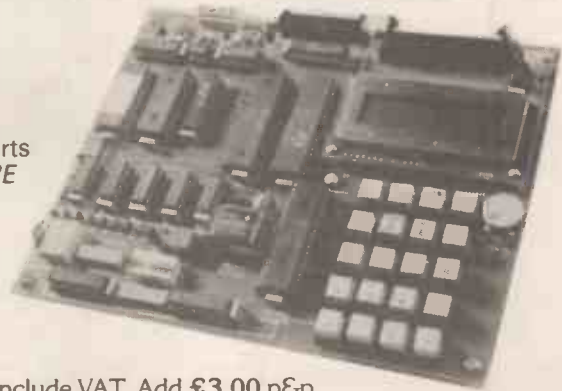
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4006	£0.40	74HC04	£0.21	74LS74	£0.25	74LS74	£0.25
4007	£0.18	74HC08	£0.21	74LS75	£0.19	74LS75	£0.19
4008	£0.31	74HC10	£0.16	74LS76	£0.25	74LS76	£0.25
4009	£0.19	74HC11	£0.20	74LS83	£0.31	74LS83	£0.31
4010	£0.23	74HC14	£0.22	74LS85	£0.35	74LS85	£0.35
4011	£0.21	74HC20	£0.28	74LS86	£0.20	74LS86	£0.20
4012	£0.16	74HC27	£0.16	74LS90	£0.44	74LS90	£0.44
4013	£0.24	74HC30	£0.22	74LS92	£0.35	74LS92	£0.35
4014	£0.30	74HC32	£0.21	74LS95	£0.42	74LS95	£0.42
4015	£0.21	74HC42	£0.25	74LS109	£0.21	74LS109	£0.21
4016	£0.30	74HC73	£0.37	74LS112	£0.24	74LS112	£0.24
4018	£0.27	74HC75	£0.22	74LS113	£0.21	74LS113	£0.21
4019	£0.48	74HC76	£0.20	74LS114	£0.21	74LS114	£0.21
4020	£0.31	74HC85	£0.24	74LS122	£0.31	74LS122	£0.31
4021	£0.31	74HC86	£0.22	74LS123	£0.31	74LS123	£0.31
4022	£0.32	74HC107	£0.40	74LS125	£0.27	74LS125	£0.27
4023	£0.16	74HC123	£0.33	74LS126	£0.25	74LS126	£0.25
4024	£0.32	74HC125	£0.24	74LS132	£0.21	74LS132	£0.21
4025	£0.15	74HC126	£0.46	74LS133	£0.36	74LS133	£0.36
4026	£0.40	74HC132	£0.37	74LS136	£0.16	74LS136	£0.16
4027	£0.36	74HC133	£0.29	74LS138	£0.40	74LS138	£0.40
4028	£0.22	74HC138	£0.25	74LS139	£0.25	74LS139	£0.25
4029	£0.40	74HC139	£0.31	74LS145	£0.56	74LS145	£0.56
4030	£0.17	74HC151	£0.33	74LS147	£1.26	74LS147	£1.26
4031	£0.70	74HC153	£0.27	74LS148	£0.40	74LS148	£0.40
4033	£0.56	74HC154	£0.85	74LS151	£0.25	74LS151	£0.25
4034	£1.24	74HC157	£0.40	74LS153	£0.25	74LS153	£0.25
4035	£0.31	74HC158	£0.25	74LS154	£0.20	74LS154	£0.20
4040	£0.38	74HC160	£0.32	74LS155	£0.25	74LS155	£0.25
4041	£0.31	74HC161	£0.28	74LS156	£0.36	74LS156	£0.36
4042	£0.22	74HC162	£0.45	74LS157	£0.22	74LS157	£0.22
4043	£0.28	74HC163	£0.27	74LS158	£0.21	74LS158	£0.21
4044	£0.35	74HC164	£0.35	74LS160	£0.48	74LS160	£0.48
4046	£0.52	74HC165	£0.35	74LS161	£0.32	74LS161	£0.32
4047	£0.48	74HC173	£0.32	74LS162	£0.44	74LS162	£0.44
4048	£0.28	74HC174	£0.27	74LS163	£0.32	74LS163	£0.32
4049	£0.22	74HC175	£0.27	74LS164	£0.24	74LS164	£0.24
4050	£0.26	74HC192	£0.45	74LS165	£0.48	74LS165	£0.48
4051	£0.43	74HC195	£0.32	74LS170	£0.30	74LS170	£0.30
4052	£0.32	74HC240	£0.37	74LS172	£0.24	74LS172	£0.24
4053	£0.40	74HC241	£0.37	74LS174	£0.24	74LS174	£0.24
4054	£0.56	74HC243	£0.48	74LS175	£0.24	74LS175	£0.24
4055	£0.34	74HC244	£0.42	74LS190	£0.60	74LS190	£0.60
4060	£0.48	74HC245	£0.46	74LS191	£0.24	74LS191	£0.24
4063	£0.29	74HC251	£0.25	74LS192	£0.60	74LS192	£0.60
4066	£0.22	74HC253	£0.25	74LS193	£0.24	74LS193	£0.24
4067	£1.96	74HC257	£0.25	74LS195	£0.24	74LS195	£0.24
4068	£0.16	74HC259	£0.57	74LS196	£0.24	74LS196	£0.24
4069	£0.20	74HC273	£0.35	74LS197	£0.24	74LS197	£0.24
4070	£0.17	74HC299	£0.64	74LS221	£0.40	74LS221	£0.40
4071	£0.17	74HC356	£0.45	74LS240	£0.32	74LS240	£0.32
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4081	£0.23	74HC393	£0.38	74LS251	£0.24	74LS251	£0.24
4082	£0.21	74HC423	£0.37	74LS257	£0.24	74LS257	£0.24
4085	£0.28	74HC553	£0.42	74LS258	£0.48	74LS258	£0.48
4086	£0.26	74HC563	£0.48	74LS266	£0.14	74LS266	£0.14
4089	£0.55	74HC564	£0.48	74LS272	£0.32	74LS272	£0.32
4093	£0.40	74HC574	£0.45	74LS279	£0.25	74LS279	£0.25
4094	£0.31	74HC574	£0.45	74LS365	£0.21	74LS365	£0.21
4095	£0.56	74HC640	£0.73	74LS367	£0.21	74LS367	£0.21
4097	£1.20	74HC688	£0.64	74LS368	£0.21	74LS368	£0.21
4098	£0.48	74HC4002	£0.16	74LS373	£0.33	74LS373	£0.33
4099	£0.38	74HC4017	£0.64	74LS374	£0.34	74LS374	£0.34
4502	£0.38	74HC4020	£0.36	74LS375	£0.34	74LS375	£0.34
4503	£0.40	74HC4040	£0.45	74LS377	£0.32	74LS377	£0.32
4508	£1.40	74HC4049	£0.25	74LS378	£0.62	74LS378	£0.62
4510	£0.36	74HC4050	£0.25	74LS390	£0.25	74LS390	£0.25
4511	£0.56	74HC4060	£0.44	74LS393	£0.24	74LS393	£0.24
4512	£0.32	74HC4075	£0.27	74LS395	£0.26	74LS395	£0.26
4514	£0.77	74HC4078	£0.32	74LS399	£0.62	74LS399	£0.62
4515	£0.99	74HC4511	£0.64	74LS670	£0.69	74LS670	£0.69
4516	£0.31	74HC4514	£0.84	Linear ICs			
4518	£0.44	74HC4538	£0.41	AD524AD	£23.04		
4520	£0.43	74HC4543	£0.90	AD548JN	£1.62		
4521	£0.62	74LS Series		AD590JH	£5.40		
4526	£0.40	74LS00	£0.20	AD592AN	£4.52		
4527	£0.40	74LS01	£0.14	AD595AQ	£14.64		
4528	£0.40	74LS02	£0.29	AD620AN	£9.88		
4529	£0.44	74LS03	£0.29	AD625JN	£16.20		
4532	£0.32	74LS04	£0.17	AD633JN	£8.25		
4534	£2.48	74LS05	£0.14	AD648JN	£2.57		
4536	£1.00	74LS07	£0.32	AD652AQ	£14.88		
4538	£0.37	74LS08	£0.23	AD654JN	£7.25		
4541	£0.33	74LS09	£0.14	AD698AP	£23.28		
4543	£0.46	74LS10	£0.17	AD707JN	£2.36		
4545	£0.34	74LS11	£0.17	AD708JN	£5.69		
4556	£0.40	74LS12	£0.14	AD711JN	£1.51		
4560	£1.18	74LS13	£0.14	AD712JN	£2.38		
4566	£1.96	74LS14	£0.21	AD736JN	£8.75		
4572	£0.25	74LS15	£0.14	AD795JN	£5.94		
4584	£0.24	74LS20	£0.16	AD797AN	£8.69		
4585	£0.47	74LS21	£0.14	AD811JN	£6.73		
4724	£0.70	74LS22	£0.14	AD812AN	£6.32		
40106	£0.37	74LS26	£0.14	AD813AN	£8.81		
40109	£0.58	74LS27	£0.21	AD817AN	£3.85		
40163	£0.46	74LS28	£0.20	AD820AN	£3.24		
40174	£0.34	74LS32	£0.21	AD822AN	£3.20		
40175	£0.36	74LS37	£0.14	AD826AN	£5.33		
40193	£0.60	74LS38	£0.19	AD829JN	£6.41		
		74LS40	£0.14	AD830AN	£6.14		

AD847JN	£6.50	SSM2143P	£3.78	BA158	£0.10	AC126	£0.44	BC337	£0.10	BDX33C	£0.49
AD966KN	£7.73	TBA1205	£0.90	BA159	£0.10	AC127	£0.50	BC337-25	£0.12	BDX34C	£0.50
AD9920AN	£5.06	TBA800	£0.70	BY126	£0.13	AC128	£0.26	BC338-25	£0.10	BDX53C	£0.47
ADM222AA	£3.55	TBA810S	£0.68	BY127	£0.11	AC137	£0.28	BC348-25	£0.14	BDX54C	£0.50
ADM232AA	£3.55	TBA820M	£0.39	BY133	£0.10	AC188	£0.48	BC348B	£0.14	BF180	£0.31
ADM485JN	£2.97	TDA1024	£1.49	OA47	£0.28	AC147	£3.84	BC357	£0.25	BF182	£0.31
ADM690AN	£5.13	TDA1170S	£1.83	OA90	£0.07	ADY19	£1.67	BC393	£0.73	BF185	£0.31
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ADM699AN	£3.58	TDA2030	£1.18	OA202	£0.29	BC107	£0.16	BC461	£0.40	BF195	£0.31
AMP04FP	£10.94	TDA2050V	£3.98	Zeners 2.7 to 33V		BC107B	£0.17	BC463	£0.29	BF244	£0.35
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CA741CE	£0.26	TL061CP	£1.37	1.37V	£0.14	BC108A	£0.14	BC479	£0.32	BF244C	£0.35
CA747CE	£0.39	TL062CP	£1.60	TL062CP	£2.60	BC108C	£0.16	BC490	£0.24	BF259	£0.33
CA3046	£0.37	TL064CN	£0.72	W005 1.5A 50V	£0.19	BC109	£0.17	BC516	£0.22	BF259	£0.33
CA3059	£1.16	TL071CP	£0.48	W02 1.5A 200V	£0.20	BC109C	£0.18	BC517	£0.20	BF327	£0.40
CA3080E	£0.72	TL072CP	£0.50	W04 1.5A 400V	£0.22	BC114	£0.41	BC527	£0.20	BF355	£0.38
CA3130E	£0.98	TL074CN	£0.58	W06 1.5A 600V	£0.22	BC115	£0.41	BC528	£0.20	BF423	£0.13
CA3140E	£0.56	TL081	£0.33	W08 1.5A 800V	£0.27	BC116	£0.41	BC537	£0.20	BF451	£0.39
CA3189E	£1.22	TL082CP	£0.54	W010 1.5A 1kV	£0.24	BC118	£0.41	BC546B	£0.08	BF459	£0.13
CA3240E	£1.12	TL084CN	£0.63	BR32 3A 200V	£0.36	BC132	£0.36	BC546C	£0.08	BF469	£0.36
DC211CF	£1.55	TL494CN	£1.49	BR44 3A 400V	£0.40	BC134	£0.36	BC547B	£0.09	BF469	£0.36
DC221CF	£1.55	TL705ACP	£1.62	BR46 3A 600V	£0.33	BC135	£0.36	BC547C	£0.09	BF469	£0.36
DC411DJ	£3.11	TL706CP	£1.62	BR62 6A 200V	£0.70	BC140	£0.41	BC548C	£0.08	BF469	£0.36
DC412DJ	£4.19	TL7272	£0.88	BR66 6A 800V	£0.59	BC141	£0.27	BC549C	£0.10	BF550	£0.25
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OOPS!

First of all our rather belated Seasons Greetings and Best Wishes for the New Year. Why are we late? Well, when I sat down to write last month's Editorial it was the beginning of November and Christmas seemed an age away. The fact that the Editorial was for the January 1996 issue, when we were still well inside 1995, was also not conducive to getting the seasonal feeling of bonhomie. Sorry – but better late than never!

PROMOTIONS

Whilst our pages are put together a few weeks before publication, articles are planned up to nine months in advance and some promotions even further ahead. In this way we can keep the editorial balance – although occasionally this is upset, as it has been this month, by articles running out much longer than anticipated. We have had to split the *PIC-Electric Meter* article in two because it simply became too long to fit into the available pages and it is too good a project to try to cut back (aren't they all!).

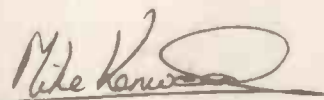
Next month's issue will be promoted in the UK with a set of **Free Stereo Headphones** plus a **Greenweld Catalogue** bagged with your issue – demand will be very high so make sure of your copy by placing an order for it *now*. This promotion has been planned for about three months but the following issue promotion was sorted out over a year ago!

The issue also carries part one of a new **Mind Machine** from Andy Flind and a specially designed test and general purpose amplifier project, both of which can use the free headphones. Even if you don't build a project that will use the headphones we are sure you will find them valuable – they will provide astonishingly good output from your personal stereo, hi-fi, TV, video, etc.

PRO LOGIC

Following the **Free Stereo Headphones** and catalogue with the March issue, the April issue will come bagged with a 64 page booklet fully describing the operation of the **Dolby Pro Logic** surround sound system and giving full constructional details of a **Dolby Pro Logic Decoder** which you can build for under £100. This is the only kit available for **Dolby Pro Logic** at present and was developed in Australia and licensed by **Dolby Laboratories** in the USA.

If you have experienced **Dolby Pro Logic** on videos or TV films you will know just how good it is. In fact it is so good that you will never get the same excitement from watching a video without this system once you have experienced it. Again make sure of your copy as demand is bound to be high. **You have been warned!**



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SIMPLE PIC16C84 PROGRAMMER

DERREN CROME

Serial programming the EEPROM version of the PIC microcontroller family is easily done from your PC.

DESCRIBED here are the circuit and software which enable an IBM PC-compatible computer to program the PIC16C84 microcontroller with a minimal amount of extra hardware.

Unlike other members of the PIC microcontroller family, the PIC16C84 is manufactured around EEPROM (electrically erasable programmable read-only memory) technology. Consequently, it can be repeatedly reprogrammed without the need for ultraviolet erasing. It is thus ideal for use in situations where programs are being developed stage by stage, or where some data parameters need to be periodically updated.

PIC16C84 SPECIFICATIONS

The PIC16C84 is a high performance, low cost, CMOS microcontroller having $1K \times 14$ -bit EEPROM program memory and 64×8 -bit EEPROM data memory. It also has 36×8 -bit SRAM (static random access memory) general purpose registers and 15 special function hardware registers. The pinouts are shown in Fig. 1.

There are four interrupt sources available: external INT pin, TMRO timer overflow, PORTB <7:4> interrupt on change, and data EEPROM write completion. Typically, the device can accept around one million erase/write cycles. Data retention is in excess of 40 years.

In-built peripheral features include: 13 I/O (input/output) pins with individual direction control, 25mA current sinking per pin, 20mA current sourcing per pin, and 8-bit real time clock/counter (TMRO) with 8-bit programmable prescaler.

Special microcontroller features include: power-on reset, power-up timer, oscillator start-up timer, watchdog timer (WDT) with its own on-chip RC (resistor-capacitor) oscillator, security EEPROM fuse for code protection, power-saving Sleep-mode, plus

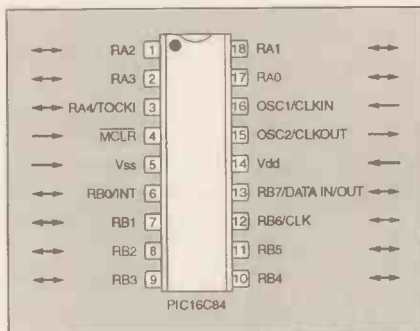
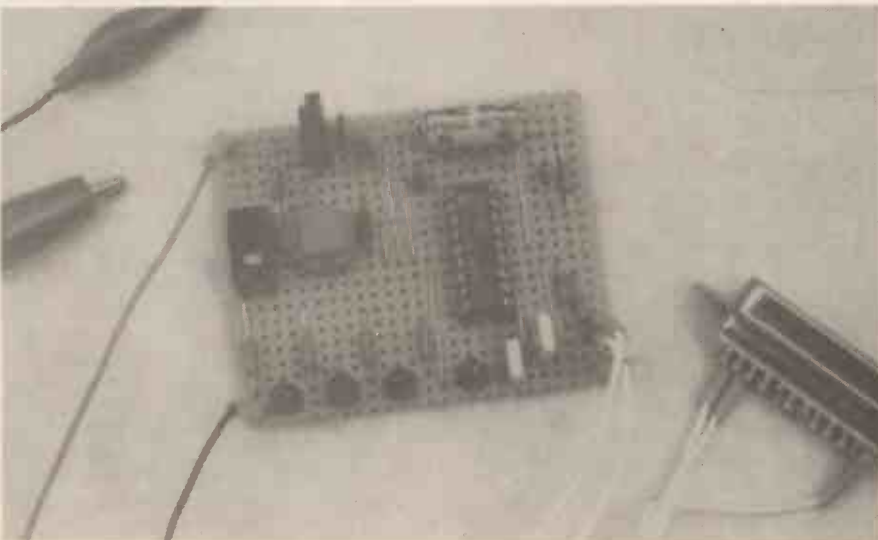


Fig. 1. PIC16C84 pinouts.

serial in-system programming (ISP) of EEPROM program and data memory using only two pins.

There are also four user-selectable oscillator options: RC oscillator (RC), crystal/resonator (XT), high-speed crystal/resonator (HS - up to 10MHz), and power-saving low-frequency crystal (LP).



INSTRUCTION SET

The PIC16C84 instruction set is shown in Table 1. However, it is beyond the scope of this article to describe the way in which the instructions are used, and readers are recommended to obtain the manufacturer's data book, which covers them at length.

The book also comprehensively covers all other members of the PIC microcontroller family and should be regarded as an *absolute must* by anyone intending to program these devices. Details on how to obtain the book are given at the end of the article.

SERIAL PROGRAMMING

Although the PIC16C84 can be programmed in either parallel or serial mode, the programming technique described here is for serial mode. The circuit diagram for this technique is shown in Fig. 2.

For the moment, ignore the l.e.d.s D2 to D5 and their resistors R3 to R6. They are not part of the programming circuit but are used in connection with an example program discussed later.

The advantage of the serial technique is that only three wires are needed to connect between the computer and the microcontroller, IC1. The three wires carry the clock and data signals, and provide the ground (0V) connection.

TABLE 1. PIC16C84 instruction set

MNEMONIC	OPERANDS	DESCRIPTION	STATUS AFFECTED
BYTE-ORIENTATED FILE REGISTER OPERATIONS			
ADDWF	F, D	Add W and F	C, DC, Z
ANDWF	F, D	AND W and F	Z
CLRF	F	Clear F	Z
CLRWF	-	Clear W	Z
COMF	F, D	Complement F	Z
DECF	F, D	Decrement F	Z
DECFSZ	F, D	Decrement F, Skip if Zero	-
INCF	F, D	Increment F	Z
INCFSZ	F, D	Increment F, Skip if Zero	-
IORWF	F, D	Inclusive OR W and F	Z
MOVF	F, D	Move F	Z
MOVWF	F	Move W to F	-
NOP	-	No Operation	-
RLF	F, D	Rotate Left F through carry	C
RRF	F, D	Rotate Right F through carry	C
SUBWF	F, D	Subtract W from F	C, DC, Z
SWAPF	F, D	Swap halves F	-
XORWF	F, D	Exclusive OR W and F	Z

BIT-ORIENTATED FILE REGISTER OPERATIONS

BCF	F, B	Bit Clear F	-
BSF	F, B	Bit Set F	-
BTFSC	F, B	Bit Test F, Skip if Clear	-
BTFSS	F, B	Bit Test F, Skip if Set	-
LITERAL AND CONTROL OPERATIONS			
ADDLW	K	Add Literal to W	C, DC, Z
ANDLW	K	AND Literal to W	Z
CALL	K	Call subroutine K	-
CLRWDT	-	Clear Watchdog Timer	\overline{TO} , \overline{PD}
GOTO	K	Go to address K	-
IORLW	K	Inclusive OR Literal to W	Z
MOVLW	K	Move Literal to W	-
RETFIE	-	Return from Interrupt	-
RETLW	K	Return with Literal in W	-
RETURN	-	Return from subroutine	-
SLEEP	-	Go into standby mode	\overline{TO} , \overline{PD}
SUBLW	K	Subtract Literal from W	C, DC, Z
XORLW	K	Exclusive OR Literal to W	Z
OTHER INSTRUCTIONS (see notes)			
OPTION	-	Load OPTION register	-
TRIS	F	Load TRIS register	-

NOTES:

- B** = Bit address within 8-bit file register
- C** = Carry/borrow bit
- D** = Destination select: D = 0, store result in W; D = 1 store result in file register F. Default is D = 1
- DC** = Digit Carry/borrow bit
- F** = File register address
- K** = Literal field, constant data or label
- \overline{PD}** = Power-down bit
- \overline{TO}** = Time-out bit

- W** = Working register (accumulator)
- Z** = Zero bit
- Usable static RAM locations range from 0C to 2F hex, inclusive.
- The instructions OPTION and TRIS are only included for code compatibility with PIC16C5X products. To maintain upward compatibility with future PIC16CXX products, the use of these two commands is not recommended. However, since both registers are readable and writable, the user can directly address them.

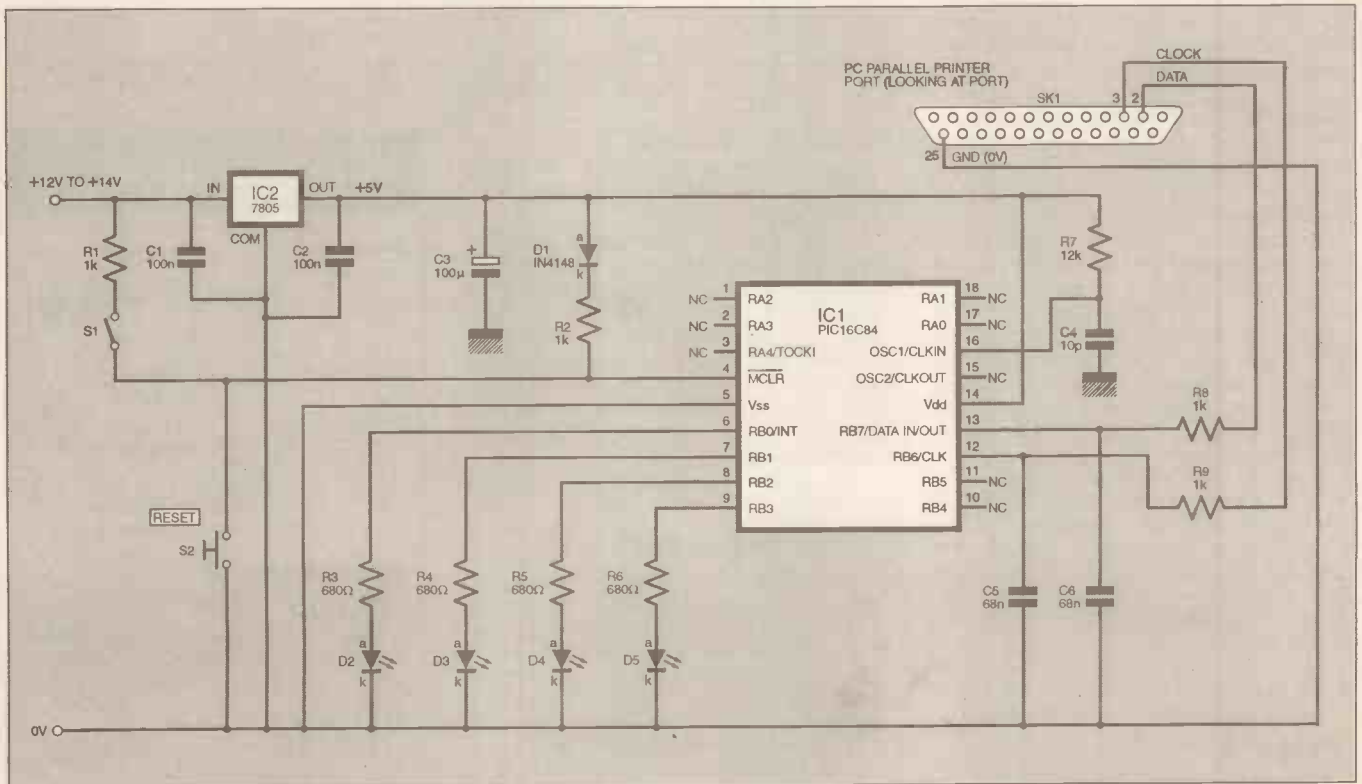


Fig. 2. Complete circuit diagram for the Simple PIC16C84 Programmer.

All three connections are made to the PC-compatible computer's parallel printer port via a 25-way male D-conductor (SK1). Serial data is sent via SK1 pin 2 (data pin D0), and the clock signal is provided via SK1 pin 3 (data pin D1). The ground connection is provided via SK1 pin 25 (one of the several parallel port 0V lines available).

Current-limiting resistors R8 and R9 are included to protect the parallel port and IC1 in case of conflicting logic levels. Capacitors C5 and C6 prevent spurious noise signals from generating false data and clock pulses. As the data and clock inputs to IC1 have Schmitt trigger operation, the resulting slightly slower

pulse rise/fall times should not cause problems.

(As illustrated in the PIC-Electric circuit elsewhere in this issue, the basic PIC16C84 programming components may be incorporated in the circuit of any design, allowing in-situ programming development. Ed.)

PROGRAMMING MODE

When in programming mode, the PIC16C84 requires a voltage of between +12V and +14V to be applied to its MCLR pin. However, the power supply across its V_{dd} and V_{ss} pins (pins 14 and 5) must be at no more than +5V. The circuit thus needs to be powered from a 12V to 14V d.c. regulated power supply, or a 12V battery. The input voltage is then regulated down to +5V by IC2. Capacitors C1 and C2 provide power line decoupling.

Resistor R7 and capacitor C4 form a CR time constant to set the PIC's clock frequency.

With programming switch S1 open, the MCLR pin is held high via diode D1 and resistor R2. In this mode, IC1 executes its stored program.

Pressing Reset switch S2 connects the MCLR pin to the 0V line, so resetting IC1 to the start of its stored program routine. In this mode, program execution ceases and all I/O pins go into a high impedance state. On releasing S2, the program restarts from address 0000 hex.

To set the PIC into program/verify mode, which is required when downloading a program or configuration data, switch S1 is closed, connecting the full programming voltage via resistor R1 to the MCLR pin. Diode D1 prevents this voltage from affecting the regulated +5V line.

Once S1 has been closed, S2 has to be pressed briefly to reset the microcontroller. Resistors R1 and R2 prevent either of the power lines from being shorted to ground when S2 is pressed.

With S1 closed and S2 open, the PIC is now in program/verify mode and waits for the first serial data command to arrive from the computer. It will remain in this mode until S1 is opened.

CONSTRUCTION

A suggested stripboard layout for the full circuit of Fig. 2 is shown in Fig. 3. The optional i.e.d.s D2 to D5 and their resistors R3 to R6 may be omitted if preferred.

The layout is designed for use with a standard 18-pin d.i.l. (dual-in-line) socket into which the PIC to be programmed is inserted. After programming, the PIC is removed using an i.c. extractor tool, or gently prised out using a screwdriver. Experienced constructors who intend to do a lot of PIC programming may prefer to change the layout so that a ZIF (zero insertion force) socket can be used instead.

Start off construction by soldering in the 18-pin d.i.l. socket. Then solder in the link wires and remaining components in any order you feel comfortable with. Ensure that the polarities of diode D1, regulator IC2 and capacitor C3 are correctly observed. Then connect wires for the power supply and socket SK1.

Make sure that all the track cuts are made as shown, and that you check everything thoroughly before using the board.

DATA TRANSMISSION

When the circuit is in program/verify mode, data present on pin 13 (RB7/Data In/Out) is clocked into IC1 on the rising edge of the clock signal applied to pin 12 (RB6/CLK). The serial data transfer protocol is as follows:

First, the binary code 000010 is sent. This instructs the PIC that the next 16 bits are program data. Next a 0 is sent,

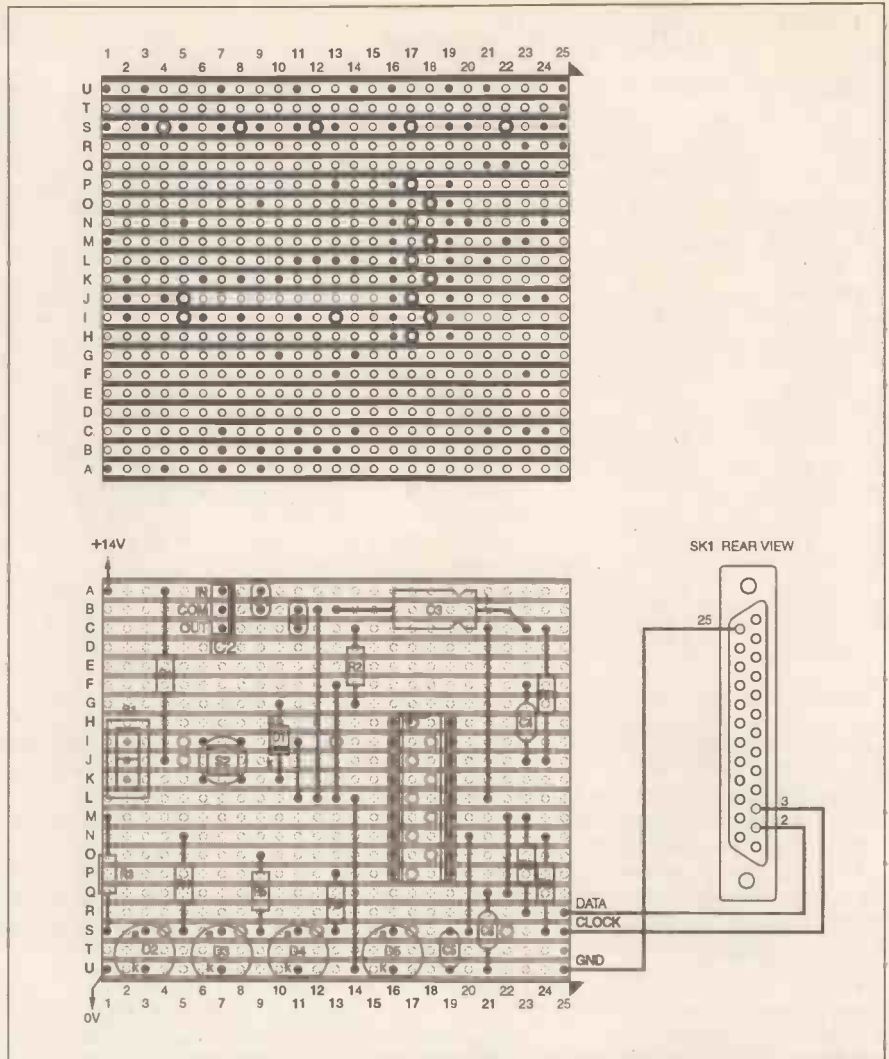


Fig. 3. Suggested stripboard layout details.

followed by the 14 data bits which make up a single program instruction, the most significant byte (MSB) being sent first. Finally, another 0 is sent.

At this point, the 14-bit data is stored in the PIC's internal buffer. To store the data in the EEPROM memory, the "begin programming" command 001000 is sent. There must be a 10ms delay between issuing this command and sending the next one, which is 000110. This instructs the PIC to increment its internal program counter, so that the next instruction will be stored in the next consecutive memory location.

The cycle is then repeated for every instruction in the program.

SOFTWARE

The software needed to program PIC16C84 microcontrollers using the circuit in Fig. 2 consists of three programs: a Text Editor (word-processing program) on which to write the instructions in mnemonic form, a Cross-Assembler, and the Send program which actually sends the data according to the above protocol.

Any standard text editor may be used to write the mnemonic instructions, providing it is capable of generating an ASCII file without additional layout formatting and printer control commands.

A cross-assembler is a program which converts the ASCII mnemonic text file into the binary code required by the PIC microcontroller. The cross-assembler required for this programmer is the Shareware software program TASM.

COMPONENTS

Resistors

R1, R2, R8, R9 1k (4 off)
R3 to R6 680Ω (4 off)
(see text)
R7 12k
All 0.25W 5% carbon film or better

See
**SHOP
TALK**
Page

Capacitors

C1, C2 100n min. ceramic disc (2 off)
C3 100μ elect. radial, 25V
C4 10p min. ceramic disc
C5, C6 68n min. polyester (2 off)

Semiconductors

D1 1N4148 silicon diode
D2 to D5 red i.e.d. (4 off) (see text)
IC1 PIC16C84 microcontroller
IC2 7805 1A +5V regulator

Miscellaneous

S1 s.p. min. slide switch, p.c.b. mounting
S2 min. push-to-make switch, p.c.b. mounting
Stripboard 25 holes × 21 strips, 0.1 pitch; 18-pin d.i.l. socket (see text); 25-way D-connector; connecting wire; solder, etc.

Approx cost
guidance only

£12

LISTING 1. Part of the translation table

```
.MSFIRST
.WORDADDRS
ADDWF ** 0700 2 TDMA 1 7 0080
ANDWF ** 0500 2 TDMA 1 7 0080
CLRF * 0180 2 TDMA 1 0 007F
CLRW "" 0100 2 NOTOUCH 1
```

Shareware software is copyrighted, but the authors of such software have given permission for it to be freely copied. However, if regular use of Shareware software is intended, then the copy must be registered by means of making a nominal payment to the author.

If you only wish to evaluate the Shareware software and then find that it is not suited to your needs, no registration payment needs to be made.

To enable TASM to assemble programming data for the PIC16C84, a translation table has been specially written for EPE readers. This is simply a text file which defines all the PIC16C84 instructions, as partly shown in Listing 1.

Also specially written for EPE is a program which sends the assembled data codes to the chip. Users of the translation table and the Sending program may freely do so without any registration payment being required.

Details about how to obtain all the software for this project are given later.

Having obtained the software, it is recommended that it is copied from the disk supplied onto the hard disk of drive C, into its own directory for which a name of PIC is suggested (other names can be given if preferred).

This can be done as follows, typing each of the commands on the DOS prompt (>), followed by <ENTER>:

```
C:
CD\
MD PIC
CD\ PIC
COPY B:**
(or, depending on
your second disk
drive, type COPY
A:**)
```

Then come out of the PIC directory (CD\) and load your text editor program.

TABLE

Every PIC instruction the user types in via their text editor consists of a mnemonic plus up to two operands.

For example, take the single instruction ADDWF \$13,1. The mnemonic is ADDWF, the first operand is \$13 and the second operand is 1. The \$ (dollar) symbol indicates to TASM that the value is in hexadecimal. If the \$ symbol is omitted, TASM will take the value as being in decimal. Binary values may be entered by prefixing them with the % (percentage) symbol, e.g. %00010011.

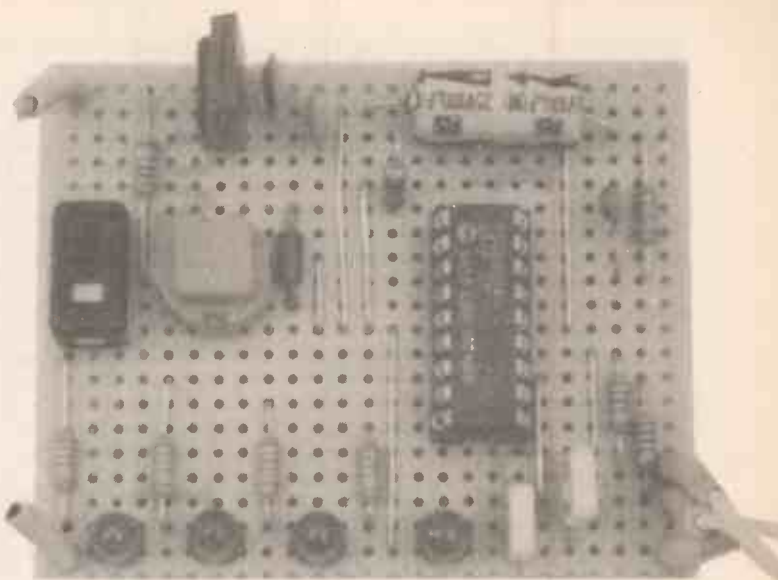
When TASM is assembling a program, it "looks" at each line in turn and produces the code for it. When it comes across a command mnemonic, such as ADDWF for example, it refers to the translation table to find out which op-code is associated with that particular command.

The operands are then combined with the op-code to produce a 16-bit word. Since the PIC16C84 only needs 14-bit

commands, the left-hand two bits are not used and are always set to zero.

Referring to the partial extract of the translation table in Listing 1 (from disk file TASM1684.TAB), first there are two assembler directive lines. The first one, .MSFIRST, instructs TASM to produce the most significant byte first, followed by the least significant byte. The next line, .WORDADDRS, instructs TASM to produce 2-byte addresses.

Following these lines is the table itself. The first command defined is ADDWF, which means add the contents of the working register to the contents of a file register. The ADDWF command expects two operands to be specified. The first is the address of the actual register file to which you wish to add. The second operand can only be a 0 or a 1. If a 0 is specified, the PIC



LISTING 2. Example program for PIC16C84

```
;EXAMPLE.ASM
;Lights i.e.d.s connected to PORT B bits 0 to 3 (IC1 pins 6 to 9) in
turn

#DEFINE PAGE0 BCF $03,5
#DEFINE PAGE1 BSF $03,5
.AVSYM
STATUS: .EQU $03 ;Located in page 0 & 1
PCL: .EQU $02 ;0 & 1
TMRO: .EQU $01 ;0
PORTA: .EQU $05 ;0
PORTB: .EQU $06 ;0
TRISA: .EQU $05 ;1
TRISB: .EQU $06 ;1
OPTION: .EQU $01 ;1
INTCON: .EQU $0B ;0 & 1
EEDATA: .EQU $08 ;0
EEADR: .EQU $09 ;0
EECON: .EQU $08 ;1
PCLATH: .EQU $0A ;0 & 1

W: .EQU 0 ;Result to go into working register
; (accumulator)
F: .EQU 1 ;Result to go into a file register.
C: .EQU 0 ;Carry flag (located in STATUS
; register)
DC: .EQU 1 ;Digit carry (located in STATUS
; register)
Z: .EQU 2 ;Zero flag (located in STATUS
; register)
PD: .EQU 3 ;Power Down bit (located in
; STATUS register)
TO: .EQU 4 ;Time-out bit (located in STATUS
; register)
.ORG $0004 ;Interrupt vector address
```

```
GOTO INTRPT ;Jump to interrupt routine on
; interrupt
.ORG $0005 ;Start of program memory
;Above lines must always be present.

PAGE1 ;Defined above.
MOVLW $00 ;Load working register
; (accumulator) with literal 0.
MOVWF TRISB ;Configure all port B lines as
; output
CLRWDI ;Clear watchdog timer
MOVLW %00000111 ;Configure timer options
MOVWF OPTION
PAGE0
MOVLW $08
MOVWF PORTB ;Set bit 3 on port B
MOVLW %10100000
MOVWF INTCON ;Enable timer interrupt

START: NOP ;Dummy main program, loops
; endlessly
GOTO START ;waiting for a timer interrupt to
; occur

;Interrupt routine
INTRPT: RRF PORTB,F ;Set next bit of port B
; MOVF PORTB,F ;Affect Z status bit
; BTFSS STATUS,Z ;Test to see if port B's value=0
; GOTO FIN ;Its value is not 0
; MOVLW $08 ;Its value is zero, Set bit 3 of port B

FIN: MOVWF PORTB
; BCF INTCON,2 ;Clear timer overflow interrupt
; flag
RETIE ;Return from interrupt
.END ;This command MUST be placed at
; end of program
```

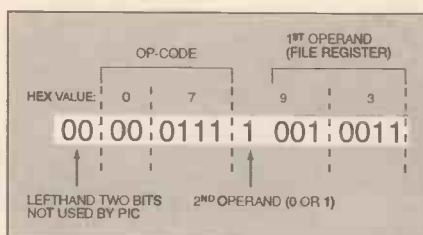


Fig. 4. Typical 14-bit pattern for program data code.

is instructed to place the result of the addition into the working register. If a 1 is specified, the result is placed back into the named file register.

For example, take the instruction:

```
ADDWF $13,1
```

For the PIC to perform this command, the 14-bit pattern held in its program memory must be as shown in Fig. 4 (ignoring the lefthand two bits).

To produce this required bit pattern, the translation table contains the following line:

```
ADDWF *,* 0700 2 TDMA 1 7 0080
```

The first part of the line, `ADDWF *,*`, instructs TASM to expect two operands after the `ADDWF` mnemonic, separated by a comma. As specified in the manufacturer's data book, 0700 is the actual hex value of the op-code. The following decimal 2 indicates that two bytes (16 bits) are to be produced for this command, i.e., binary 00000111 00000000 (07 hex and 00 hex).

Next, `TDMA` is a command to inform TASM what to do with the operand(s). What TASM actually does is to logically OR the 0700 hex with the first operand, which in this case is the \$13 hex (00010011 binary) in the original command line. This results in 0713 hex (00000111 00010011 binary).

The second operand is decimal 1, indicating that the result of the instruction is to be placed back in the file register. The decimal 7 in the table line tells TASM to shift the bit pattern of this operand seven bits to the left. This intermediate result is ANDed with 0080 hex, producing 10000000 binary, which is then ORed with 0713 hex, resulting in 0793 hex (00000111 10010011 binary).

The table continues in a similar fashion for all the PIC16C84 commands. It will be seen that other commands occur in the table lines, such as `TI` and `NOTOUCH`. A full description of the translation table, including these commands, is given the additional text file `TASMTABS.DOC` which is supplied with the software.

Readers will be interested to know that the Shareware software also contains translation tables for processors other than the PIC16C84, including 6502, 6805, 68xx, 8048, 8051, 8085 and Z80 (but not 8086).

EXAMPLE PROGRAM

Once constructed, the programming circuit can be checked out using an example program (`EXAMPLE.ASM`) included with the software supplied. The program file can be loaded into your text editor for examination. When the assembled program code is loaded into the PIC, it causes four l.e.d.s (D2 to D5) to light in sequence and has its listing shown in Listing 2.

It will be seen in the listing that lines three and four use the `#DEFINE` command. This command allows alias

string names to be defined. For example, line three states:

```
#DEFINE PAGE0 BCF $03,5
```

This simply tells the TASM assembler that when it is assembling the object code file, each time it comes across the statement `PAGE0`, it is to replace it with the statement `BCF $03,5`. Any desired aliases can be defined in this way. (The use of `PAGE0` and `PAGE1` is covered in the data manual.)

After aliases have been defined, the statement `.AVSYM` must be included.

Next, string names can be defined and allocated to specific values. For example, the manufacturer's data for the PIC16C84 states that the `STATUS` register is located at \$03. Thus the line:

```
STATUS: EQU $03
```

tells TASM that each time the name `STATUS` occurs in the text file it is to be replaced by the hex value \$03.

The idea of equating values to string names is that it makes programs more readable and therefore easier to debug, and easier for other people to understand. Furthermore, it is also easier for programmers to remember names rather than numbers.

As will be seen, not only can locations be defined in this way, but also specific flag bits within bytes, e.g. the zero status flag, which is bit 2 of the `STATUS` register, is defined by:

```
Z: EQU 2
```

Thus, if the command `BTFSS STATUS,Z` is encountered, the assembler will take this line to mean `BTFSS STATUS,2`, i.e. to tell the program to test the status of bit 2 in the `STATUS` register and branch accordingly.

Comments may be included anywhere in the text file but they must always be prefixed by a semi-colon (;).

Following the definition of names and their values come three further instruction lines to the assembler software:

```
.ORG $0004
GOTO INTRPT
.ORG $0005
```

The `.ORG $0004` command followed by the command `GOTO INTRPT` puts the address of the interrupt routine into address \$0004 in the PIC. If interrupts are not required in a program, this line should still be included, but a dummy interrupt routine should be defined, e.g.:

```
INTRPT: RETFIE
```

In this situation, if an interrupt mistakenly occurs in the program, instead of crashing, the program will jump to this dummy interrupt routine and jump straight back to where it left off in the main program (as instructed by the `RETFIE` command - return from interrupt).

The next line, `.ORG $0005`, instructs the assembler to assemble the program starting at address \$0005. This is the address from which the PIC16C84 will start executing the program at switch on, or when reset by taking the `MCLR` pin low.

Next come various other "housekeeping" operations in which the input/output configurations of the ports are defined and the watchdog timer operation is specified.

Now come the first two lines of the program itself:

```
START: NOP
GOTO START
```

The word `START:` is used as a label. A label allows the programmer to specify

jumps or calls to various parts of the program without actually specifying the actual addresses to which they are made. The assembler program automatically calculates the required address each time it comes across the label. Labels must be suffixed by a colon (;) when used in the left hand column.

In the above two program lines, the program repeatedly loops through the commands until an interrupt occurs, in this case until the watchdog timer count reaches zero.

When the interrupt occurs, the program jumps out of the loop and to the interrupt routine whose label was specified earlier on in the program (`.ORG $0004 - GOTO INTRPT`).

All the commands associated with the interrupt routine are then performed until the command `RETFIE` is encountered, whereupon the program jumps back to the `START:` loop at the point from which it had exited. The loop then continues to cycle until the next interrupt occurs.

The actions taken within the example interrupt routine here are all associated with incrementing a count value output to `PORTB`, resulting in the respective l.e.d.s being turned on or off as dictated by the count value. A high output on any of the four `PORTB` pins turns on the respective l.e.d.

Finally, at the end of the program listing is the command `.END`. This must be included so that the assembler knows when it has reached the end of the program it has to assemble.

ASSEMBLING CODE

When the program instructions have been written as mnemonic text, the text must be saved to disk. It is recommended that it is saved as two files if it has been written on a text editor which does not automatically save the file as an ASCII file.

First save it as an ordinary file which includes all the non-ASCII commands normally associated with the editor, using an easily recognisable extension code, such as `.PIC`. For example, the above listing could be saved as `EXAMPLE.PIC`.

Then select the text editor's function which causes files to be saved as pure ASCII text files without any formatting or layout commands, using a different extension, e.g. `EXAMPLE.ASM`.

This technique allows files to be worked on according to the text editor's normal formatting requirements while still generating a file which will be correctly acted upon by the TASM assembler. Be aware that ANY non-ASCII text editor commands may cause the assembler to misinterpret the mnemonic code lines.

(Before this fact was recognised when testing the program at our offices, a non-ASCII file was somehow erased when TASM failed to recognise some command lines. This resulted in it having to be retyped. Ed.)

When the mnemonic text files have been saved, exit the text editor and change directories. For example, assuming that all the PIC16C84 programs have been installed in a directory named `PIC`, at the DOS prompt type:

```
CD\PIC
```

Now invoke the assembler, telling it which file it is to assemble, i.e.:

```
TASM -1684 -B <filename>
```

The command `TASM` invokes the assembler, `-1684` instructs it to relate the file

to the PIC16C84 translation table, -B instructions it to assemble the code as a binary file, and <filename> should be replaced by the full name of the file to be assembled, including its extension. Note the space between each of the four commands. (The command may be typed in capital or lower case letters.)

Thus to assemble the above example program, type:

TASM -1684 -B EXAMPLE.ASM

The assembler then creates three files, an object file (.OBJ), a listing file (.LST) and a symbol (.SYM) file, in this case:

```
EXAMPLE.OBJ
EXAMPLE.LST
EXAMPLE.SYM
```

The object file (.OBJ) is the file whose binary data (machine code data) will be sent to the chip being programmed. The listing file (.LST) is a text file which shows all the mnemonics, addresses and object codes. The .SYM file can be ignored.

Any errors which are encountered in the source code (in the .ASM file) will be reported on screen. They are also reported in the .LST file, which can be examined from the text editor.

If errors exist, note them down, return to the text editor and correct them in the .PIC file. Then re-save, both as a .PIC file, and as a .ASM (ASCII) file, as discussed above. Having done so, re-assemble via TASM as before.

Note that TASM checks for basic syntax errors or operands that are out of range. However, it will not check the logic of the program or for correct programming functions, such as typing in the wrong memory locations or testing the wrong bits prior to jumping, for example.

Once the program is error free, its .OBJ file can be downloaded into the PIC.

From the .PIC directory, at the DOS prompt type:

```
SEND
```

A menu will be presented with three options:

- 1..... PIC16C84 configuration set-up
 - 2..... Load object code and send to PIC
 - 3..... Quit program
- enter option 1, 2 or 3

Option 1 allows the PIC to be configured. This needs to be done first when using a new PIC16C84, or if a PIC's previous configurations are inappropriate to the new program about to be loaded.

When Option 1 is chosen, another menu is displayed:

Program to set configuration fuses
WARNING: Any program presently in the PIC16C84 will be erased

Please enter which type of oscillator you wish the PIC16C84 to use:

- 1... LP low power crystal oscillator (32kHz - 200kHz)
 - 2... XT crystal oscillator (100kHz - 4MHz)
 - 3... HS High speed crystal oscillator (4MHz - 10MHz)
 - 4... RC Resistor capacitor oscillator
- Enter selection 1 to 4

As this menu shows, there is a choice of four oscillator types which can be selected to control the timing of the PIC16C84. For use with the programming circuit shown in Fig. 2, select Option 4, for RC.

Having selected the oscillator option, you are asked:

Enable watchdog timer?
enter Y or N

If the watchdog timer is not required, as it is not for this circuit, press N, otherwise press Y. Next you are asked:

Enable power-up timer?
enter Y or N

Usually it is beneficial to have the power-up timer enabled, so press Y.

You are then asked if you wish the configuration data to be sent to the PIC. If you are happy with it, press Y. The following prompt then appears:

Make sure PIC16C84 is in program mode (12V-14V on pin 4)
then press a key to begin transfer.

This means that switch S1 should be switched on, and switch S2 (reset) should be briefly pressed and then released. Now press any key, whereupon the configuration data is sent to the chip, and the following statements displayed:

Configuration data sent
Now reset the PIC16C84 (pin 4 low briefly), press a key

To reset the PIC, simply press switch S2, but leave switch S1 turned on. Then, as instructed, press any key, which will cause the original three-option menu to be displayed again. Select Option 2 if you wish to send the program data to the chip.

Having selected Option 2, you are requested to enter the name of the object file that is to be downloaded. The .OBJ extension does not need to be entered since the program automatically assumes that the file is an object file (it does not matter, though, if the .OBJ extension is included).

When the file name has been entered, in this case as EXAMPLE, press <ENTER>. The file will be loaded, the screen displaying the hex value of the bytes involved, the total number received, and the amount of PIC memory which will be used by them, both as a word count and as a percentage of available space.

The procedure is now the same as for the configuration programming. Confirm that you want to send the program, ensure that S1 is switch on, briefly press reset switch S2, and then press any key. The program will be downloaded and confirmation displayed, followed by the instruction:

Return pin 4 of PIC to +5V then press reset to run program
Press a key to return to main menu

This means that you should turn off switch S1, then briefly press switch S2, after which press any key, causing the three-option menu to re-appear. Select Option 3 to quit the Send program.

Now observe the l.e.d.s being controlled by the example program, they should be correctly turning on and off as expected. The sequence may be restarted at any time by pressing Reset switch S2.

The same programming technique applies when other programs are to be downloaded into the PIC16C84, such as the program for the PIC-Electric circuit in this issue of EPE.

OBTAINING SOFTWARE

The TASM software and associated program files discussed above (but not including a text editor) are available on a 3.5in. disk from the EPE Editorial offices for £2.50 (overseas £3.10 surface, £4.10 air-

mail) to cover administration costs. Also included on this disk is the software for the PIC-Electric project.

This is not a payment for the software itself, for which we make no charge. The current registration fee for the shareware TASM assembler software is \$40 US. This fee is only payable if you intend to regularly use the software beyond a reasonable evaluation period.

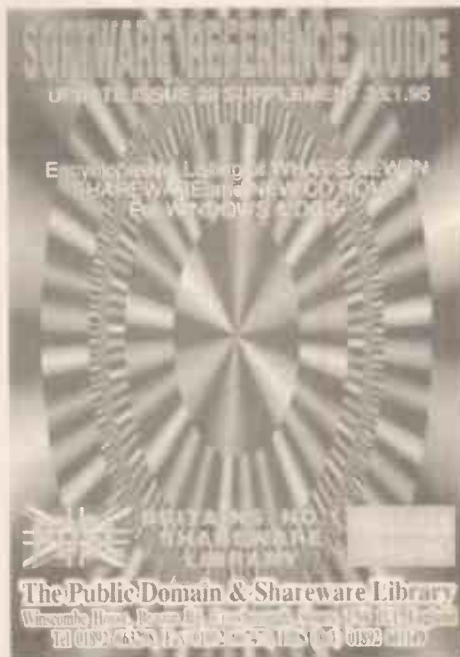
Readers are strongly recommended to honour the registration payment request. Registered users receive the following benefits:

1. The most recent version of TASM
2. TASM source code, in C
3. Bound TASM manual
4. Telephone support
5. Knowledge that they are supporting the development of useful but inexpensive software.

The address of the organisation (in the USA) who administer the TASM registration payment is quoted on the software disk.

The Shareware library which supplied the original TASM programs to the author is: The Public Domain and Shareware Library, Dept EPE, Winscombe House, Beacon Road, Crowborough, Sussex, TN6 1UL. Tel: 01892 663298.

The PDSL have a great deal of shareware software available - it is well worth while asking them for their catalogue.



PIC DATA BOOKS

Arizona Microchip's PIC16/17 Microcontroller Data Book 1995/1996 referred to earlier is a 1276-page overview of the PIC16Cxx and PIC17Cxx families of 8-bit RISC-based microcontrollers. It contains full product and programming specifications, development system and software support information for designers working on embedded control applications.

Also of interest is their *Embedded Control Handbook*, which has over 1000 pages full of programming examples for all PIC chips.

For more information about these books, and PIC chips in general, contact Arizona Microchip Technology Ltd, Dept. EPE, Unit 6, The Courtyard, Meadowbank, Furlong Road, Bourne End, Bucks, SL8 5AJ. Tel: 01628 851077.

FOX REPORT

by Barry Fox



Theremin Revival

Nice to see the Theremin revived as a construction project in the September 1995 issue. Leon Theremin invented his music synthesiser in 1920 while still in Russia. It had no keyboard, just two aerials which change the pitch and volume of a note with movement of the performer's hand.

The inventor moved to the USA in the thirties and licensed RCA to make a consumer model. Composer Joseph Schillinger (who later taught both Glenn Miller and Benny Goodman musical theory) wrote a Suite for RCA Theremin in 1929, to promote the instrument.

In the forties and fifties musicians toured, giving solo performances. Clara Rockwell was the leading exponent. Bob Moog, father of modern synthesisers, has always given full credit to Theremin's pioneering work.

In the years following World War II, young Moog made electronic gadgets with his father. In 1964 he built his first music synthesiser, demonstrating it to the Audio Engineering Society's exhibition in New York. In 1968 Walter Carlos, later Wendy Carlos, released a record of Bach's compositions, played on Moog's synthesiser. Carlos used the same instrument to record the music for Stanley Kubrick's movie, *A Clockwork Orange*.

In Japan, musician Tomita rearranged Gustave Holst's *Planets Suite* for performance on a synthesiser. Representatives of the Holst estate disliked the effect so much that they applied for, and won, an injunction to ban the record.

Sound Track

As the construction article explained, the Theremin was used on many early science fiction movies, such as *The Day The Earth Stood Still*. Its eerie sound, a cross between a soprano voice and violin, fitted the genre. A Theremin was used on the sound track of the recent feature movie about the world's worst sci-fi film-maker, Ed Wood. It is now out on video.

If you want to hear what the Theremin sounds like, rent the movie. Or you can hear one on the Beach Boys' classic track, *Good Vibrations*. Better still look out for an LP record of Clara Rockwell which Moog produced twenty years ago.

Although there have been Japanese versions, which use transistors, the original RCA valve models have a characteristic sound. They are very rare and expensive. If you ever find one in a junk shop, grab it!

Not the First

The Theremin was not the first electronic musical instrument. In 1896 Thaddeus Cahill, of New York, filed a patent application (US 580 035) on the "art of and apparatus for generating and distributing music electrically".

Long before oscilloscopes could display the shape of waveforms, Cahill very clearly described how music is built from sine waves. He warned that pure tones on their own sound "colourless and insipid". But if the pure tone is mixed with harmonic overtones or "partials", which have a clearly defined mathematical relationship, the change is dramatic.

Some of the mathematical relationships make the sound pleasant, "like a good pianoforte". But other pairings make the sound "disagreeable".

Telharmonium

Cahill was patenting the idea of an enormous tone generator, which he later called a Dynamophone or Telharmonium. Literally dozens of shafts, like carpenters' lathes, carried "rheotomes". These were cylinders built from alternate strips of metal and insulating material.

A motor and pulley-belts turned the shafts while a dynamo fed current through electrical brushes to the rheotomes. Each rheotome produced a fluctuating electrical signal as its strips made and broke contact with the brushes.

The speed of the fluctuation, and the musical pitch of the signal, depended on the speed at which the rheotomes were turning, and the number of their conducting parts. Audible sound was produced by feeding the fluctuating signal to a telephone head-set.

Cahill suggested an instrument built from 84 rheotomes on twelve shafts, rotating at different speeds to mimic the 84 notes of a seven octave piano. Fine tuning was by physically filing the pulleys to precise size.

Wrong Number

In the early years of the 20th century, Cahill built three Telharmoniums, and teamed up with US telephone company AT&T to feed music signals down its telephone lines. While a musician played the Telharmonium keyboard, paying subscribers in the New York area could plug in their earpieces and listen to synthesised sound. The project failed commercially, largely because the signals from the Telharmonium drove up to one

amp of current into each receiver. This produced a loud sound but was the system's undoing.

The piped music interfered with ordinary telephone calls which were running through wires in the same underground ducts. Business callers heard music instead of speech.

The piped synthesis service ended in 1914. No-one knows where the original instruments ended up. As they were nearly 20 metres long, made of steel and weighed some 200 tonnes, it is a safe bet that they were sold for scrap.

Sounds of Ondes and Ondioline

In 1928 Maurice Martenot built his Ondes Martenot in Paris. It used two oscillators working at around 80kHz. One was fixed and the other was variable by a few hundred Hertz, under the control of a keyboard. Mixing the two signals produced an audible difference tone at a few hundred Hertz.

The similar Ondioline was developed and built by Georges Jenny, in Paris during World War II. When hostilities ended Jenny sold his Ondioline in kit form, for home construction.

The device looked like a radio, with a keyboard attached to the top. It was demonstrated at the Atomium Building, during the Brussels World Fair in 1958.

Although the Ondioline used only a single oscillator pair, and could thus play only one note at a time, Jenny devised circuitry which generated an extraordinary range of overtones.

A row of switches at the front controlled a bank of electronic filters to shape the waveform. A rotary knob switched the circuit through seven octaves.

Physically moving the keyboard slightly side to side slightly changed the pitch to create vibrato. Pushing a lever under the keyboard controlled the volume.

Demonstration Record

An instruction sheet told users which switches to put up or down to imitate the sound of many different instruments. The Ondioline could do passable impersonations of the Hawaiian guitar and jazz bass, as well as all the instruments of a classical orchestra.

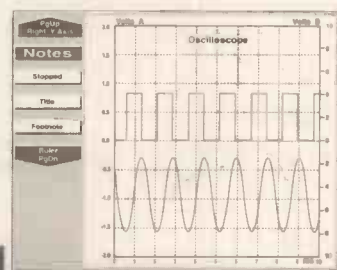
Jenny produced his own demonstration record, and sold it to prospective constructors for 4.95 francs. A few working Ondiolines still exist, and sell as musical antiques.

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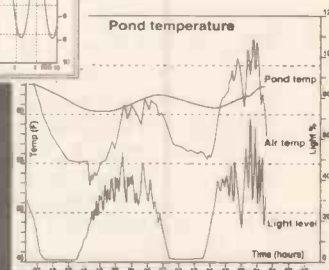
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MAINS SIGNALLING UNIT

12V CAPACITIVE PSU TWO-TONE SIREN ALARM



ANDY FLIND

Part 2

Adding a low cost power supply and alarm siren for the "through-the-mains" communications link.

LAST month a simple system was described for using house mains wiring to transmit a signal. As this was originally intended to extend a doorbell, the Receiver module required the addition of a simple mains Power Supply Unit (PSU) and a Two-Tone Siren Alarm. Other applications for the system, such as a garage intruder alarm or relaying a smoke alarm from another floor, would need similar add-ons.

With a simple mains power supply and a low-current piezo sounder the entire Receiver system can be fitted into a small plastic box, creating a self-contained unit that can be plugged in anywhere in the house. This article describes the construction and use of these extra circuits.

Both simple circuits should find many other uses, especially the Two-Tone Siren Alarm Generator, though the Mains PSU is of the "capacitive dropper" type so circuits powered by it are *hazardous and should NOT be touched*. However, any circuits that are *totally enclosed and insulated* can use it, and experimenters wishing to try this type of supply in their own designs will find it a lot safer and more convenient to use one of these boards than normal bread-boarding techniques.

CAPACITIVE PSU

Beginning with the power supply, the full circuit diagram for the simple 12V Capacitive PSU is shown in Fig. 1. It uses resistor R1 and capacitor C1 in place of the more common transformer to reduce the mains a.c. voltage. A constant current flows through these, the value being determined by the capacitance and supply voltage values.

The circuit is a "half-wave" type. When the "live" is positive of "neutral", current from C1 flows through diode D2 and Zener diode D3.

The 12 volts that develops across D3 is stored in capacitor C2 which continues to supply the output during the negative half-cycle, whilst current returns to C1 through diode D1. VDR1 is a 230V mains transient suppressor, which clips any brief

high-voltage spikes in the mains supply to protect C1.

Resistor R1 restricts the brief but heavy current inrush that would occur if the circuit was plugged in at the exact instant where the mains voltage was at a high

point in the cycle. A rugged two watt component is used for this. Resistor R2, a high-voltage type, discharges capacitor C1 when the circuit is disconnected to eliminate the possibility of shocks to the user from the plug. The capacitor C1 is a special "IS" type intended for suppression applications, designed to withstand *continuous* connection across the 230V mains supply.

The advantages of this circuit over a transformer are that it is smaller, lighter, cheaper, and does not generate any heat or noise. Transformers invariably warm up a little and can generate hum. The disadvantage is that circuits powered by it are in direct contact with the mains so they *must be fully insulated*.

The maximum current available depends on the value of the capacitor C1 and in this case is about 10mA. Most of the current passing through the capacitor is "reactive", and does not appear on the electricity bill. Only the tiny part picked off by the resistive element of the circuit being supplied will register.

This type of circuit has obvious hazards and should only be built by constructors with sufficient experience to recognise and avoid them. Those in doubt should use a small transformer instead; the receiver circuit will operate happily from either supply source.

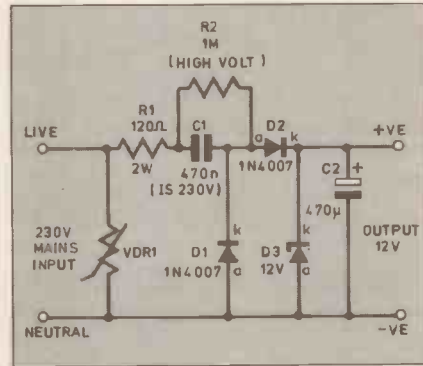
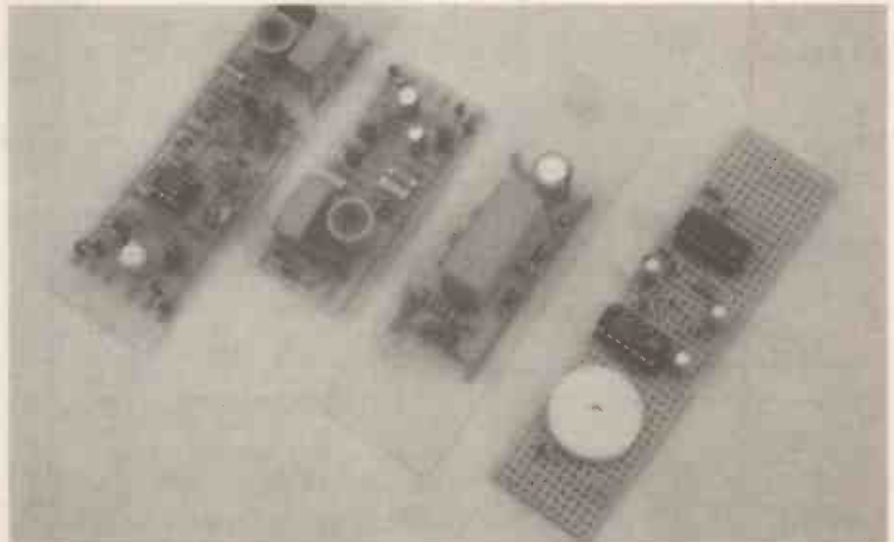


Fig. 1. Circuit diagram for the simple 12V Capacitive Power Supply.



Line-up of modules for the Mains Signalling System (left to right) Receiver, Transmitter, Power Supply and Two-Tone Sounder.

COMPONENTS

Power Supply Board

Resistors

R1	120Ω 2W metal film
R2	1M high-voltage metal film

See
**SHOP
TALK**
Page

Capacitors

C1	470n "IS" 230 volt suppression type
C2	470μ radial elect. 35V

Semiconductors

D1, D2	1N4007 1A 1000V-rectifier diode (2 off)
D3	BZX61C12 12V 1.3W Zener diode

Miscellaneous

VDR1	250V mains transient suppressor
------	------------------------------------

Printed circuit board available from *EPE PCB Service*, code 975; plastic case, size to choice; cable clamps to suit input and output wires; multistrand connecting wire; solder pins; solder etc.

Approx cost
guidance only

£8

excl. case

PSU CONSTRUCTION

For safety, the simple 12V Capacitive PSU is constructed on a small, robust printed circuit board (p.c.b.) with widely-spaced tracks. This board is available from the *EPE PCB Service*, code 975.

The components can all be fitted as shown in Fig. 2; working from the smallest component up to the large "continuous mains operation" IS capacitor C1. Take care with diode polarity, especially the Zener diode D3 which is the opposite way around to the other two.

Leads can now be fitted to the board for testing and a meter, set to the appropriate voltage range, connected to the output terminals *before* it is powered-up. The board *MUST* be connected to the mains supply through a suitable fuse – one with a rating of 3A or lower should always be used with this type of circuit.

At switch-on the "test" meter should read 12V, plus or minus about half-a-volt. If this is OK, construction and testing is complete.

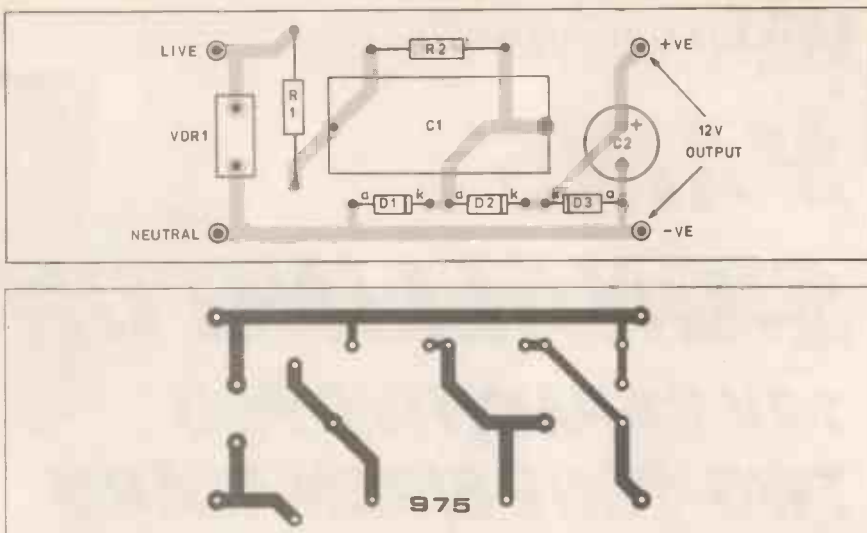


Fig. 2. Printed circuit board component layout and full size foil master for the 12V Capacitive PSU. The extra board space at each end allows it to safely slot into its case.

It is perhaps worth mentioning that should a supply that is negative or "neutral" be required, this can be built by simply reversing the three diodes D1 to D3 and capacitor C2. This is sometimes useful in circuits where a triac is to be triggered with the low current available from a supply of this type as they tend to be more sensitive to negative gate current.

ALARM SOUND GENERATOR

For the alarm, a distinctive sound was required. The world these days is full of things that go "bleep", especially in an electronics workshop, so something instantly recognisable was needed.

The circuit diagram shown in Fig. 3, produces a two-tone sound a bit like a panic-stricken police siren, using an ICM 7556 dual timer to generate the signal and a CMOS 4093B quad Schmitt NAND gate i.c. for control and output buffering functions.

HOW IT WORKS

A positive input causes the output of IC1a to go low, discharging capacitor C1 through diode D1. When the input goes low, IC1a output returns high and recharges C1 through resistor R2.

Recharging of C1 takes four to five seconds so there is at least four seconds of positive output from IC1b. This was arranged so that brief presses of the Doorbell would result in substantial output from the

remote repeater. If this feature is not required C1 can be omitted.

The output from IC1b powers IC2 which then generates the sound. This is a micropower version of the 556 dual timer and runs quite happily on the current available from the output of a single CMOS gate.

The two timers are connected as oscillators. The first, using resistor R3 and capacitor C3, runs at about 3Hz. The output of this, pin 5, is used to modulate the second by connection to its "control" input, pin 11, through resistor R4.

The centre frequency of this second oscillator is set to around 1.6kHz by resistor R5 and capacitor C4, but is modulated into a two-tone sound by the control voltage from the first. Its output, pin 9, is buffered and inverted by gates IC1c and IC1d to create a "bridge" output for the piezo sounder WD1, thereby obtaining maximum volume.

The output will be too loud for many applications so the resistor R6 can be added to reduce it. The value of 2.2 kilohms proved about right for the prototype but constructors can experiment with this.

ALARM CONSTRUCTION

Construction of the Alarm unit is carried out on a small piece of stripboard, with 11 strips of 45 holes, although only a length of 33 holes is taken up by the circuit. The

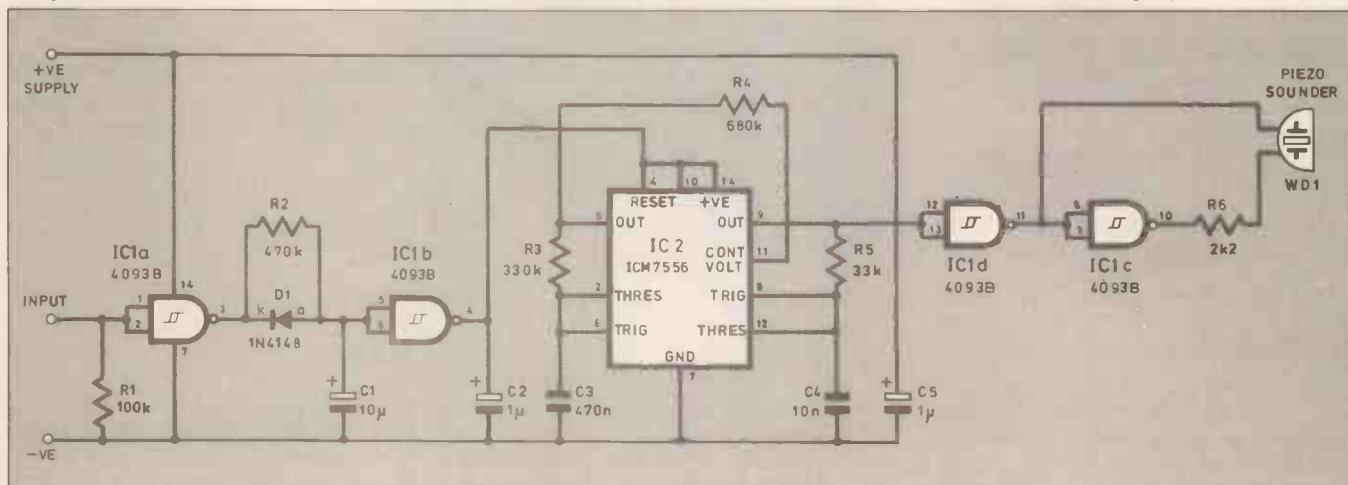


Fig. 3. Complete circuit diagram for the Two-Tone Siren Alarm.

COMPONENTS

Two-Tone Siren Alarm

Resistors

R1	100k
R2	470k
R3	330k
R4	680k
R5	33k
R6	2k2 (see text)

All 0.6W 1% metal film

Capacitors

C1	10 μ radial elect. 50V
C2, C5	1 μ radial elect. 100V (2 off)
C3	470n resin-dipped ceramic
C4	10n resin-dipped ceramic

Semiconductors

D1	1N4148 signal diode
IC1	4093B CMOS quad Schmitt NAND gate
IC2	ICM7556 dual CMOS timer

Miscellaneous

WD1	3V to 24V d.c., p.c.b. mounting, piezoelectric sounder
-----	--

Stripboard, 0.1in. matrix, 11 strips of 45 holes; case, ABS box 118mm x 98mm x 45mm; 14-pin d.i.l. socket (2 off); multistrand connecting wire; solder pins; solder etc.

Approx cost guidance only

£8

See
**SHOP
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Page

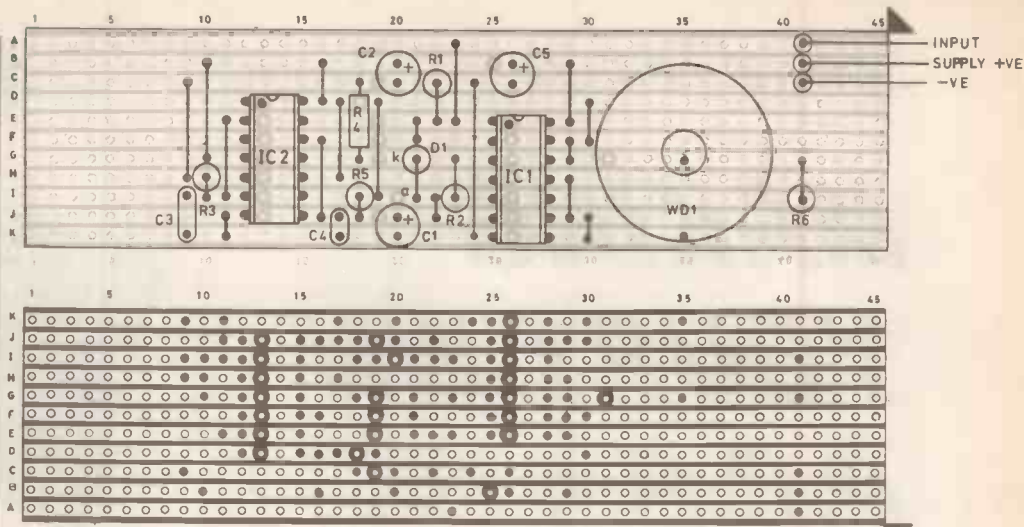


Fig. 4. Two-Tone Siren Alarm stripboard component layout and underside copper break details.

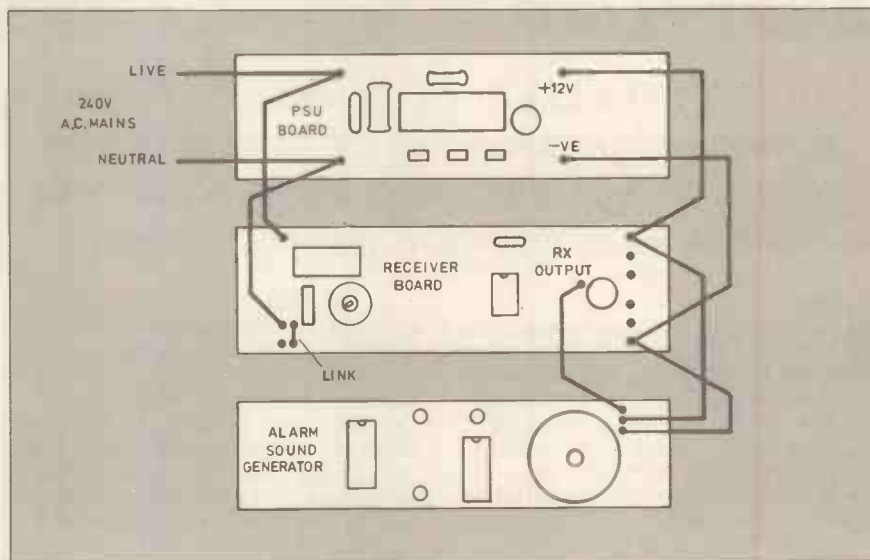


Fig. 5. Linking the two boards to last month's Receiver to produce a "through-the-mains" alarm repeater.

reason for the extra length of both this and the PSU is that they fit neatly into the moulded slots in the specified case used.

Underside breaks in the copper strips and board topside component layout are shown in Fig. 4. Construction should start with the cutting of the 23 breaks as shown, after which the 17 wire links can be fitted.

Following this the components can be inserted, care being taken to insert diode D1 correctly. As shown, it should have the marked (cathode) end facing down towards the board. As mentioned earlier, if the timed operation feature is not needed capacitor C1 should be omitted.

It is recommended that d.i.l. sockets be used for the two i.c.s. When inserting the i.c.s care is recommended as both are CMOS types and IC2, the ICM7556, has proved to be a trifle more sensitive than most to static. The sounder is a p.c.b. mounting type and is soldered directly onto the board.

Testing consists of applying a suitable supply voltage, anywhere between 5V and 12V and touching the input to positive. The unit will normally sound immediately on power-up as capacitor C1 charges. Following this positive pulses to the input should trigger further operation. Current drain should be zero in the standby state, and about 2mA to 3mA when operating, though this may vary a little with supply voltage and the value of resistor R6 if fitted.

IN USE

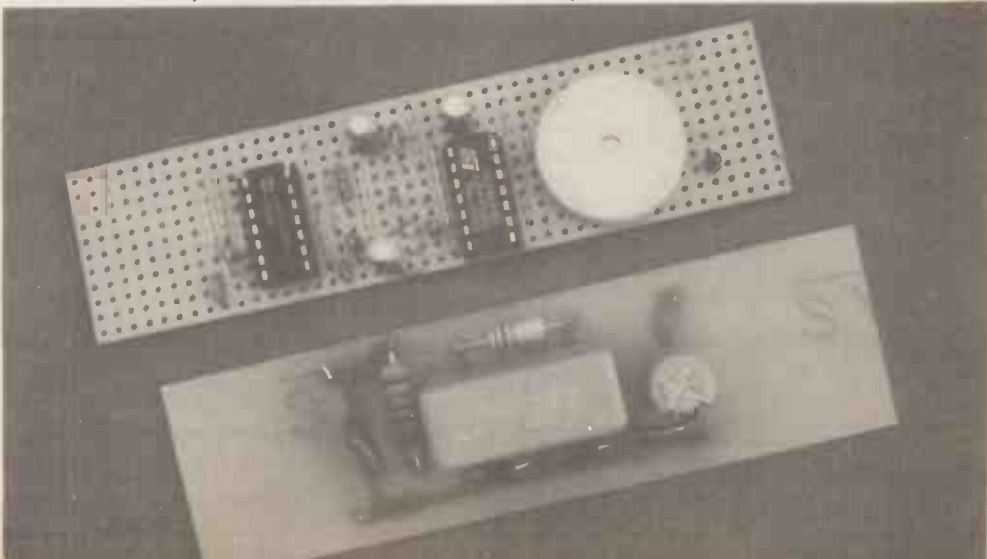
The wide supply voltage range and zero standby current features of this unit should ensure that it finds plenty of applications beyond the simple doorbell repeater it was designed for. However, if it is used with the Receiver of the Mains Signalling Unit described last month, it can be connected as shown in Fig. 5, which shows complete interwiring for the Alarm together with the PSU board.

Constructors of the Mains Signalling System might be interested to know that the Receiver of the signalling project originally had a much shorter time constant in the section of the circuit following IC1a, but when used with the Alarm Sounder board, with its timed output feature, it proved susceptible to false triggering caused by noise in the mains supply. The time constant, set by resistor R14 and capacitor C9 on the Receiver board, was increased to the value shown last month and the problem disappeared.

This setting is inevitably something of a compromise. The longer the time constant the better the noise immunity, but if it is too long there will be a perceptible delay in operation. With the present values operation still has an "instant" feel to it.

If any constructors do experience problems of this nature and are not able to cure them by adjustment of preset VR1 on the Receiver board, the value of capacitor C9 can be increased. At 470n there is a slight delay in response, but it should respond to most inputs satisfactorily. □

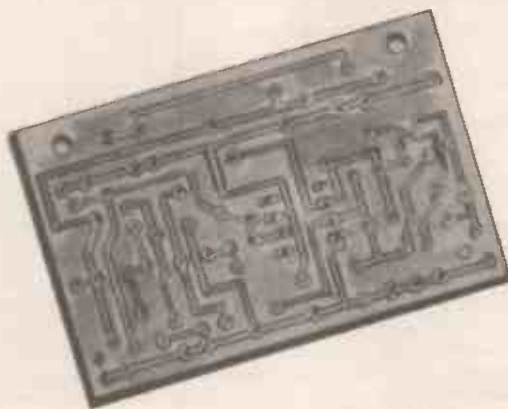
The completed Two-Tone Alarm and 12V Capacitive PSU boards.



MAKING YOUR OWN P.C.B.s

ANDY FLIND

*Printed Circuit Board Making on a Budget
Unmasking some of the pitfalls
that may be encountered when
producing your own p.c.b.s.*



SOONER or later, most serious electronics enthusiasts will want to make a printed circuit board, "p.c.b." for short, for themselves. Either a track pattern will be available but not the ready-made board, or it might be that a circuit has been designed from scratch and is considered worthy of a "proper" board rather than stripboard or tagstrip construction.

There are many ways to make a p.c.b. and over the years the author has tried most of them. As there are pitfalls for the unwary and often little advice on how to go about the task without expensive equipment, it seems worthwhile to pass on some of the experience gained.

Be Sensitive

Undoubtedly the best method for producing a p.c.b. is photographic, using a board coated with a photosensitive "resist" material. This is exposed to ultraviolet light shining through a track pattern on a transparent sheet, then developed and placed in etching fluid to dissolve away unwanted copper to leave the desired tracks. The resist is then removed and the board is drilled and trimmed to size ready for component assembly.

This method produces neat results, extra boards can be produced easily and, where necessary, minor layout alterations are usually simple to make.

At this point, readers may be wondering about the cost of a UV Lightbox and tanks for the chemicals, but in fact a lightbox can be built for a quite modest outlay and the chemistry can be carried out at the kitchen sink. There is definitely no need to shell out for a full production lab to produce the odd board for hobby use.

Making a Master

The first task in making a p.c.b. is to produce the transparent master. To do this by hand, a good method is to begin by drawing up a layout on 0.1 inch squared

graph paper. This paper is difficult to find in pads and often expensive, but large sheets can be bought cheaply in W.H. Smith and cut into conveniently sized pieces.

A soft 0.5mm pencil and pencil-shaped eraser are recommended for initial layout work as these make alterations as simple as they would be on a computer. This part can be done in comfort in front of the TV!

Once the layout is finalised, a transparent "master" is required. Stationers and photocopying shops can provide clear acetate sheets, and one of these may be taped in place over the layout and the track pattern laid out using either transfers or adhesive tapes and symbols. Using adhesive tapes is much preferred where this method has to be used.

Computer Aided

Where a computer is available, life becomes much easier. Many professional printed circuit packages are available (see *advertisements in this issue*) offering various extras such as schematic capture, autorouting, design rule checking and so forth. Often these features are more suitable for rapid prototyping than really good finished designs but the basic layout routines will always produce *clean artwork* and this can be done rapidly from a layout drawn up on paper.

Computer Aided Design "CAD" type drawing packages can also produce track patterns. For this work the program should have "layers" and "symbol libraries", and, of course, must be able to draw lines of widely varying width.

Layers are useful for generating different views of the board, with components on one layer, pads on another, tracks on a third and so on. These views can be turned on or off as necessary for layout and printing purposes. Symbols can be designed to represent the components used, various sizes and shapes of pad, and patterns of pads for i.c.s etc.

If any readers have Acorn Archimedes computers, the "Vector" art package sold by "4-mation" is highly recommended. This is similar to Acorn's "Draw", but has many extra features including layers and symbol libraries. Prior to the acquisition of a PC the author used this software for several years.

Computer generated artwork will need conversion into a transparent master. It might be possible to print direct onto transparency at 1:1 scale, but the author's attempts to do this with an ink-jet have so far proved unsuccessful. A good quality printout is not an absolute essential, inexpensive inkjets can do an excellent job and even an 8-pin dot matrix may be used if the output is scaled up and then correspondingly reduced on a photocopier.

The printed copy can be reduced and transferred to acetate transparency in one go, usually at a cost of around 50p a sheet. Most copiers can reduce to 70 per cent in one go, so the author's usual practice is to print at the inverse of this, 1.49:1, and then ask for a 70 per cent reduction straight onto acetate at the copyshop. This easily handles detail such as tracks between i.c. pins.

Shortcomings

This is a good time to discuss some photocopier shortcomings. To start with, photocopies are not usually dense enough for direct use in a UV exposure process. When held up to a light the black areas usually appear slightly "porous".

This is often worse in large black areas, which is a good reason for avoiding these in the layout. However, two copies carefully taped together nearly always achieve adequate density.

Another photocopier problem is that they don't always achieve the exact print size expected. Usually, at least for small boards, this is not a problem, but it's worth taking along a 1:1 printout for checking. A similar problem is acetate copies turning out at slightly different sizes, the difference being tiny but sufficient to prevent the holes in the pads lining up when they are taped together.

The cause of this is probably expansion of the acetate sheet; by the time the second

UV LIGHTBOX CONSTRUCTION

sheet passes through the copier will have warmed up so it will receive the image after being heated, and expanding, more than the first. A recent experiment was to ask for three copies instead of the usual two and, sure enough, two were a greatly improved match.

Right Exposure

Having produced the transparency, the next stage in the process is exposure. Pre-coated photosensitive board is available from most electronic suppliers and is easy to use. The instructions supplied by a major retailer used to suggest that exposure could be carried out with incandescent light.

Don't bother trying this! The author once did, using a 500-watt bulb and an exposure of about fifteen minutes. The results were very fuzzy, certainly not good enough to warrant any further use of this method.

Ultraviolet is essential for the exposure. However, it is certainly not necessary to shell out seventy quid or so for a lightbox as this can be constructed for little more than the cost of the tubes, starters and a choke. Currently the cheapest source of tubes is probably Electromail, who offer a kit consisting of two 8-watt replacement tubes with starters for their small lightbox at a very reasonable cost.

Constructors can design their own exposure unit using these, the essential dimensions are shown in Fig. 1. Connections for the components are shown in Fig. 2, where it will be seen that only one choke is required to supply both tubes.

Glass can usually be cut very accurately to size for very little cost by a local glazier. The exposure time required varies with different makes of board but is usually somewhere between two and six minutes. Since the board is fairly expensive, it's worth trying some small test pieces to determine the optimum time before committing a larger and more expensive bit.

Chemical Works

Once the board has been exposed, it's time to open the chemical works! This consists of developing the photosensitive coating so that the exposed portion dissolves away and the remainder is "fixed", remaining to protect the copper beneath it during etching.

It's possible to develop using dissolved caustic soda crystals, but this appears to be very temperature dependant so a proprietary developer is preferable for the job. This is cheap and re-useable, and gives much more consistent results. It's important to allow enough time for all the unwanted resist to dissolve, otherwise a thin film may be left which can hinder the etching.

Commercial tanks are available for developing and etching, especially the latter where the solution is often heated and agitated by bubbling air past the immersed board. Again, this is not essential, the processes can be carried out in literally any glass or plastic container that will hold the chemicals and the board. The lack of bubble agitation simply means the process will take slightly longer - but a cheap aquarium air pump could be used for the task.

As with developing, ferric crystals are available for making up etching fluid, but the preferred and most convenient method is to use ready-mixed fluid. This lasts for ages before having to be discarded, so the

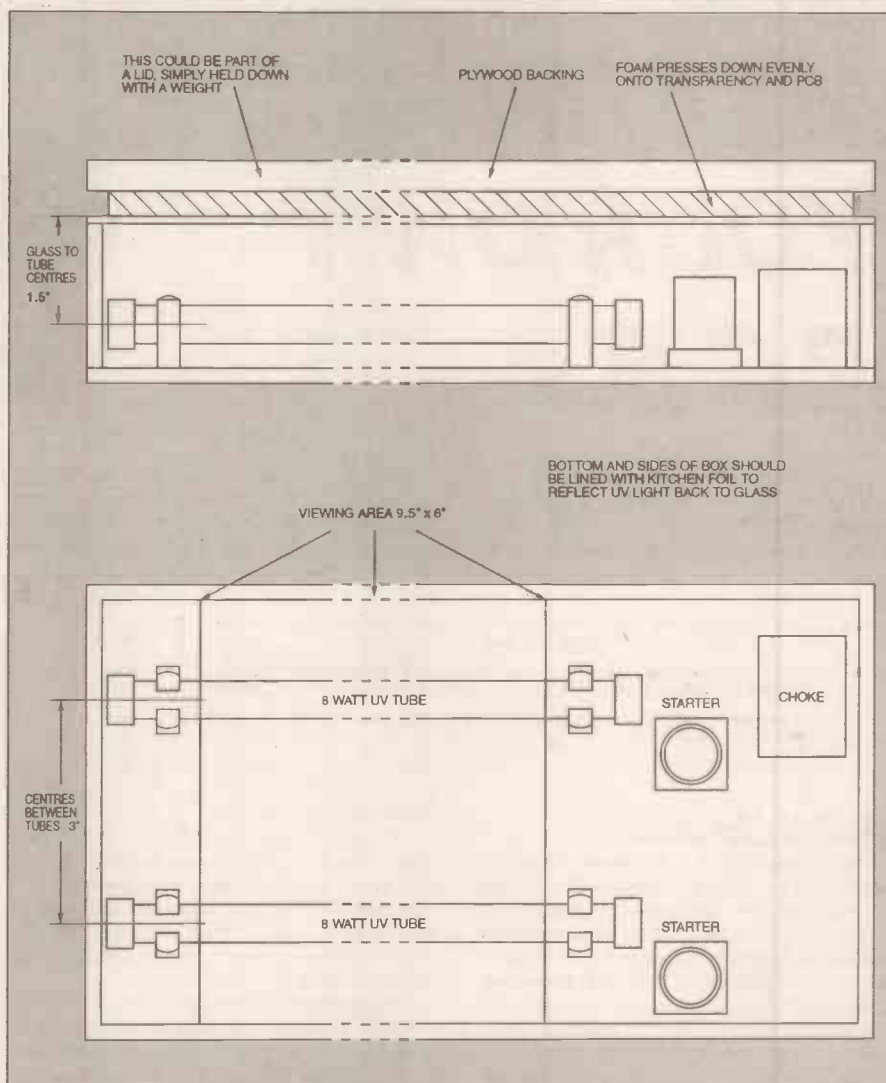


Fig. 1. Dimensions and layout suggestion for a two-tube UV Lightbox.

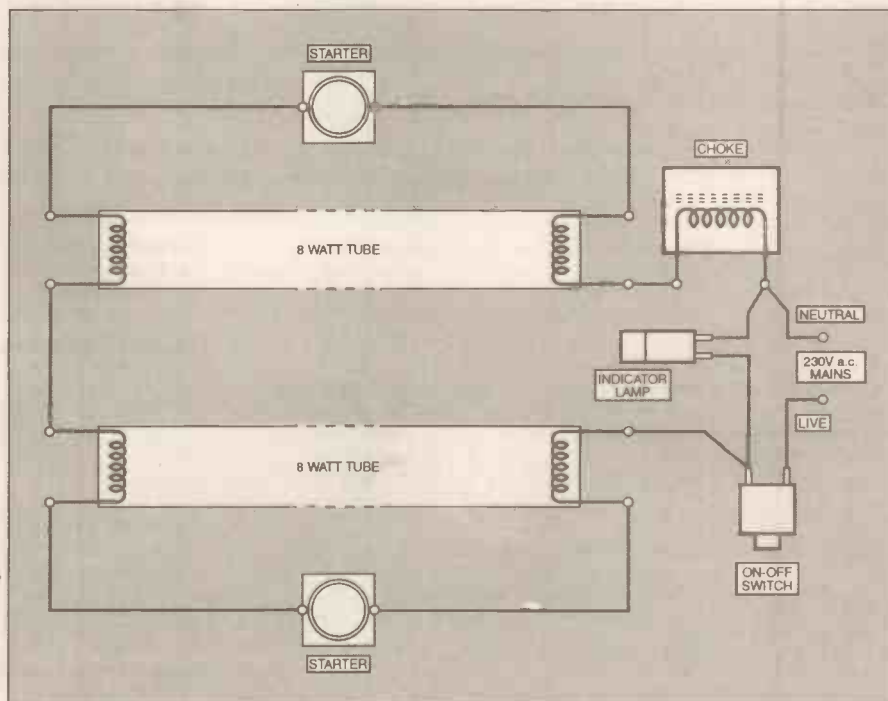


Fig. 2. Interwiring between tubes, starters, choke, mains switch and indicator lamp. Note that the unit should be wired with a switch that only allows the tubes to be turned on when the lid is closed. UV can damage eyes.

small extra cost is not an important consideration.

In Suspension

During etching, the solution becomes heavier as copper dissolves into it so the board should be arranged to allow the fluid to fall away from it as this happens. Small boards can be stood on edge in a jar of fluid, larger ones can be supported face down in a flat tray.

The author's latest method is to make a support by twisting single-core plastic covered wire round the board as shown in Fig. 3, which holds it in the correct position and provides a convenient "handle" for removal. An extension of this would be to support the board vertically with a wire loop that would hook over the edge of a jar, keeping it just clear of the gunge that inevitably forms in the bottom of such a jar.

Many domestic chemicals such as disinfectants, cleaners etc are now supplied in plastic bottles that are oval rather than round in section, the bottom half of one of these would make an ideal small etching tank.

Etching time depends on the state of the fluid and on temperature. Heat speeds the process considerably so it is worth placing the tray in a sink of hot water to warm it. Don't make the mistake once made by the author of placing a glass dish over a low gas flame though – the heat cracked the dish and the etching fluid did the cooker no good at all!

Polished Job

Following etching, the resist must be removed from the remaining copper tracks. Special chemicals are sold for this, but a wire-wool pad does the job just as well and imparts a wonderful polish to the copper beneath, leaving it in ideal condition for soldering. Thorough washing and rinsing is essential to remove every trace of etching fluid.

The chemicals used are not so much dangerous as unpleasant. The developer is caustic; if it comes into contact with the skin it will give a nasty "soapy" feel that

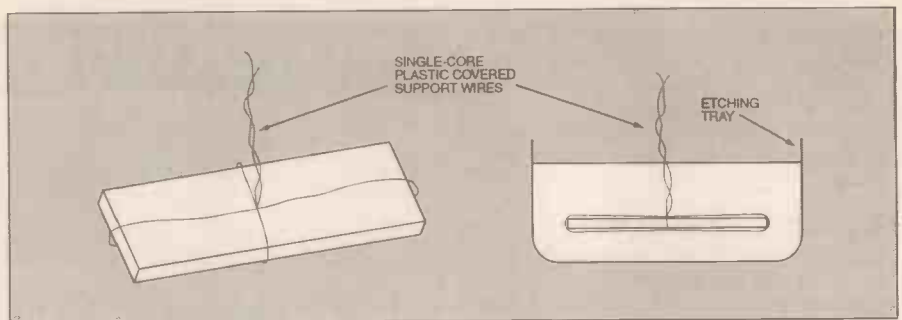


Fig. 3. Supporting a printed circuit board for etching.

persists even after thorough washing. *Eye contact should be avoided at all cost.*

The etching fluid will permanently stain almost anything it comes into contact with and corrode just about any type of metal. It even appears capable of producing "rust" spots on stainless steel.

However, contact with the fingers seems to produce nasty staining rather than instant burns. The rule for handling both must be to wear rubber gloves and handle with great care to avoid splashes and spillage. Eye protection in case of splashes is also advisable.

Right Drill

Finally, some notes on drilling the board. In general it is very difficult to drill a p.c.b. using a hand-held drill. It certainly can't be done with the Black and Decker, though one of the mini-drills used for fine modelling work might do.

The ideal is a mini-drill with a suitable stand. They usually require an amp or two of d.c. supply, but check the junkbox for a suitable transformer before buying a custom power supply. If one is to hand, all that is needed with it is a bridge rectifier so again useful savings can be made.

Hole size for component leads is usually 0.8mm or 1mm. Occasionally larger components, or items such as presets, will require 1.3mm. The author usually drills all the holes to 1mm and opens up any that prove too small during construction, using the mini-drill.

If the board is Paxolin there will be no problem with drill bit type but glass-fibre board, preferred by many constructors, blunts ordinary steel drills rapidly. Solid carbide drills last much longer but are very fragile. They are also far more expensive so it is very frustrating when one breaks.

However, don't let anyone tell you they are for machine-controlled drills only. With suitable care a 1mm solid carbide bit can be used with a mini-drill in a stand, and will remain sharp enough to cut clean, accurate holes for far longer.

Have A Go

One final tip concerns preservation of the board after construction. Commercially-produced boards are normally roller-tinned. This prevents oxidation indefinitely, so the board always solders well and looks clean. The bare copper of a home-produced board does not have this advantage and will oxidise quite rapidly.

For easy soldering construction should be carried out fairly soon after cleaning, within say, a day or two. A coating with a spray-on p.c.b. varnish will then keep it looking good almost indefinitely, and will help to reduce other problems such as insulation breakdown between tracks.

Hopefully, these hints and tips will encourage many more enthusiasts to "have a go" at making their own p.c.b.s to near professional standards. Who knows, in time we might even see some of the results in the pages of *EPE*. □

Fault Finding

Here is a fault-finding guide to help locate any problems that might arise when producing boards using the ultra-violet technique.

Develops O.K. but excessive exposure time required.

Artwork drafting film is too opaque – use appropriate clear/translucent film.

Aerosol resist coating too thick – increase exposure time or use spray more sparingly.

UV tubes need replacing.

Very long developing time, or resist does not develop fully or at all.

Resist is underexposed to UV light: – increase exposure period according (only areas which have been thoroughly exposed to UV light will be developed).

Resist may also be too thick or artwork film too opaque, and has not been thoroughly activated by the UV light – see above.

Developer cold, weak or exhausted. Renew.

Image is developed but then disappears.

PCB has been over-exposed. Reduce exposure time. (Applies especially to good quality sensitive pre-coated boards.)

Artwork layout is not opaque to UV light, permitting UV to pass through transfers etc.

Board has been left in developer for too long.

All of the etch-resist disappears when developing.

Developer could be too hot or concentrated.

The whole board has previously been exposed to UV light. (e.g. sunlight).

Unwanted copper is left on the p.c.b. when etching.

Unwanted etch-resist left on board, due to under-exposure or under-development. Try removing excess resist with a cotton-bud dipped in acetone, then re-immense in etchant.

Excessive etching time.

Etchant may be exhausted: – dispose of safely and renew.

Narrower tracks are etched away.

Over-exposure to UV may affect very narrow etch-resist tracks which will be removed/reduced in width by etchant.

Developer or etchant may be too strong, undermining narrow sections.

Copper pads lift off when soldering.

Excessive heat applied during soldering.

Diameter of pads too small.

Diameter of the drilled hole too large!

If conductor is intact, repair by applying Super Glue Gel to the affected area, to encapsulate the lifted pad in resin.

Breaks in copper track.

Flaws in etch-resist coating or artwork.

Extremely thin conductors may be undermined by excessive etching time, resulting in the tracks being etched through.

Repair with silver-loaded paint or solder in a jumper wire.

Is your PCB design package not quite as "professional" as you thought? Substantial trade-in discounts still available.

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- Forward annotation with part values
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£395

BoardMaker

BoardMaker1 - Entry level

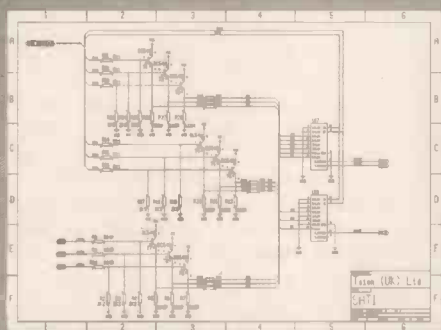
- PCB and schematic drafting
- Easy and intuitive to use
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- Ground plane fill
- Copper highlight and clearance checking

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BoardMaker2 - Advanced level

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Board Router

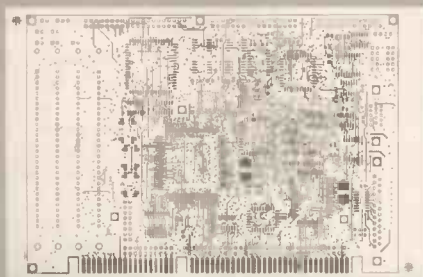
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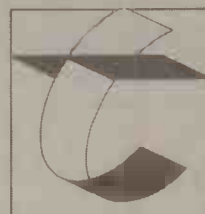
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IN-CIRCUIT ALARM AIMS TO DETER COMPUTER THEFT

— by Hazel Cavendish

If you were one of the 775,000 British motorists who had your car radio stolen this year, relax. Better times are ahead. If it was your home PC or office computer that went missing, the news is even better. A happy collaboration between miniaturisation expert William Johnson and two top scientists from the University of Southampton has resulted in the development of a remarkable little alarm device which aims to protect all electronic equipment from theft in a way that has never before been achieved.

A-SIC Burglar

"ELARM" breaks new ground in being so miniscule that it can be built directly into an application specific integrated circuit (ASIC) of any computer, radio, TV or video — or, indeed, any electronic unit. The alarm has its own power source and is activated the moment the current is cut off — such as when the thief unplugs the equipment to escape with his loot. The owner possesses an ultrasonic key which switches it on and off (and his spouse can have one too).

What about power cuts? Those boys have thought of that. The machine can pick up the surge which always precedes a power cut, and the Elarm chip is programmed to be "intelligent" to that possibility and will ignore it.

Even an ever-sceptical Police force admits to being keenly interested in the new device. Chief constables countrywide are deeply concerned by the £600 million figure of computers stolen from offices over the last year, and Inspector Alan McInnes, Secretary to the Chief Police Officers' Crime Prevention Committee, says they are always ready to look at anything likely to prove effective in dealing with the problem of computer theft. He added that a great many electronic devices intended to protect had appeared on the market without marked success in achieving their aim.

"This new development could present a great advantage if its electronics form an integral part of a computer, or other electronic product, which is subsequently unable to be compromised by someone attacking it, or by a thief using a computer disk to access it," he said.

Human Reaction

The event which brought about such a profitable partnership at the University was just another street crime — hardly remarkable in the big city of Southampton — but in this case the thief who stole an expensive radio from a brand-new Audi chose the wrong man to rob, and did his fellow criminals no favours. The Dean of the Faculty of Engineering and Applied Sciences is a world expert on

human reaction to noise, uniquely well placed to mastermind an alarmed device as he occupies the chair of Subjective Acoustics in the University's Institute of Sound and Vibration Research.

Professor Christopher Rice was still fuming when he telephoned Willy Johnson in Guernsey. "Let us get together and do something to beat these thieves," he said. "How about combining your inventive powers with the facilities offered by our Faculty to find an answer to the problem?" Johnson, never averse to a new challenge, agreed at once, but added "Stolen computers are being taken off by the lorry load, and if we find a way of alarming a car radio we should be able to extend that protection to the computer market."

Transducer

Dr Stephen Hughes, Director of the University's Institute of Transducer Technology, was invited to join the team as his department's main research subjects include transducer interfacing, ultrasonics and the design of electromagnetic transduction devices.

Eight months later the team's £100,000 project produced the first prototype of Elarm for demonstration at the private launch. It was half the size of a small matchbox and emitted a terrifying volume of noise when



Prototype of Willy Johnson's Elarm, with a typical d.i.l. i.c. to show scale.

activated. The final device will be even smaller than the prototype. The electronic system which releases 110 decibels continues to sound for 10 minutes.

"Such a volume of noise at close quarters will be so startling that the reaction of a thief will usually be to get away from it as quickly as possible," said Professor Rice. "If he should attempt to stay to try and stop the noise he will not succeed, because the extremely robust device is embedded in the system. In the event of him attempting to escape with such an attention-grabbing item, it will restart immediately he tries to reconnect the equipment elsewhere.

Elarm will be codified, and every electronic unit of equipment containing it will carry a unique indelible sign. Johnson



Left to right, Dr Stephen Hughes, Willy Johnson and Prof. Christopher Rice, with the prototype alarm.

points out it should soon become known in criminal circles, and will result in thieves avoiding anything marked with the symbol as being altogether too troublesome, and impossible to "move on".

Certain misgivings about noise have been expressed by the Police. Inspector McInnes observed that the University team would need to pay regard to the 1993 Noise and Statutory Nuisance Act, while a Hampshire Crime Protection officer feared the sounding of the alarm in city streets, when attempts to steal radios set them off, would be likely to worry Environmental Health authorities. Johnson's riposte was that Elarm would

only sound for 10 minutes, whereas troublesome house and some car alarms went on all day.

Dr Hughes says "We are looking at a 5mm x 5mm cube. The limiting size of 5 x 5 is because of the acoustic requirement that one needs space to get sound out, but the actual electronics - the driver for the sound - will be very small. The other limitation on size is the battery, so we need to use the best quality and the highest power density that is re-chargeable."

Surprising is the low cost of building-in the new deterrent. Johnson believes their invention need only add a maximum of £5

to the cost of each electronic unit, with a slightly higher cost anticipated for one that is retro-fitted. A demand for the latter is anticipated, as many people in possession of valuable computers, or with expensive stereo equipment in their cars, may wish to avail themselves of the new deterrent.

Initial reaction to the new system is encouraging to the team. Fourteen multinational blue-chip companies and computer manufacturers have shown interest in the invention, which was launched hard on the heels of the Government's IT Security Survey focusing on the escalating wave of chip thefts throughout the country.

SOOP-ER TELGUARD

"Soop-er, smashin' lovvli - loook wot wi wun!!" So starts the latest Press Release from ComTel!

Back in our Jan '95 issue, we gave publicity to ComTel's excellent new security system, TelGuard. The company now tell us that this publicity has helped them to attain considerable business success through enquiries from readers. (We like the chatty style in which we have been told!)

Just to recap, TelGuard is a Communications and Access Control System. Using the existing telephone network, it enables you to remain in control of your property from anywhere in the world. It is vandal resistant and weatherproof, and can be flush mounted in a brick pier or wall. Surface mounting can also be done, for example, by using a purpose built stand at a height and position convenient for drivers and pedestrians.



Natalie Earl, TelGuard's self-styled Marketing "Mangler" says that had it not been for readership response to the news item, she would not have been able to put forward TelGuard as a serious contender for the Innovation Award of the Surrey Business Awards 1995. Entry to this award required proven product marketing success and evidence of effective PR.

We are delighted to report that TelGuard won this award! Well done TelGuard, and Natty!

For further information, contact Natalie Earl, ComTel Ltd., P.O. Box 192, Dorking, Surrey, RH4 3YJ. Tel: 01306 877889.

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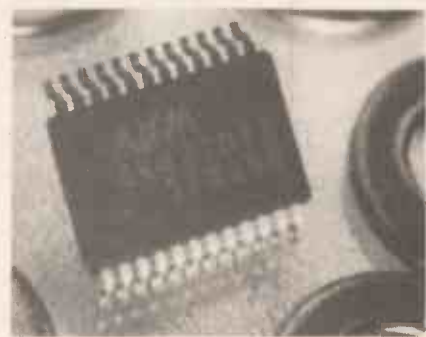
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STEREO DAC

Audio-constructing enthusiasts will be interested to know about the new 16-bit stereo digital-to-analogue (DAC) chip recently introduced by DIP International.

The AK4310 operates at three sampling frequencies, 32.0kHz, 44.1kHz and 48.0kHz. Although designed principally for multimedia and portable audio equipment applications, it will undoubtedly find favour with those who delight in experimenting with the designing of digital audio circuits.

The device features high accuracy to clock jitter as it uses switched-capacitor filter (SCF) techniques, which in turn allow on-chip post filtering.

Total harmonic distortion/noise is quoted at -86dB. The device has a dynamic range of 92dB and a wide band of voltage operation from 3V to 5.5V. Packaged in a 24-pin surface mount format (SSOP) the AK4310 has a low power dissipation of 75mW at 5V and an operating temperature range from -10°C to +70°C.

For further information contact Simon Hilson, DIP International Ltd., Dept. EPE, Sheraton House, Castle Park, Cambridge, CB3 0AX. Tel: 01223 462244.

subject interests you (and one of them must as you're reading *EPE!*), then do get hold of their latest catalogue, it lists masses of highly desirable printed data sources, and at very reasonable prices.

Subjects cover Satellite and TV, Computing, Video, Audio, Office, CB Radio, Semiconductors and much else. Also included is information about the expansion of their popular Monitor Circuits Compendium, which is now into its second volume.

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New Technology Update

Ian Poole asks "is this the comeback of bipolar transistors?" and also looks at the impact cell phone production is having on i.c. technology. Are manufacturers calling the tune?

CELLULAR phones are being produced in vast quantities these days. Manufacturers like Motorola, Nokia and many others are leading the way producing smaller and more complicated designs. This development is having a major impact on shaping many sections of the electronics industry.

In view of the enormous volumes involved, these manufacturers are able to call the tune with their requirements. New battery technologies are emerging to fill the requirement for longer operational times, and many new i.c.s have been designed specially for cell phones.

Many of the very specialised i.c.s have a very short production life. In view of the enormous volumes, some i.c.s may be designed for a specific manufacturer, or even for a particular phone and the production life of the chip may only be a year or two.

Despite the fact that manufacturers can lead the market where they want it to go there are still a number of areas where levels of integration are not as high as they might want. Radio frequency circuits is one particular area.

Monolithic microwave i.c.s (m.m.i.c.s) have been available for a number of years. These chips have virtually all the necessary circuit elements including inductors integrated onto a single chip. However, they are generally aimed at much higher frequencies than those used for cellular phones.

Although some m.m.i.c.s are available at reasonable cost, generally the ones with a wide range of printed components are very expensive, and well beyond the cost of anything which might be considered for cellular phones where price is a prime consideration.

Integrated Level

One of the keys to making mass produced equipment cheaper is to increase the levels of integration. Accordingly, engineers at AT&T in Reading, Pennsylvania have devised a new system that enables inductors to be placed onto one of their silicon processes. This enables many more functions required in radio frequency design to be put onto the integrated circuit.

The inductors are fabricated on a silicon process called CBIC-V2 introduced just over two years ago. This was introduced as a result of industry demand for a low cost radio frequency technology for cellular phones. With this process it is possible to integrate a wide variety of radio frequency components and functions onto the silicon.

The basic CBIC-V2 process uses vertical *npn* and *pnp* transistors with cutoff frequencies of over 5GHz. As the process also

generates low-noise circuits it forms the ideal basis for fabricating high performance radio frequency integrated circuits. Now with the possibility of including inductors onto the basic chip the flexibility of the process has been vastly increased.

The inductors have a quality factor or Q of up to twelve. This is not as high as most conventionally wound inductors. However, it is four times higher than anything which was previously possible and it is perfectly adequate for many applications. Indeed, the low Q is partly compensated by the fact that the inductor is on the chip itself and does not have long leads with high levels of spurious inductance and capacitance.

Gold Standard

The inductors are formed by laying a layer of metallisation down onto the substrate in the required pattern, as shown in Fig. 1. One of the problems with achieving a high level of Q with a normal process is that a very conductive substrate increases the transmission losses reducing the effectiveness of the coil.

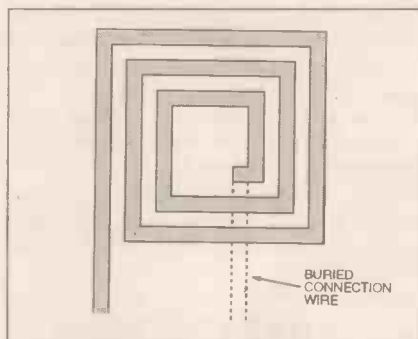


Fig. 1. An i.c. inductor.

Typical figures for the resistivity of normal substrates might be around 10 ohm/centimetres. The substrate for the CBIC-V2 process is much higher at around 200 ohm/centimetres.

To improve the performance of the inductor even further aluminium used for most i.c. metallisation processes is replaced by gold. This reduces the resistance of the coil, another feature which improves its Q .

Track widths can be anywhere between five and 24 microns, with the gap between them only four microns. With these dimensions and the square coil, inductors with values between two and 35 nanoHenries can be made.

From the diagram it can be seen that one of the problems to be overcome is that the centre connection needs to be brought out to connect with the other circuitry. This is done using a wire running under the coil. This is insulated from the remainder of

the coil using a thin layer of silicon oxide nitride.

Using these coils it is possible to save having to include costly inductors outside the chip. Tuned circuits and various forms of filter can all be made, reducing the number of components which are required outside the chip and thereby enabling the performance of the whole circuit to be improved.

Bipolar revitalised

Nowadays everybody seems to be looking to f.e.t.s to replace bipolar transistors. However, the bipolar transistor is fighting back and proving that there is still plenty of life in this technology.

Field Effect Transistors (f.e.t.s) are fast, have a good high voltage performance and they are easy to drive. For similar die sizes, though, the f.e.t. will have a higher ON resistance. The way around the problem is to increase the size of the die, but this results in the device needing a larger package.

This means that the cost increases, reducing the advantages of the f.e.t. when compared to a similar bipolar transistor. Although the bipolar transistor may appear to have an advantage there are still some problems to be overcome.

Increasing the current capability of a f.e.t. is relatively simple. They consist of thousands of small f.e.t.s in parallel. Increasing their capacity simply requires more f.e.t.s to be placed in parallel in the die.

Matters are not nearly as simple for a bipolar device. It is not possible to place a number of transistors in parallel with one another in the same way. Instead the structure of the device has to be changed.

A bipolar transistor uses the substrate as the collector, as shown in Fig. 2. The base and the emitter are areas which are diffused into this. As a result the base of the transistor is buried in the structure.

In order to increase the current carrying capability of the device, the current flowing into the base must be increased, and distributed evenly over its area. Unfortunately

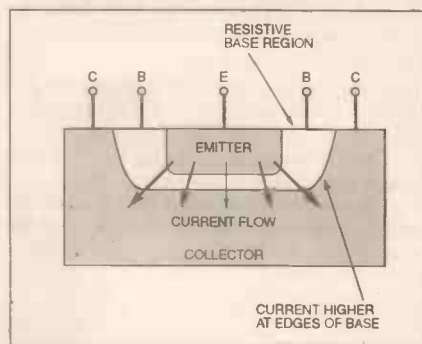


Fig. 2. A typical bipolar transistor.

the base area is resistive and this means that there will be less current flowing in the inner regions of the base than those closer to the edge. In turn this leads to an uneven flow of collector current and poor usage of the transistor's capability.

To overcome this problem a matrix structure has been developed by Zetex. This involves connections being made to the inner parts of the base through vertical wells cut through the emitter section of the transistor, as shown in Fig. 3. Aluminium metallisation is then used to ensure that all areas of the base are connected together, thereby allowing efficient use of all the area available.

The results of this process enable small transistors to be used for switching very high currents.

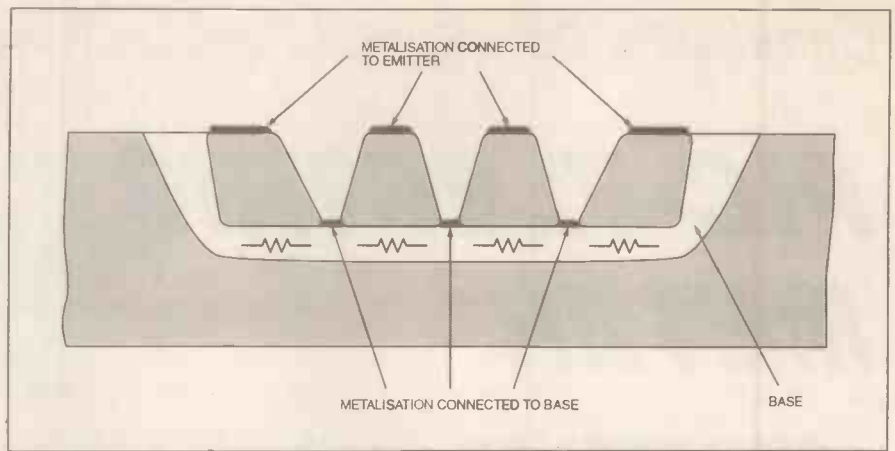


Fig. 3. The concept of a matrix transistor.

SHOP TALK

with David Barrington

PIC-Electric Meter

Some of the components needed to complete the requirements for the *PIC-Electric Meter* have been specially selected for their "performance" and consequently the printed circuit boards have been designed to accept these components. Also, being a bit "special" these are not readily available items.

The special "Hall-effect" current transducer is an RS device and is the multi-range version. This can be ordered through their mail order outlet, **Electromail** (☎ 01536 204555) code 286-311.

The 3VA mains transformer, with twin 12V secondaries, was also purchased from the above source, code 210-780. Likewise, the four-digit 7-segment display was obtained at the same time, code 597-024 (common anode). Other common anode displays may possibly be available from different suppliers, but check the pinout alignment against the circuit and p.c.b. before purchase.

In case of any difficulty in finding the TLC549 8-bit serial ADC, this can be ordered (see above) as: code 650-093. Do NOT use the 4078 (from the 4000 series of i.c.s.), the near-equivalent, in place of the 74HC4078 OR/NOR gate, it does not have the extra OR gate.

A ready-programmed PIC16C84 EEPROM is obtainable, together with the two p.c.b.s, from **Magenta Electronics**, Dept EPE, 135 Hunter Street, Burton-on-Trent, Staffs, DE14 2ST, for the sum of £21. They are also happy to supply the p.c.b.s on receipt of £9.90 or the chip alone for £12. There is a post and packing charge of £3.

The two printed circuit boards for the *PIC-Electric* are available from the *EPE PCB Service*, codes 977 (Sens/PSU) and 978 (Cont/Disp) respectively. The source-code listing is obtainable on a 3.5in Disk (together with the Simple PIC Programmer software) from the Editorial Offices (see page 101 for address) for £2.50 (overseas - surface £3.10; airmail £4.10).

Analogue Frequency Meter

The LM2917N frequency-to-voltage converter i.c., which forms the heart of the *Analogue Frequency Meter* project, may prove a little elusive to find locally. Most of our component advertisers should stock this item, but you must request the 14-pin version when ordering.

Similar problems may arise when trying to locate a local source for the voltage converter i.c. This device may be prefixed with the letters ICL or SI and either chip is suitable for this circuit. The ICL7660 is currently listed by **Electromail** (☎ 0153 204555)

and **Farnell Components** (☎ 0113 263 6311) and the SI7660, as used in the model, by **Maplin** (☎ 01702 554161), code YY75S.

Remember to quote the L suffix when ordering the BC184L and BC214L transistors, other types have differing pinout arrangements. The 22-turn cermet potentiometer should be the vertical mounting type with an in-line pin format and a top adjusting preset screw.

There are various options open regarding selection of the meter and this is left to individual choice. Suffice to say, **Bull Electrical**, **Greenweld** and **J&N Factors** often have "deals" on panel meters and it may pay to ring them first before making a final decision.

The single-sided printed circuit board is available from the *EPE PCB Service*, code 957.

Mains Signalling Unit

Particular care must be exercised when selecting the two resistors and capacitor C1 for the small 12V *Capacitive PSU* section of the *Mains Signalling Unit*.

The resistors should be new and unused metal film types: Resistor R1 being rated at 2W; and R2 from a "high voltage" range, quoted as being up to 2500V a.c. and 3500V d.c. for the one megohm value. These should be available from most of our components advertisers, the ones used on the p.c.b. came from **Maplin**, codes D120R and V1M respectively.

As with last month's Transmitter and Receiver, capacitor C1 **MUST** be new and rated for *continuous* connection directly across the 230V a.c. mains supply. These capacitors are normally sold as suppression components and should be available from any good component supplier. The one on the PSU board is a "high voltage interference suppression (IS)" type purchased from **Maplin**, code JR36P. A normal high voltage capacitor is NOT suitable and **MUST NOT BE USED**.

The transient suppressor or voltage dependent resistor (VDR) also came from the above source, code HW13P. The PSU printed circuit board is available from the *EPE PCB Service*, code 975.

We do not expect any buying problems to be encountered when putting together the parts for the *Two-Tone Siren Alarm*.

Finally, constructors of the Mains Signalling Units must heed the warnings in the articles regarding the presence of mains voltages and take due care. It is important that all polarities are double-checked before making any final connections.

Simple PIC16C84 Programmer

As far as the components for the *Simple PIC Programmer* go, they should all be readily available from your usual component supplier. Most of them should have supplies of unprogrammed PIC16C84 microcontrollers and certainly carry the 25-way D-connector.

Switching to the programming side, the TASM software and associated program files (but not including a text editor) are available on 3.5in. disk from the *EPE* Editorial offices for £2.50 (overseas - surface £3.10; airmail £4.10) to cover administration costs. This is not a payment for the software itself, for which we make no charge. The disk also contains the *PIC-Electric* software.

The current registration fee for the shareware TASM assembler software is about £25. This fee is only payable if you intend to *regularly* use the software beyond a *reasonable* evaluation period.

Readers are strongly recommended to honour the registration payment request. Payments for the use of the TASM software can be made to a USA address, details are given on the disk.

For further information about TASM and other shareware software contact: **The Public Domain Shareware Library**, Dept EPE, Winscombe House, Beacon Road, Crowborough, Sussex, TN6 1UL.

Vari-Speed Dice (Teach-In '96)

We do not anticipate any component buying problems to occur to when shopping for parts to build the *Vari-Speed Dice*, this month's *Teach-In '96* project.

The small p.c.b. for the Dice is available from the *EPE PCB Service*, code 974.

PLEASE TAKE NOTE

Sound Switch (Oct '95)

The remote location of the sensing loudspeaker extends the mains earth (via 0V rail of 12V supply) outside the building. Under exceptional mains fault conditions, it could be "live" up to 240V relative to any nearby surfaces at ground potential (e.g. metal railings, metal greenhouse frames) and may present a shock risk.

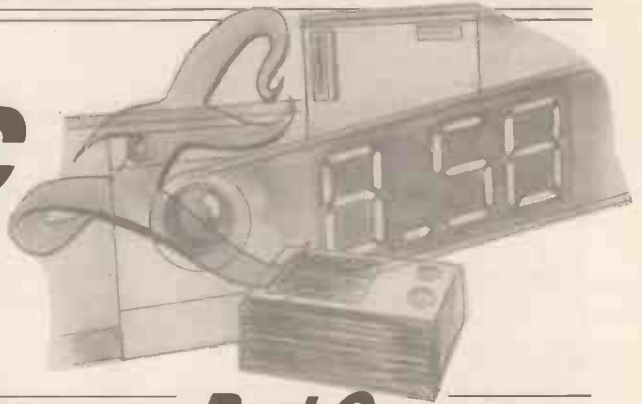
Readers should ensure that the cable to the speaker is doubly insulated and that the speaker itself is adequately enclosed in its plastic case without possibility of external contact to it being made. If in any doubt, consult a qualified electrician.

Similar action should be taken when any mains earth connection is extended outdoors.

Digital Delay Line (Nov '95)

Some readers have experienced excessive output level problems from the Digital Delay Line. The output level of the circuit can be reduced by increasing the value of R9. If the problem is related to input overloading, it might be better to increase the value of R1. The value of R6, which controls the gain of the 8955's internal preamp, could be reduced.

PIC-ELECTRIC METER



JOHN BECKER

Part One

Know just how much each electrical appliance in your home is adding to your electricity bill.

Learn more about the EEPROM version of the PIC family of microcontrollers.

THIS microcontrolled PIC-Electric Meter monitors domestic electricity consumption and gives a digital readout of cost. Any 230V to 240V a.c. mains powered electrical appliance, such as a Fridge; Washing Machine; Tumble Dryer; Room Heater; Kettle; Computer and so forth, can be plugged into the meter.

Loads from about 60W to 3500W can be monitored. Data acquired using the meter has obvious benefits in terms of evaluating the economical use of most household electrical equipment, so helping to keep electricity bills down.

Since PIC-Electric carries potentially lethal mains voltages at high currents, its construction should only be undertaken by an experienced constructor. It should NOT be attempted by the beginner, unless carefully supervised by a qualified person.

Be aware that while PIC-Electric is plugged into the mains supply, potentially lethal voltages will be present within its case. Always *unplug* the unit from the mains *before* making any assembly changes.

WHAT IT DOES

Current sampling takes place 100 times a second, detecting the amperage being drawn by the monitored appliance at the positive and negative peaks of each mains a.c. sinewave. The total number of electrical units (one unit = one kilowatt/hour) and the cumulative cost since monitoring commenced is updated at each sampling.

A four-digit l.e.d. module displays the results, automatically alternating between the two totals. Elapsed time since monitoring started can be displayed by pressing a pushbutton switch. Instantaneous load values can also be displayed.

The cost per unit of electricity, to two decimal places, is programmed into PIC-Electric by two pushbutton switches. The value is stored in the microcontroller's non-volatile memory which retains the data even when it is unpowered.

Stored information can be updated at any time. The cumulative totals of the units used and their cost are reset each time PIC-Electric is switched on, and can also be reset at any time during monitoring.

The advantage of taking samples synchronously with the mains cycles is that with appliances whose consumption varies irregularly, such as a washing machine working through its programmed cycle, for example, the operational costs over a given period can be calculated with an excellent degree of accuracy. Estimating the running costs of such equipment from its quoted maximum wattage specification is highly unreliable.

Cumulative units and cost are displayed in a repeating cycle of four display formats: pounds, pence to two decimal places, hundreds of units, tens of units to two decimal places, each being displayed for about five seconds.

IN CONTROL

The microcontroller used in the PIC-Electric is the PIC16C84 device manufactured by Microchip Technology. This is a high performance, low cost, CMOS device having 1K × 14-bits of EEPROM (Electrically Erasable Programmable Read-Only Memory) program memory, 64 bytes of 8-bit EEPROM data memory and 36 × 8-bit general purpose SRAM (Static Random Access Memory) registers.

SPECIFICATION...

There are six basic display functions available:

- ★ Cost per unit of electricity to 99.99 pence
- ★ Units of electricity used to 9999.99
- ★ Cumulative cost to £99 99.99 pence
- ★ Elapsed time to 159 hours 59 minutes and 59 seconds
- ★ Instantaneous current flow up to 15A
- ★ Initial setting-up (very simple)



PIC-Electric has been designed so that the PIC16C84 can be programmed in situ on the assembled printed circuit board. Data is transferred to the microcontroller via the serial port of a PC-compatible computer.

Other than a connector and cable, no additional hardware is needed, although a suitable software program is required. This facility makes it possible to use the PIC-Electric assembly for other applications, using different analogue sensors and controlling software. Both software and pre-programmed PIC16C84s are available – see *Shoptalk* page.

HOW IT WORKS

A block diagram for the PIC-Electric Meter is shown in Fig. 1. The meter comprises a current sensor, analogue-to-digital converter (ADC), sync pulse generator, microcontroller, display module and a power supply (PSU).

The sensor is connected in series with the load (appliance) being monitored, producing an output voltage which increases linearly with the amount of current flowing. The resulting voltage is fed to a serial ADC which is sampled by the microcontroller each time a sync pulse derived from the mains power supply is received.

Software programmed, the microcontroller processes the sampled data, stores it and displays the appropriate results according to the stage of the processing cycle and in response to the "mode" pushbutton switch commands.

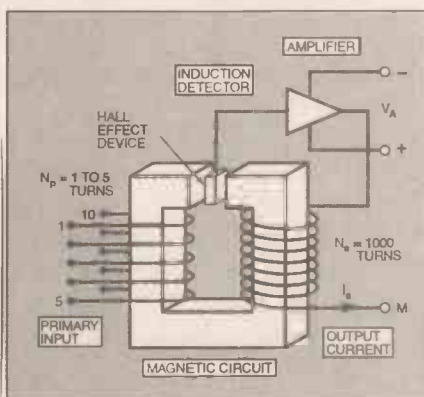


Fig. 2. Hall-effect current sensor and transducer functional diagram.

CURRENT SENSOR

The current sensor is a dedicated transducer which uses Hall-effect technology, whereby current measurement is carried out by measuring the magnetic field that is generated by a current carrying conductor. The schematic drawing of the Hall-effect Transducer is shown in Fig. 2.

Basically, the device consists of a ferromagnetic former around which are wound two coils. The primary coil is tapped and the number of turns through which the current flows can be selected according to the maximum current to be monitored. In the PIC-Electric, the primary winding is connected so that only one coil turn is used, allowing a theoretical maximum of 25A to be drawn through the sensor.

Within the gap between the legs of the magnetic former is a Hall-effect semiconductor device. This is placed at right angles to the magnetic field generated by current passing through the primary coil. The resulting voltage generated across the semiconductor is linearly proportional to the

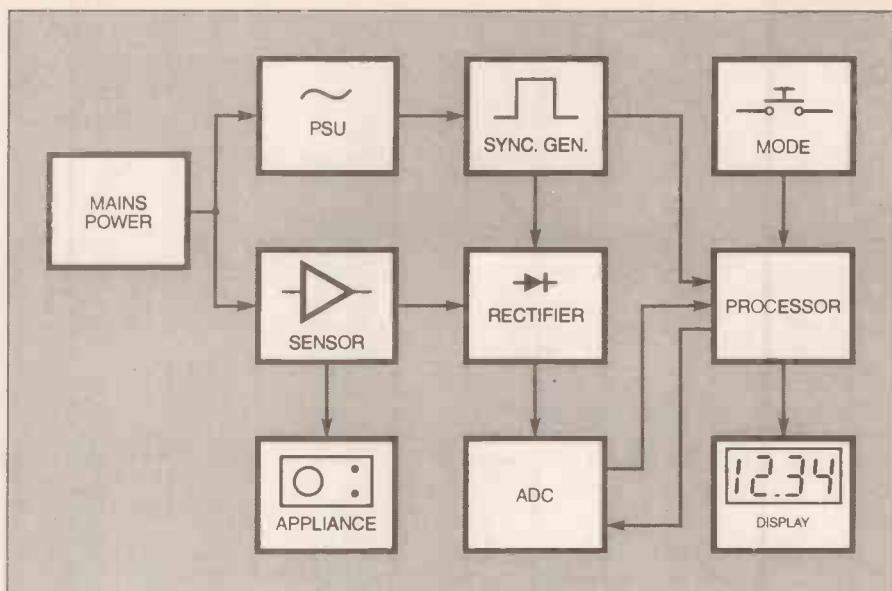


Fig. 1. Block diagram for the PIC-Electric Meter.

magnetic field, and hence to the current flowing in the circuit.

The device can be used to measure alternating or direct currents (a.c. or d.c.). Its output does not depend on a changing magnetic field, only on the instantaneous strength of the field. The bandwidth of the device is from d.c. to 150kHz.

The voltage generated across the semiconductor is processed by an internal amplifier and fed through the secondary winding of the transducer, generating an output current. An output current of 25mA is generated by a 25A primary current flowing through the sensor, to within ± 0.6 per cent. By feeding the current through a known value resistor, typically 100 Ω to 190 Ω , the current can be converted to an equivalent output voltage.

When connected for 25A maximum current, the resistance of the primary coil is only 0.3 milliohms, and so imposes very little insertion loss between the mains power source and the appliance being monitored. The isolation between the primary coil and the sensor's output is 2.5kV r.m.s. at 50Hz for one minute.

The sensor also requires a dual d.c. supply voltage of $\pm 15V$, consuming about 10mA, plus the output current.

SENSOR CIRCUIT AND PSU

The circuit diagram for the Sensor connections and the Main Power Supply for the PIC-Electric is shown in Fig. 3. Mains power input to the circuit is via plug PL1.

The Hall-effect sensor, X1, has its primary winding inserted in series with the Live connection between PL1 and the output socket SK1. The mains Neutral and Earth lines are taken direct to SK1.

From PL1, mains power is also supplied to the primary winding of transformer T1. This has two 12V secondary windings connected in series, with the junction, or centre tap, of the two windings providing the 0V line. The output of the sensor is connected to the 0V line via resistor R1, into which the output current flows, creating an equivalent voltage which is destined for the ADC (IC7 in Fig. 6, later).

The secondary voltage from transformer T1 is bridge rectified by REC1, whose posi-

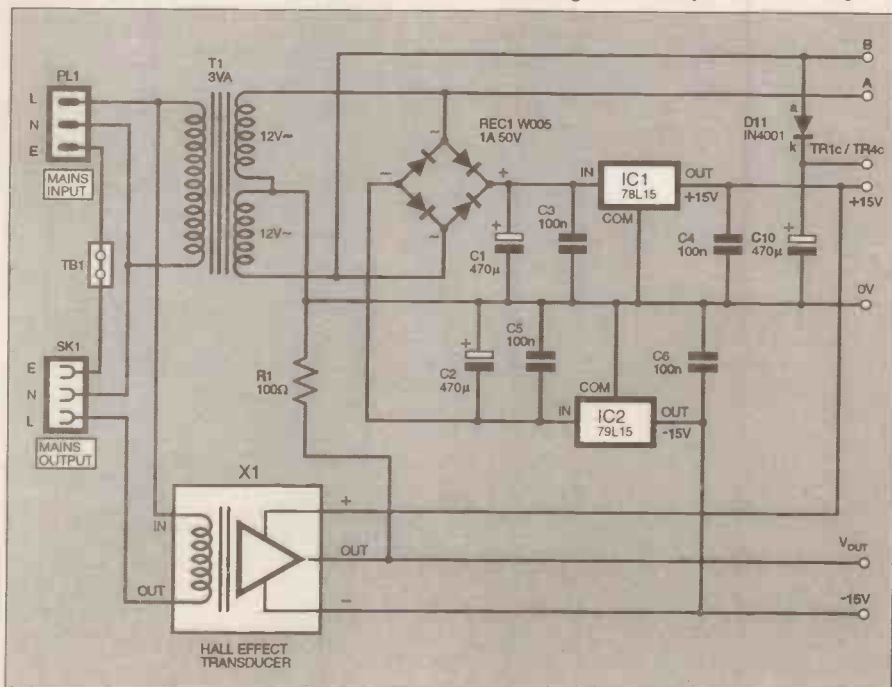


Fig. 3. Circuit diagram for Sensor and Power Supply.

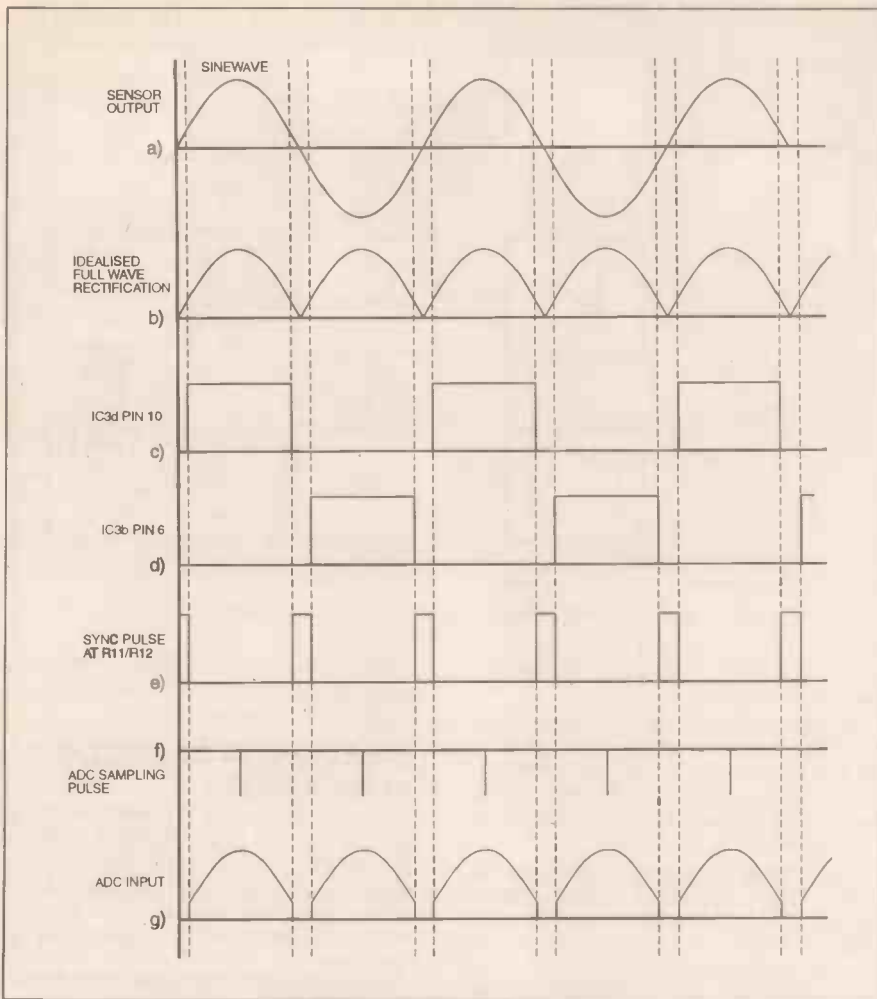


Fig. 4. Significant waveforms associated with the PIC-Electric.

tive output is smoothed by capacitors C1 and C3, and regulated down to +15V d.c. by IC1. The negative output from REC1 is smoothed by capacitors C2 and C5, and regulated down to -15V by IC2. This dual voltage (+/-) 15V supply powers the d.c. aspect of the sensor X1.

An additional unregulated positive d.c. voltage is required to power the 7-segment display (X3) i.e.d.s. This is generated from only one of the transformer's secondary windings. Diode D11 half-wave rectifies the voltage and capacitor C10 provides the necessary smoothing.

SIGNAL FORMAT

The output from the Hall-effect sensor X1 is a sine wave whose amplitude increases with the current sensed, peaking above and below the 0V power line, as shown in Fig. 4a. To suit the ADC, the signal needs to be rectified so that the negative portion of the waveform is inverted to make both its aspects positive, as shown idealised in Fig. 4b.

Normally, rectification requires the use of diodes in series with the voltage path. Silicon diodes, though, cause an insertion loss of about 0.7V, which is undesirable when dealing with low level signals.

There are several ways in which this problem can be overcome. The technique chosen here is shown in the Signal Formatting and Sync circuit diagram of Fig. 5. Also shown is the circuit which generates the 100Hz synchronisation signal.

The Hall-effect sensor output signal is first fed to the non-inverting buffer op.amp IC5a pin 3, whose output is fed to analogue gate "switch" IC4a pin 4, via resistor R7. The output from IC5a is also inverted by IC5b and fed through resistor R8 to a second analogue gate, IC4b pin 1. Diodes D3 and D4 prevent IC4a and IC4b from being adversely affected by the negative aspects of the signals.

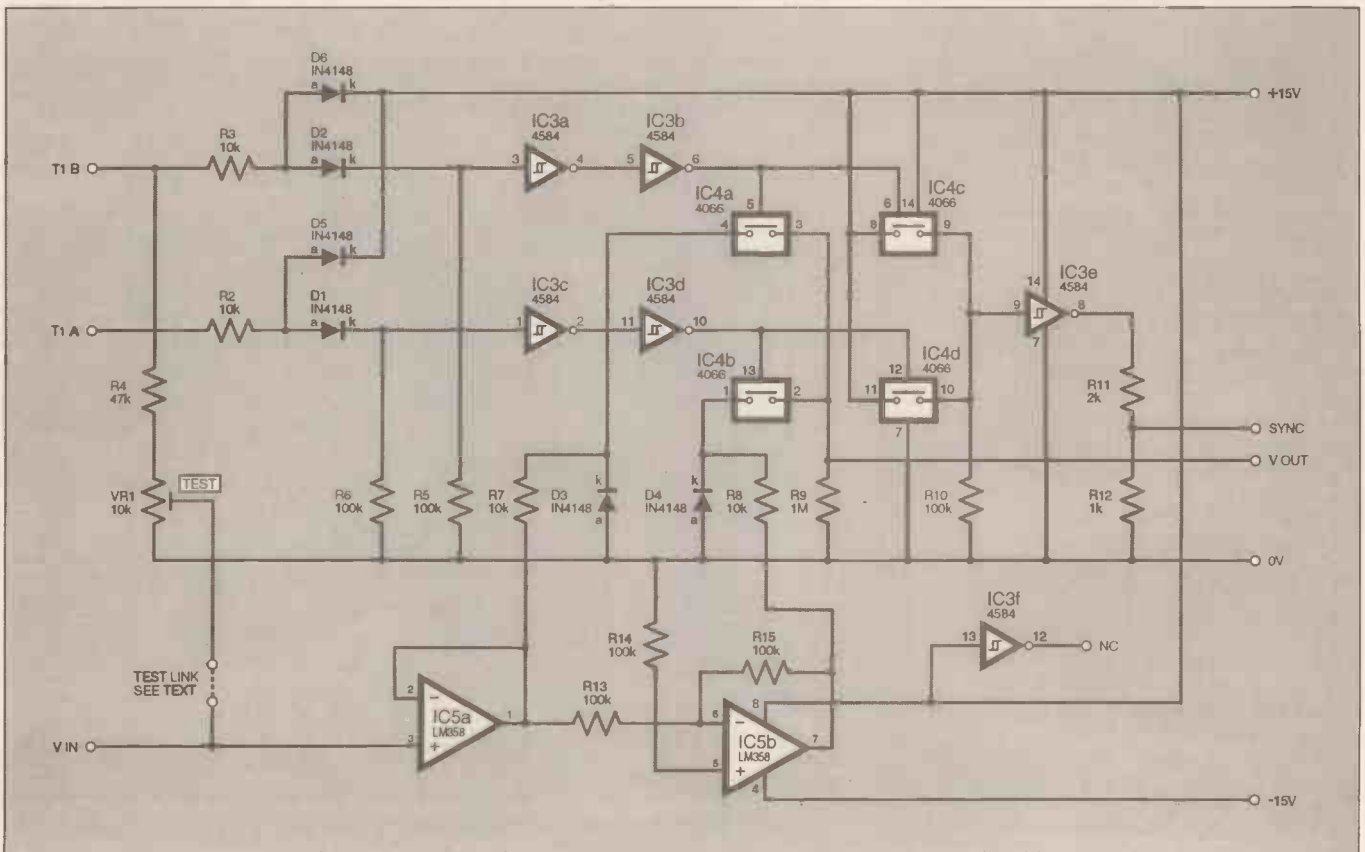


Fig. 5. Sync and Signal Formatting circuit diagram.

CONTROL SIGNALS

Controlling signals for IC4a and IC4b are derived from the secondary windings of transformer T1. Transformer line B in Fig. 3 is fed, via resistor R3 and diode D2, to Schmitt trigger inverters IC3a and IC3b.

This sequence of components rectifies the positive-going signals from the transformer, reshaping them to square wave pulses at positive supply line amplitude. Only voltages above the positive-going Schmitt trigger threshold of about 8V trigger IC3a (with +15V supply); the equivalent negative-going threshold is typically about 6.9V. Diode D6 limits the maximum voltage which can be presented to the input of IC3a.

The output from IC3b controls analogue gate IC4a via its pin 5 which, when high, allows signals from IC5a to pass through the gate from pin 4 to pin 3.

Signals from transformer line A, which are of opposite phase to those from line B, are similarly processed by inverters IC3c, IC3d and their associated components, controlling analogue gate IC4b and the signals fed to it from IC5b.

The outputs of IC4a and IC4b are connected together, feeding into resistor R9 from where they are routed to the ADC (IC7). Since the controlling signals are of opposite phase, the gates open or "switch" alternately, passing through only the positive aspects of the analogue voltages from the op.amps. Because the Schmitt threshold voltages for IC3a and IC3c are several volts above 0V, the analogue voltage presented to the ADC appears similar to the waveform in Fig. 4g.

Note that an oscilloscope may show slight differences in the relative amplitudes of alternate peaks of the actual waveform fed to the ADC. This is due to the inherent and uncorrected offset voltages of the op.amp circuits. The differences are balanced out in the software summing routines.

Synchronisation pulses at 100Hz are generated by gates IC4c and IC4d, which are controlled respectively by the outputs from IC3b and IC3d. Both inputs (pins 8, 11) to IC4c and IC4d are tied to the positive supply line.

COMPONENTS

Approx cost
guidance only **£55**
excluding case, mains socket and cable

Resistors

R1, R24 to R32	100Ω (10 off)
R2, R3, R7, R8, R33	10k (5 off)
R4	47k
R5, R6, R10, R13 to R17	100k (8 off)
R9	1M
R11, R34	2k (2 off)
R12, R18 to R23, R35 to R37	1k (10 off)
All 0.25W 5% carbon film or better.	

Potentiometers

VR1, VR2	10k enclosed carbon preset (2 off)
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Capacitors

C1, C2, C10	470μ radial elect., 35V (3 off)
C3 to C7, C11, C12	100n polyester (7 off)
C8, C9	15p polystyrene (2 off)

Semiconductors

D1 to D8	1N4148 signal diode (8 off)
D9	red l.e.d., sub-min
D10	BZY88C12 12V 400mW Zener diode
D11	1N4001 1A 50V rect. diode
REC1	W005 50V 1A bridge rect.
TR1 to TR4	BC337 npn transistor
IC1	78L15 +15V 100mA regulator
IC2	79L15 -15V 100mA regulator

IC3	4584 Hex Schmitt inverter
IC4	4066 quad bilateral analogue switch
IC5	LM358 dual op.amp
IC6	78L05 +5V 100mA regulator
IC7	TLC549IP 8-bit serial ADC
IC8	74HC4078 8-input OR/NOR gate
IC9	PIC16C84 programmed EEPROM microcontroller (see text)

Miscellaneous

X1	current transducer, Hall-effect
X2	4MHz crystal
X3	4 × 7-segment display module, common anode d.p.s.t. min. slide switch, p.c.b. mounting (see text)
S1	pushbutton p.c.b. mounting switch, push-to-make (see text) (3 off)
S2 to S4	pushbutton p.c.b. mounting switch, push-to-make (see text) (3 off)
T1	3VA mains, p.c.b. mounting, transformer with twin 12V secondaries

Printed circuit boards for Sensor/PSU and Controller/Display, available from the *EPE PCB Service*, codes 977 (Sen/PSU) and 978 (Cont./Disp.) respectively; 8-pin d.i.l. socket (2 off); 14-pin d.i.l. socket (3 off); 18-pin d.i.l. socket; plastic case, 188mm × 108mm × 160mm; mains cable gland (2 off); 2-way 15A mains terminal block; mains plug and socket; p.c.b. mounting supports, screw base (4 off); nuts and bolts; connecting wire; mains cable; cable ties (3 off); terminal pins; solder, etc.

See
**SHOP
TALK**
Page

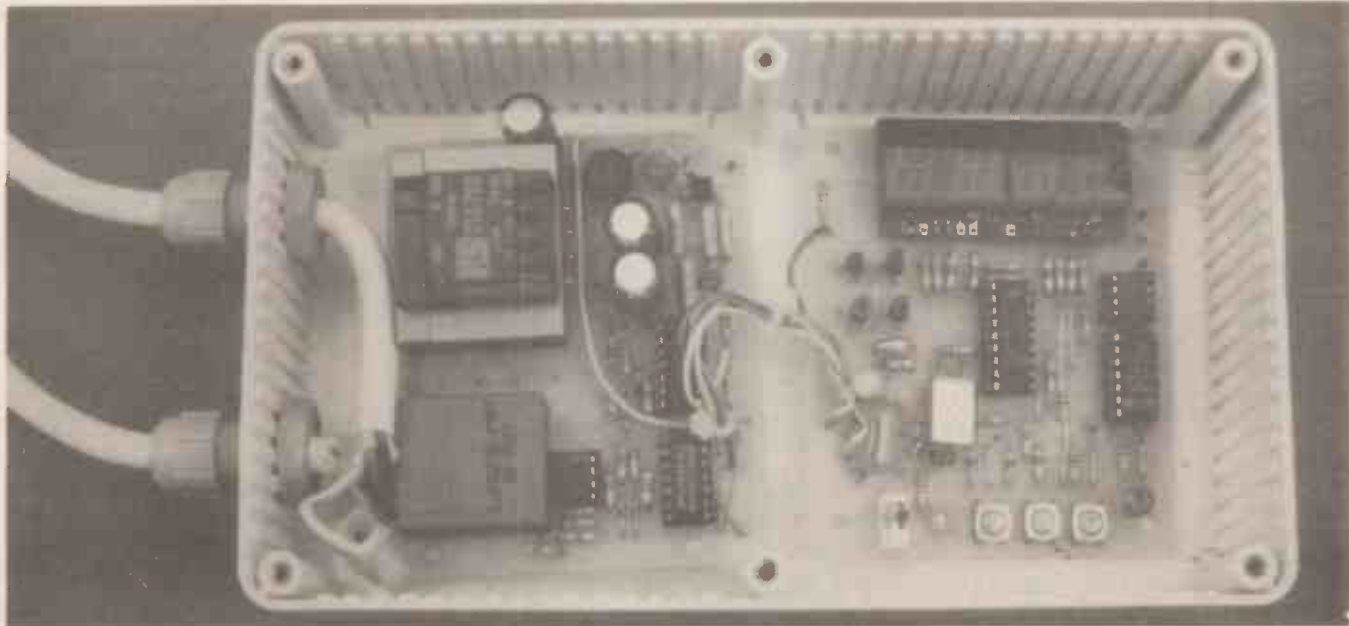
Their outputs (pins 9, 10) are connected together and fed into resistor R10 and Schmitt inverter IC3e. The potential divider formed by resistors R11 and R12 across the output of IC3e limits the resultant sync pulse amplitude to a maximum of +5V, to suit the PIC microcontroller IC9.

The waveforms of the sync pulse and the signals which control IC4 are shown in Fig. 4c to Fig. 4e. The point at which the ADC samples the analogue signal is shown in Fig. 4f.

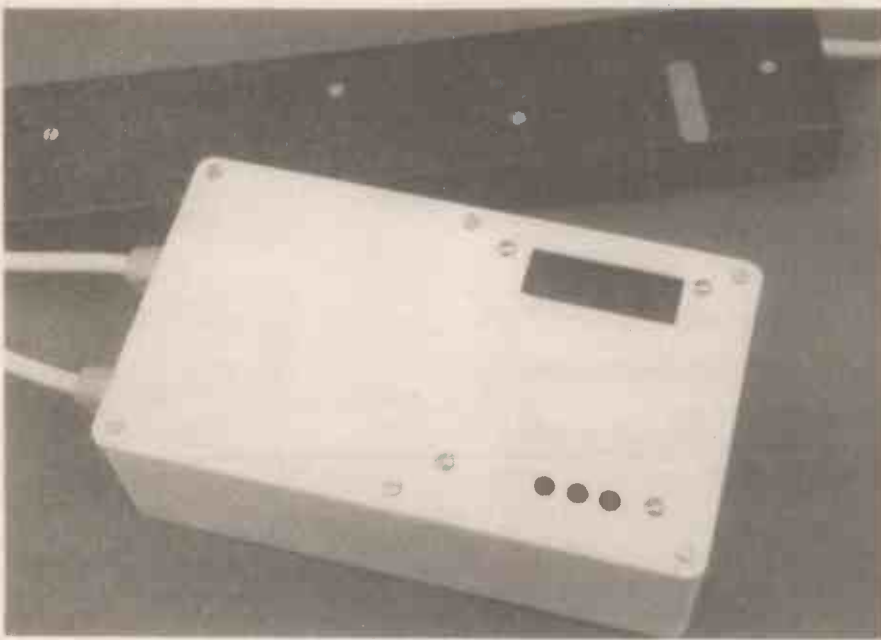
TEST CIRCUIT

Also shown in Fig. 5 are details of a simple test circuit formed by resistor R4 and preset VR1. R4 is connected to transformer line B which supplies a sinewave having the same phase as that from the sensor.

The wiper of VR1 can be linked to the analogue processing circuit at IC5a pin 3 to provide a test signal in place of that from the sensor. This allows tests to be made without plugging a mains appliance into PIC-Electric.



The completed PIC-Electric Meter with lid removed to show siting of circuit boards. Note that the Display p.c.b. is normally bolted to the rear of the case lid, behind the display window.



The completed PIC-Electric Meter showing the readout display window and three holes for access to the Reset and Function setting switches.

CONTROL AND DISPLAY

Details of the Control and Display circuit are shown in Fig. 6. Basically, the circuit comprises the PIC microcontroller IC9, the ADC IC7, and display module X3. The majority of the circuit is under control by the microcontroller and its software.

The power supply for most of this circuit has to be regulated at +5V, a function which is carried out by IC6.

ADC

Analogue-to-digital conversion of the processed signal is performed by IC7. This is an 8-bit serial ADC chip whose reference voltage is provided by the potential divider consisting of resistors R33, R34 and preset VR2.

Data conversion and output are controlled by the chip's internal clock system and external input/output (I/O) clock pulses. The maximum sampling rate the chip can handle is about 40kHz.

When IC7's \overline{CS} pin 5 is high, the data output (D OUT) pin 6 is in a high impedance state and the I/O clock (CLK) pin 7 is disabled. Reading of the conversion result is initiated when \overline{CS} is brought low.

On this action, the most significant bit (MSB) of the previous conversion appears on the data output. The falling edges of the next four I/O clock cycles shift out the next four MSB data bits.

The on-chip sample-and-hold begins sampling the analogue input after the fourth high-to-low transition of the I/O clock. The sampling operation basically involves the charging of internal capacitors to the level of the analogue input voltage.

Three more I/O clock cycles are then applied to the CLK pin and the final three conversion bits are shifted out. After the eighth I/O clock cycle, \overline{CS} must go high or the I/O clock remain low for at least 36 internal system clock cycles to allow completion of the internal hold and conversion functions.

In Fig. 6, the \overline{CS} pin is brought low only when microcontroller IC9 lines RA0 to RA3 are all low simultaneously, causing IC8's output pin 8 to also go low. Note that IC8 is a 74HC4078 8-input OR/NOR

gate used in its OR mode and that the 4000 series near-equivalent 4078 cannot be substituted since the latter is purely a NOR gate without the extra OR inversion at pin 1.

DISPLAY MODULE

Each of the multiplexed four digits of the l.e.d. display module has seven segments and a decimal point which are controlled by microcontroller's data lines RB1 to RB7, plus RA4. The segments and decimal point are turned on when their respective data lines are low. Resistors R24 to R31 limit the current flowing through the segments.

Technical literature shows that PIC16C84 microcontrollers can supply (source) 20mA or sink 25mA per data line, though each port (RA or RB) is limited to the total amount of current which can be sunk or sourced: 80mA sunk by Port RA, 150mA sunk by Port RB, 50mA sourced by Port RA and 100mA sourced by Port RB.

With resistors R24 to R31 at the values shown, when each digit has all seven segments and a decimal point turned on, the source current required is about 120mA. Although Port RB can sink this amount of current, Port RA cannot source it. Increasing the resistor values to suit Port RA would not allow the l.e.d.s to glow with adequate brightness, consequently current boosting is required and is supplied by transistors TR1 to TR4.

The transistors are connected in series with the common-anode digits of the display and are controlled by IC9's data lines RA0 to RA3. Each data line when taken high allows the transistor to conduct voltage to the selected digit. Although the transistors' collectors are fed from a voltage greater than the +5V available from IC7, the maximum voltage which is fed from their emitters to each digit is about 0.7V below the voltage of the controlling RA data line connected to their bases, i.e. about 4.3V.

FUNCTION SWITCHES

Function switches S3 and S4 select which data is displayed on the l.e.d. module.

Their use and effect is determined by which routine the software is running at the time of their pressing, as discussed next month.

In all routines, the status of the switches S3 and S4 can only be read when software sets data lines RA0 to RA3 low, so setting low IC8 pin 1. If either of the switches is pressed at that time, a logic 0 will be read from the respective data line RB2 or RB3.

Resistors R16 and R17 tie the outputs of the switches to the positive rail, consequently if a switch is unpressed or IC8 pin 8 is high, a logic 1 will be read. R36 and R37 ensure that no connection is made between the two data lines if both switches are pressed simultaneously.

MICRO-CONTROLLER

The PIC16C84 microcontroller is shown as IC9 in Fig. 6. As a device which has an EEPROM program memory, it can be repeatedly reprogrammed without the need for ultra-violet (UV) erasure, unlike the rest of the current PIC range of microcontrollers. The reprogrammability, of at least 1000 times and probably more, makes it ideal for situations where controlling software is being developed step by step.

An additional advantage over other PIC devices is that this chip also has a EEPROM data memory which can be written to and read from by the controlling software, with a maximum of about one million write cycles. This facility makes the processor eminently suitable for systems which require some data factors to be changed according to varying situations, such as the need to periodically update the PIC-Electric Meter with revised electricity unit prices.

PIC-Electric has been designed so that the microcontroller can be serially programmed from a PC-compatible computer, running suitable software, whilst plugged into the printed circuit board. All that is required is that the PC should provide data via resistor R22 to IC9 pin 13, the DIO/RB7 data line, and a clock signal via R23 to IC9 pin 12, the CLK/RB6 data line, plus the 0V common connection.

The PIC16C84 cannot be programmed by the PIC-DATS System published in EPE May '95 issue, but it can be programmed by the Simple PIC16C84 Programmer published in this issue. Proprietary software is also available from a variety of commercial sources. The chip's programming instruction codes are common to all current PIC devices, except for four additional commands.

The microcontroller IC9 is powered at +5V and in normal running mode its MCLR (master clear, or reset) pin 4 is held at about the same voltage, as supplied via diode D7 and resistors R20, R32. In programming mode, though, the pin needs to be held at between +12V and +14V.

For programming, S1 switches the +15V supply line through diode D8, overriding the voltage from D7. Zener diode D10 reduces the programming voltage to +12V.

To reset IC9, MCLR has to be taken to 0V, an action performed by pushswitch S2. Resistor R20 prevents the voltage at the D7/D8 junction from being shorted to 0V when S2 is pressed. R32 is included at the manufacturer's recommendation.

The microcontroller contains its own clock generating circuit whose frequency and mode of operation is determined by a choice of external component types, as

detailed in the chip's data sheet. For this application, a clock frequency of 4MHz is set by crystal X2 in conjunction with capacitors C8, C9 and resistor R21.

Since the microcontroller effectively acts upon software instruction codes at one quarter of the clock frequency, an operational speed of 1MHz is achieved here. This is more than fast enough to process data acquired from the ADC at a 100Hz sampling rate, even though the software contains around 700 commands.

SOFTWARE

Software of the source-code listing for the PIC-Electric Meter (together with Simple PIC16C84 Programmer software) can be supplied from the Editorial Office as a 3.5in. disk (UK £2.50, overseas surface £3.10, airmail £4.10). A pre-programmed PIC16C84 chip (together with p.c.b.s) for PIC-Electric, ready to plug straight in, is obtainable from Magenta Electronics. See *Shoptalk* for details.

Detailed description of all the software for the PIC-Electric is beyond the scope of this article. A brief operational description follows the "First Tests" section (next month). The source code listing available has comments embodied into it which clarify further aspects of the program.

There are also four software routines in the listing which will be of general interest to PIC programming readers since they show practical examples of coding procedures which were found to be unclearly explained by the *Microchip Data Book*. The

routines include EEPROM data storage and retrieval, multiplexed display look-up tabling, and indirect addressing.

Next Month: Constructional details, testing procedures and using the Meter.

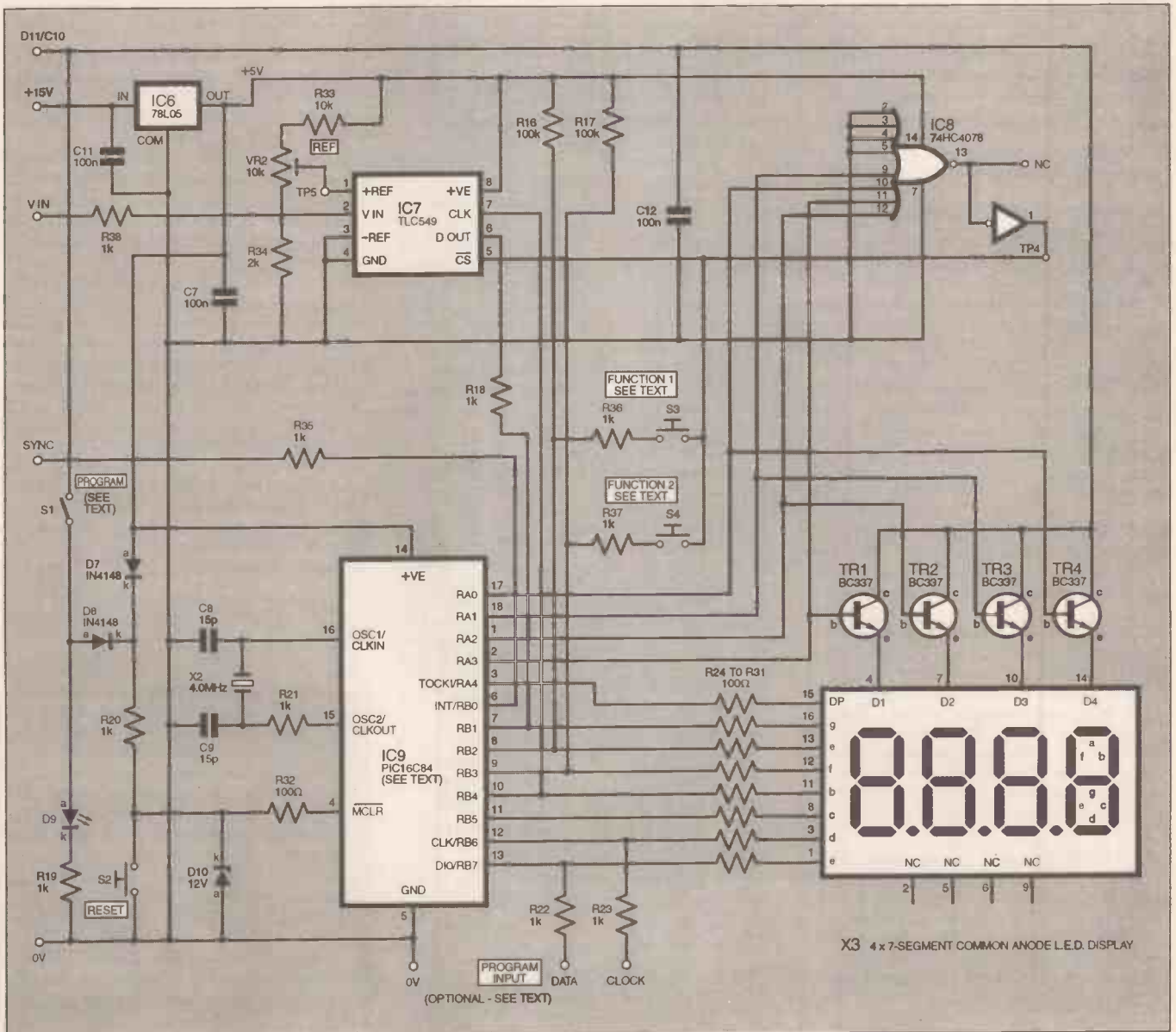
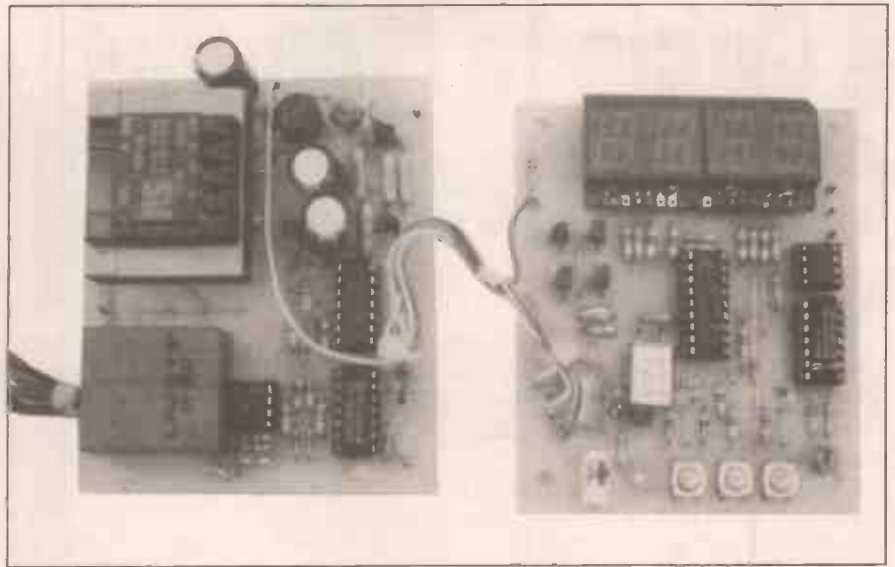


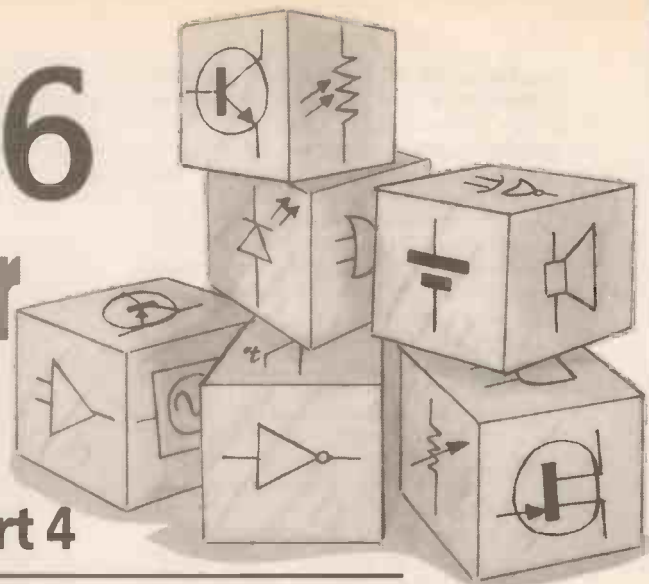
Fig. 6. PIC-Electric Controller and Display circuit.

TEACH-IN '96

A Guide to Modular Circuit Design

Max Horsey

Part 4



DURING this series of articles, a range of circuit modules is examined, divided into Input, Processor and Output sections. Where possible a choice of module is offered within each section.

Each of the ten Parts of the Series is accompanied by a constructional article explaining how a complete project may be devised by employing the modules described, together with a p.c.b. design. Each project will be one of many possible ideas that could be implemented and it is

hoped that readers will design for themselves a variety of circuits by combining modules provided in the whole series.

The proposed range of modules covered by the Series is detailed in Part 1, Table 1.1. Each module is chosen to link easily with adjacent modules in the same Part, but modules may also be linked with modules in other Parts of the Series.

Max Horsey is Head of Electronics at Radley College.

HERE in this fourth Part of *Teach-In*, the following Input, Processor and Output modules are examined:

INPUT MODULES: Astables, based on:

- logic gates – simple arrangement
- voltage controlled variable frequency version
- logic gates – improved square wave oscillator
- 741 relaxation oscillator
- 555 timer

PROCESSOR MODULES: Decade chaser and counter

OUTPUT MODULE: L.E.D., discussing series resistance

The accompanying example project described separately is based around a selection of these modules and is a Vari-Speed Dice indicator. It contains two sets of six l.e.d.s which "chase" when a switch is pressed. When the switch is released the chase speed slows down and finally stops, resulting in a pair of random numbers being highlighted. The effect can be likened to the action of a roulette wheel.

ASTABLE MODULES

Astable circuits based around digital gates generate a continuous stream of "clock pulses", usually square waves. The term *clock pulse* implies a clean change between two voltage levels, often between 0V and close to the positive power rail voltage, generally referred to as *logic 0* and *logic 1*, respectively.

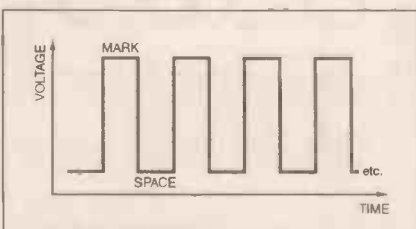


Fig. 4.1. Pulse train with even mark/space ratio.

Some oscilloscopes may have difficulty displaying the vertical aspects of *good quality* pulses (i.e. which rapidly change their logic states), such as those forming the pulse train illustrated in Fig. 4.1, and only the horizontal parts may be seen clearly.

If the time for which the pulse voltage is high equals the time for which it is low, it is said that the pulse *mark/space* ratio is equal, a condition which defines a square wave. If the *mark* (logic 1 level) time is added to the *space* (logic 0 level) time, the total is known as the *period* of the waveform. From this quantity, the frequency of the waveform (i.e. number of waves per second) can be calculated using the formula:

$$\text{Frequency} = 1 / \text{Period}$$

where the frequency is measured in Hertz (Hz), and the period is measured in seconds (s).

Counter circuits increment (add one to) their count value at the instant when the voltage on their clock input changes in a given direction, either positive-going (upwards) or negative-going (downwards). Although most counter circuits require a clock pulse having a clean transition between the two voltage levels, the pulse's mark/space ratio need not be equal.

SIMPLE ASTABLE

If the inputs of a NOR gate or a NAND gate are connected together, the NOR or NAND behaves like a NOT gate or inverter. Since all the following logic-based astable circuits require NOT gates, it follows that NOT gates, NOR gates or NAND gates may be used, and the choice may depend upon the requirements of other parts of the project.

The circuit diagram in Fig. 4.2 shows how a pair of NOR gates can be used to produce a simple astable which generates reasonably good square wave pulses. The frequency is variable by means of potentiometer VR1.

The output frequency signal is normally taken from point Y, as shown, but an inverted output is available from point X if required. Output X is positive when Output Y is at 0V, and vice-versa.

Frequency is determined by the values of capacitor C1, resistor R1 and the resistance set by potentiometer VR1. If the total resistance set by R1 plus VR1 is doubled, or if the value of C1 is doubled, the frequency will be halved.

Select a maximum value for VR1 which provides a frequency slightly lower than that likely to be needed. Resistor R1 should be about one kilohm (1k), and is used to prevent the total resistance approaching zero when VR1 is set for minimum resistance.

Example component values and output frequencies are as follows:

C1	R1 + VR1	Frequency
10nF	56kΩ	1kHz
10nF	560kΩ	100Hz
100nF	560kΩ	10Hz
100nF	56kΩ	100Hz
100nF	5k6Ω	1kHz

Note: 10nF (nanofarads) = 0.01μF (microfarads) and 100nF = 0.1μF.

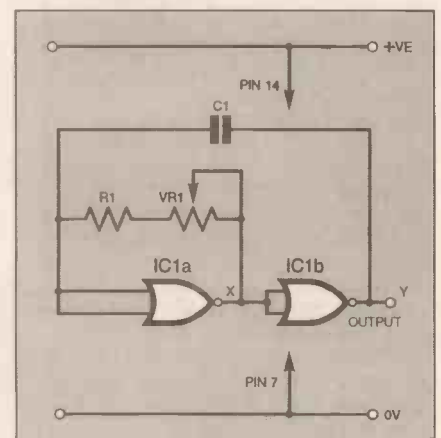


Fig. 4.2. Astable based on two NOR gates.

Be aware that the results shown are approximate and that this type of circuit should only be used if the exact frequency is unimportant.

In practice, select a total resistance ($R1 + VR1$) of between 4k7 and 1M ohms, and a capacitor in the range 56pF to 100µF. Electrolytic capacitors should have their positive ends connected to the output of IC1b. If capacitor values larger than 100µF (for lower frequencies) are required, use the "improved square wave oscillator" module described later.

If a fixed frequency is required, potentiometer VR1 may be omitted, connecting R1 between the input and output of IC1a.

STARTING AND STOPPING

It is often useful to be able to start and stop an astable circuit without switching off the power supply. The circuits in Fig. 4.3 show how the connections to one gate (IC1a) may be modified so that the gate is forced into one state ensuring that the circuit cannot oscillate.

The gate must be either a NOR or a NAND. Note that the logic levels at the control input and the output when "jammed" in Fig. 4.3a are opposite to those in Fig. 4.3b.

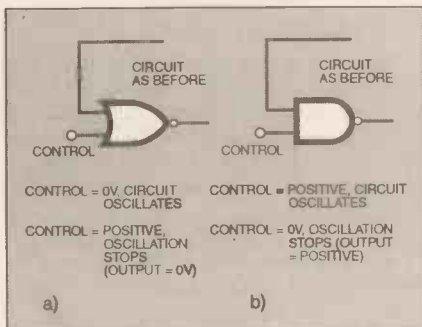


Fig. 4.3. Gated control for astable.

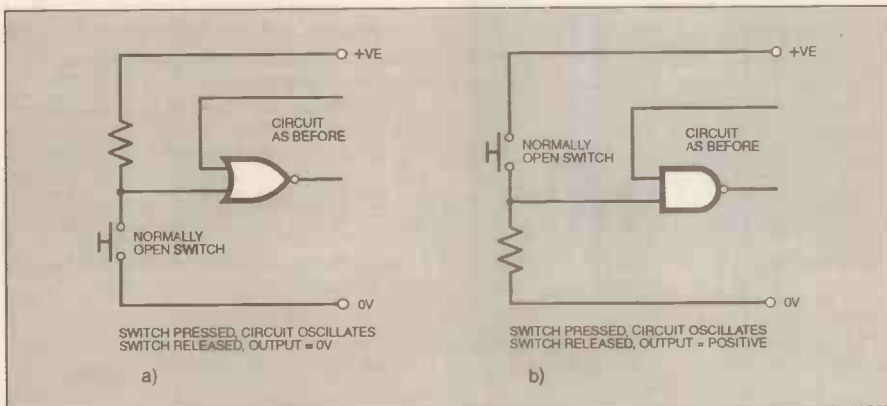


Fig. 4.4. Switched implementation for the circuit in Fig. 4.3.

As explained in Part 1, inputs to CMOS logic gates must not be left "open circuit". Consequently, the control input must be connected to a definite logic level, such as the output from another gate in the main circuit. Alternatively, switches may be used to control the logic level of the control input, as shown in Fig. 4.4.

The value of the biasing resistor is not critical and should be somewhere between 10k and 1M ohms.

Either of the two gates in the astable circuit of Fig. 4.2 may be controlled in this way. The choice of which is used will depend on the needs on the following circuit, and on the signal availability from the preceding circuit.

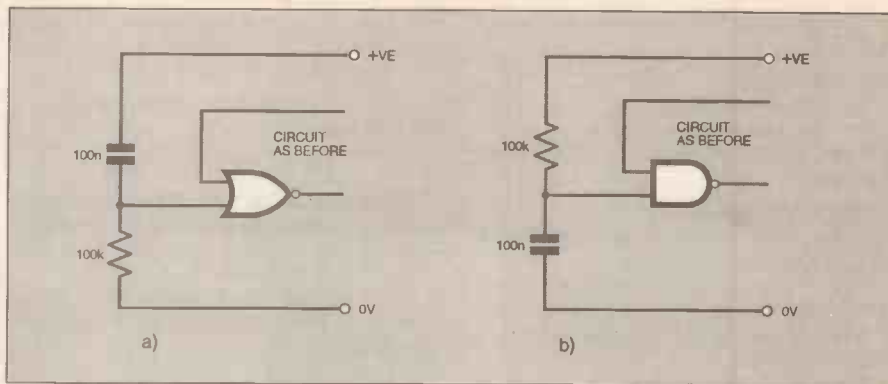


Fig. 4.5. Using a resistor and capacitor to "kick-start" an astable.

Note that the word *output* in Fig. 4.3 and Fig. 4.4 refers to the output of the gate under control, which may or may not be the final output of the astable. For example, if the gate under control is IC1a in Fig. 4.2, the output at IC1b will have the opposite logic level to that shown in Fig. 4.3 and Fig. 4.4.

KICK-STARTING

The circuit shown in Fig. 4.3 may not reliably start to oscillate when power is first switched on and may "jam" into one particular and unpredictable state. Adding one of the switched controls shown in Fig. 4.4 will solve the problem, although manual control is not always convenient.

A useful alternative is to add a resistor and capacitor to "kick-start" the circuit whenever power is applied, as shown in Fig. 4.5.

Referring to the NOR gate circuit in Fig. 4.5a, when power is first applied, the rising voltage at the top end of the capacitor (as seen in the diagram) causes a similar rise on the lower side, (see A.C. Coupling In Part 2). After a very short time, the voltage on the lower side will collapse as the charge leaks to 0V through the resistor. The action is similar

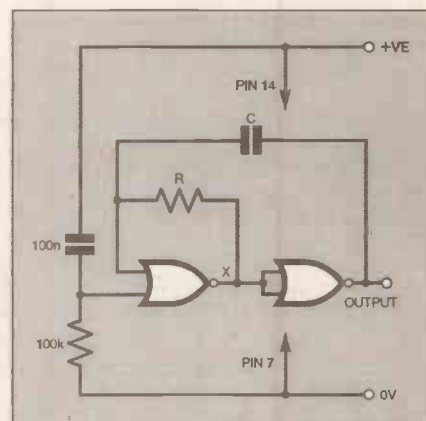


Fig. 4.6. A practical "kick-started" astable.

by mechanically setting a variable resistor. The circuit of Fig. 4.2 may be modified to allow simple voltage control as shown in Fig. 4.7.

If the voltage control input is connected to 0V, the circuit will oscillate at its maximum frequency – as determined by the values of the resistors and capacitors. If the voltage control input is raised above 0V the frequency will be reduced, reaching its minimum when the voltage control is at half the supply voltage. If the control voltage is raised further, the frequency will increase again.

This circuit may be also be started and stopped using the control shown in Fig. 4.4 and Fig. 4.5, or kick-started when first switched on by the arrangement shown in Fig. 4.6.

These simple astable circuits sometimes produce "glitches" (unclean switching pulses) which can cause problems in counting circuits.

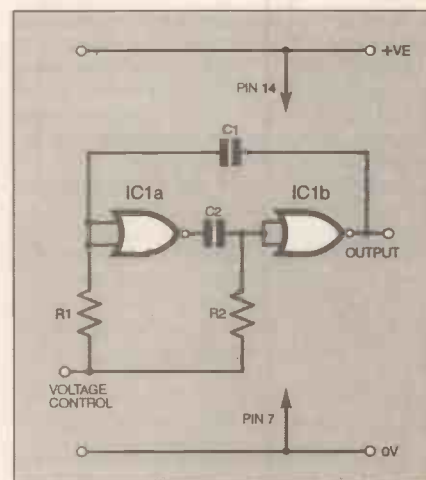


Fig. 4.7. Voltage controlled oscillator.

to pressing the switch in Fig. 4.4, and the circuit jerks into action.

A similar, though opposite, effect applies to the NAND gate circuit. When first switched on, the voltage on the top side of the capacitor is zero. After a very short time enough current will have passed through the resistor to positively charge the capacitor to a logic 1 level. This is also like pressing the switch in Fig. 4.4.

A practical circuit, based on NOR gates and using the kick start method from Fig. 4.5, is shown in Fig. 4.6.

VOLTAGE CONTROL

It is sometimes useful to control frequency by a varying a voltage, rather than

To sum up the astable circuits in Fig. 4.3 to Fig. 4.7:

ADVANTAGES:

- Wide frequency range
- Very low current consumption
- Easy to interface (connect) to other modules

DISADVANTAGES:

- Frequency is approximate, and tends to vary with the supply voltage
- Output is quite a good square wave, but not perfect
- Glitches may be produced, which could cause problems
- Unreliable starting at power-up without additional controls

If a better square wave output without glitches is required, a third gate may be used as shown in Fig. 4.8.

in Part 3, it may be more convenient to measure R in megohms, and C in microfarads. For example:

if $R = 330k\Omega (= 0.33M\Omega)$ and $C = 0.1\mu F$, then

$$f = 1 / (8 \times 0.33 \times 0.1) = 3.8Hz$$

Note that in this, as in the previous modules, no resistor should have a value of less than $4.7k\Omega$ or too much current will flow via a CMOS 4000 series output.

This type of circuit, with a Schmitt trigger at its heart, is known as a relaxation oscillator.

The circuit of Fig. 4.8 could be simplified by using a single 2-input Schmitt NAND gate, as shown in Fig. 4.9. The CMOS 4093 chip houses four 2-input Schmitt NAND gates, and the CMOS 40106 houses six Schmitt NOT gates (inverters).

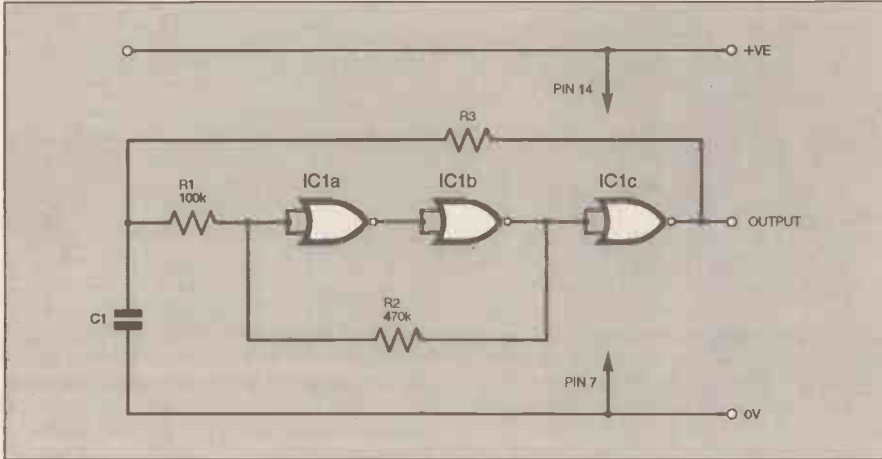


Fig. 4.8. A more reliable square wave oscillator.

IMPROVED SQUARE WAVE OSCILLATOR

An improved square wave oscillator circuit is shown in Fig. 4.8. As can be seen, a third NOR gate is required but the circuit always self-starts at power on, and produces a glitch-free output. Two considerable advantages!

The gates may be NORs as shown, or NANDs or NOTs. Any of the three gates (unless they are NOT gates) may be given the treatment shown in Fig. 4.3 and Fig. 4.4 to enable start/stop control.

The first two gates, IC1a and IC1b, together with resistors R1 and R2, make a non-inverting Schmitt trigger circuit (see Part 1). The third gate, IC1c, inverts the output voltage from IC1b feeding it back to capacitor C1 via R3.

Resistor R3 and capacitor C1 control the frequency of the module. For example, if R3 has a value of 10k and the capacitor a value of 10nF, then the frequency will be about 1.25kHz. If R3 and/or C1 are reduced in value, the frequency will increase proportionally.

Variable control of the frequency may be achieved by inserting a potentiometer, wired as a variable resistor, in series with R3. Note that the ratio of R1 to R2 will also have a small effect on the frequency.

In general terms, and assuming that the values of R1 and R2 are as shown in Fig. 4.8, the frequency will be given by:

$$f = 1 / (8 \times R \times C)$$

where, f = frequency, R = R3, C = C1

Remember that as in all such formulae, R should be measured in ohms, C in farads and f in hertz, although, as discussed

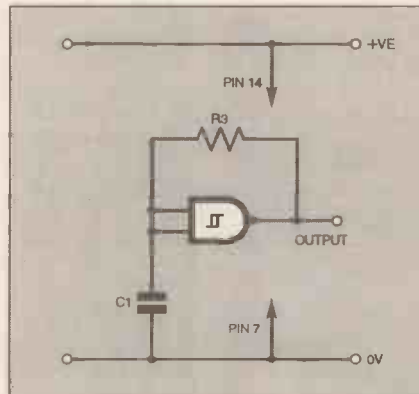


Fig. 4.9. Schmitt trigger oscillator.

To sum up the improved square wave oscillator circuits of Fig. 4.8 and Fig. 4.9:

ADVANTAGES:

- All the advantages of the previous circuits (Fig. 4.2, Fig. 4.7)
- Output is free of glitches
- Single Schmitt gate can be used for Fig. 4.9

DISADVANTAGES:

- An extra gate is required for Fig. 4.8
- Frequency is slightly dependent on the supply voltage

OP.AMP OSCILLATOR

Like the last two modules, Fig. 4.8 and Fig. 4.9, the op.amp relaxation oscillator circuit shown in Fig. 4.10 is always self-starting at power on and provides an output free of glitches.

The frequency of the output depends upon the values of resistor R1 and

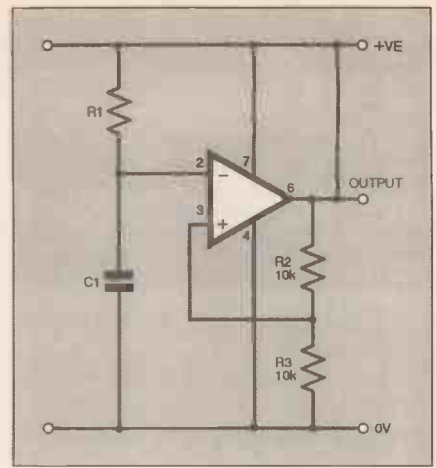


Fig. 4.10. Op.amp relaxation oscillator.

capacitor C1, and is given by the formula:

$$f = 1 / (2.2 \times R1 \times C1)$$

where f is measured in hertz, R1 in ohms and C1 in farads.

As before, a more manageable combination of units is: R in MΩ, C in μF; f will still be in hertz. As an example:

if $R1 = 470k\Omega (= 0.47M\Omega)$ and $C1 = 0.22\mu F$, then

$$f = 1 / (2.2 \times 0.47 \times 0.22) = 4.4Hz$$

The formula may be changed round if a particular frequency is required. For example, suppose a frequency of 2kHz (i.e. 2000Hz) is needed. Since the range of values of capacitors is limited, choose a capacitor value and then calculate the required resistor.

Selecting a capacitor with a value of 100pF (= 0.0001μF) and changing the formula round:

$$R = 1 / (2.2 \times f \times C)$$

$$\text{therefore, } R = 1 / (2.2 \times 2000 \times 0.0001) = 2.27k\Omega$$

In practice, select a 2.2kΩ (2k2) resistor, or use a 4.7kΩ (4k7) preset and adjust it for the correct frequency.

For many simple applications below about 20kHz, a type 741 op.amp may be used in the above circuit. For higher frequencies, other op.amps, such as the 748 or TL071, will provide good results. Low current CMOS versions of op.amps may also be substituted.

To sum up the op.amp relaxation oscillator in Fig. 4.10:

ADVANTAGES:

- Uses a simple op.amp
- Produces a stable, glitch-free output

DISADVANTAGE:

- Output may not swing fully between power line levels
- Uses more current than a logic gate i.e.

555 ASTABLE

The timer i.c. type 555 is specifically designed for monostable and astable circuits. When used as an astable, as shown in Fig. 4.11, it is another example of a relaxation oscillator.

Referring to the graph in Fig. 4.11, where T1 is the "mark" time in seconds, T2 is the "space" time and "Total T" is the whole period, then:

$$T1 = 0.7 (R1 + R2) \times C$$

$$T2 = 0.7 \times R2 \times C$$

$$\text{and Total T} = 0.7 \times (R1 + 2R2) \times C$$

$$\text{thus, } f = 1 / (0.7 \times (R1 + 2R2) \times C)$$

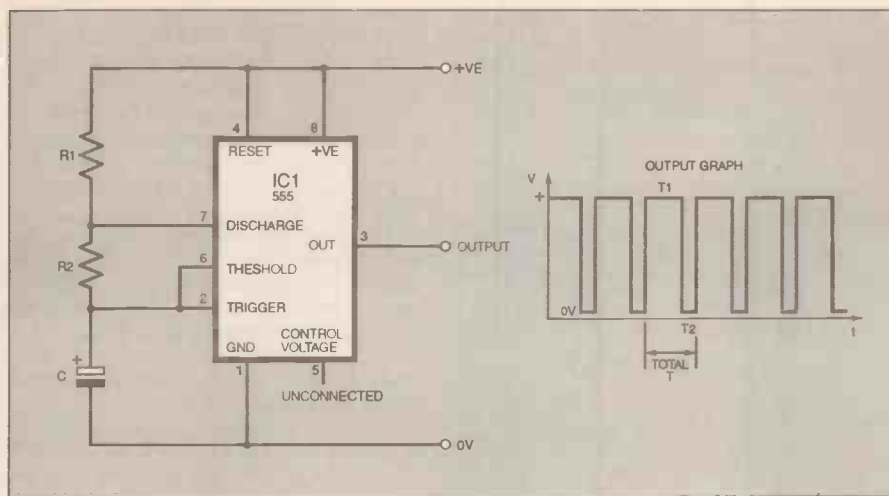


Fig. 4.11. A 555 astable and example output graph.

however, if R2 is much larger than R1 (e.g. R2 = 100kΩ, R1 = 4.7kΩ)

$$\text{then, } f = 1 / (1.4 \times R2 \times C)$$

For example, suppose a value of 680kΩ is selected for R2, but R1 remains at 4.7kΩ. This would be a sensible choice since it results in the output having a nearly equal mark/space ratio, and the simple formula which ignores R1 can be used.

Using a capacitor of, say, 10nF and changing the units: 680kΩ = 0.68M and 10nF = 0.01μF

$$\text{then, } f = 1 / (1.4 \times 0.68 \times 0.01) = 105\text{Hz}$$

Note that in Fig. 4.11 an electrolytic capacitor is shown, which is more suited to low frequencies. For higher frequencies, a non-polarised capacitor would normally be used.

The formulae above can be used to calculate:

Time period (T1) for which the output is positive

Time period (T2) for which the output is at 0V

Total time period (T1 + T2)

Frequency for all values of R1 and R2

Frequency formula simplified, if R2 is much larger than R1

Remember that if R2 is much larger than R1, the output wave has a nearly equal mark/space ratio (i.e. T1 = T2).

Some further example values and results are as follows (the answers are approximate):

R1	R2	C	f
4.7kΩ	100kΩ	0.001μF (1nF)	7kHz
4.7kΩ	100kΩ	0.01μF (10nF)	700Hz
4.7kΩ	1MΩ	0.01μF (10nF)	70Hz
4.7kΩ	1MΩ	0.1μF (100nF)	7Hz

If a variable frequency is required, replace R2 with a potentiometer wired as a variable resistor.

To sum up the 555 astable circuit of Fig. 4.11:

ADVANTAGES:

Easy to handle and use (standard version is not static sensitive)

Provides a stable frequency

Output can supply at least 100mA, and can drive small loudspeakers directly

DISADVANTAGES:

Standard version consumes more current than CMOS logic gates

Standard version can cause interference to other chips, e.g. counters

CMOS version is static sensitive

DECADE COUNTER AND CHASER

The Processor/Output module shown in Fig. 4.12 is based on the CMOS decade counter i.c. type 4017. Whenever its "clock input" (pin 14) is switched from 0V to positive, the i.c. counts up by one.

When the counter is in its reset condition, output Q0 (pin 3) is positive (high) and all the other outputs (Q1 to Q9) are at 0V. At each count, the currently high output pin returns to 0V and the next output pin in sequence switches high, in numerical Q order. When Q9 is high, the next clock pulse sets it low, and Q0 again goes high.

Note that the clock input must not be left "floating". It must either be connected to the output of another circuit, or be connected to 0V via a resistor of, say, 100k. Output pin 12, the CO (carryout) pin, is not used in this circuit and must not be connected to either power line.

In Fig. 4.12, outputs Q0 to Q9 are connected to i.e.d.s. Since only one i.e.d. is ever on at any time, a single series resistor is used to control their current.

Using the standard 4017, the i.e.d.s will not be very bright (although low current, high brilliance types could be used), since the outputs are not really designed for driving them, being capable of delivering very little current (see Part 1).

Alternatively, the 74HC4017 version could perhaps be substituted, which can deliver about 25mA per output pin. The i.e.d.s will be brighter, but this version of the counter *must* be used on a lower supply voltage. A *maximum* of 6V is permitted, although in practice it is safer to use a 4.5V battery, or a 5V regulated supply.

In reality, more current can probably be drawn from the pins of the standard 4017 than nominally allowed, although the output voltage level will fall accordingly. The subject of i.e.d. series resistors is discussed later, but assume now that a value of 220Ω for the resistor in Fig. 4.12 will probably be satisfactory when the circuit is powered at 12V.

Although the counter outputs are shown driving i.e.d.s, they may be used to drive other devices, such as transistors, if a larger output current is required. (See the section on npn drivers and Darlington drivers in Part 1.)

COUNTER RESETTING

Although the counter automatically resets back to zero on the tenth pulse, it is often desirable for it to be reset at an earlier point in the cycle. This may be achieved by using the counter's reset (RST) input pin 15. When pin 15 is connected to 0V the i.c. does not reset until each tenth pulse is received, but if pin 15 is made positive at any time, the counter will reset immediately (i.e. output Q0, pin 3, will switch high again).

There are several ways in which the counter can be reset. A manual reset control can be provided by a pushswitch, as shown in Fig. 4.13a. Normally, pin 15 is held at 0V via the resistor but when the pushswitch is pressed, pin 15 goes high, so resetting the counter.

In another situation, it may be required that the counter should be reset on a count

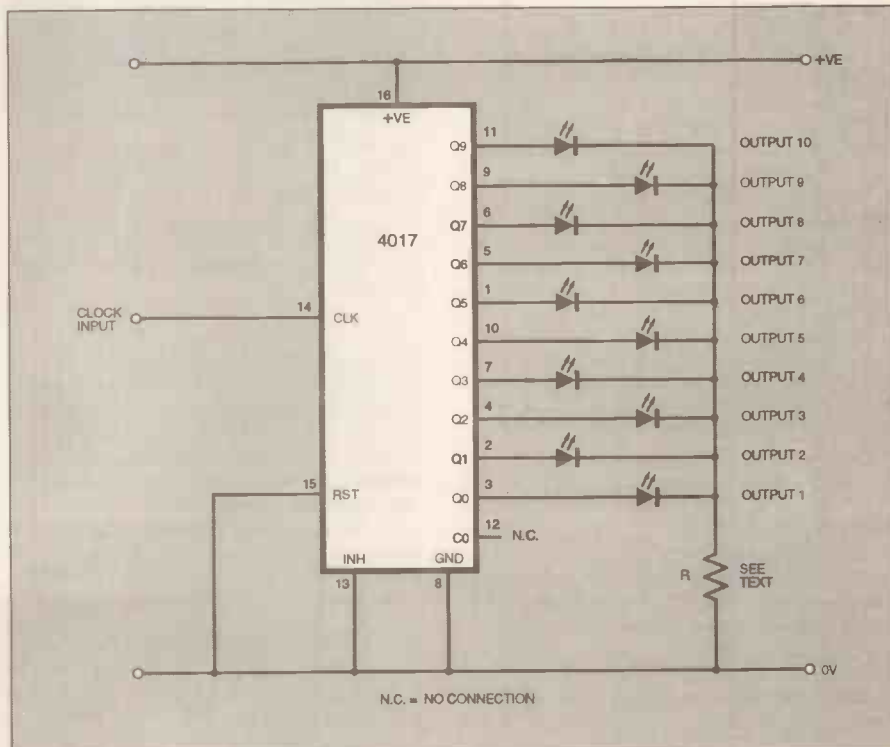


Fig. 4.12. Decade counter and chaser circuit.

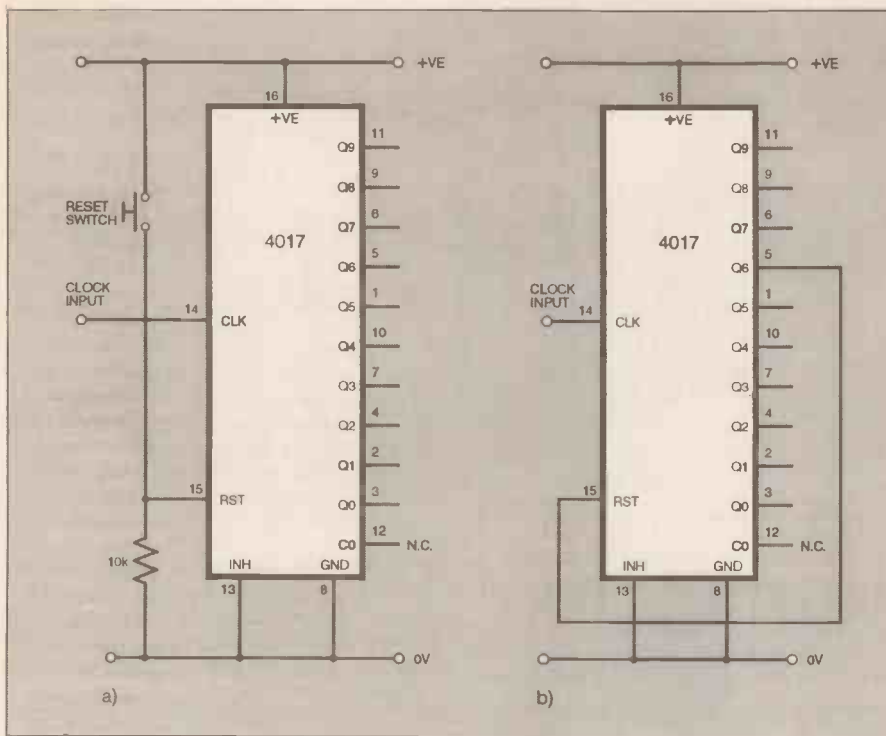


Fig. 4.13. Two methods by which the 4017 can be reset.

of six (for use as a dice indicator, for example). How this is done is shown in Fig. 13b.

The reset pin 15 is connected to the seventh output (Q6), which is normally at 0V. Starting from output Q0, the count proceeds upwards to output Q5, each output remaining high until the next clock pulse is received.

On the sixth clock pulse, though, output Q6 goes high, automatically resetting the counter back to zero via pin 15, and setting output Q0 high again. Consequently, output Q6 is only momentarily held high, a pulse period which is so short that it would be difficult to see it even on an oscilloscope.

CASCADING AND INHIBIT

A "carryout" function is provided via pin 12 (CO). It may be used to drive the clock input of a second counter if it is necessary to count up beyond nine. The use of this principle is illustrated in the *Vari-Speed Dice* project (see other pages).

An "inhibit" function is also provided on this type of counter, via pin 13 (INH). If this pin is taken high, the counter will cease to respond to clock pulses on its input pin 14, with the last-triggered output remaining high.

As soon as pin 13 is returned to 0V, the counter again responds to clock pulses as normal, continuing from the last output triggered. The inhibit function can be controlled by a switch in same way as shown in Fig. 4.13a.

L.E.D. SERIES RESISTORS

So far in this series, values for various l.e.d. series resistors have been suggested. These values were first calculated, and then the result was sometimes modified according to experience with a particular circuit.

For example, the 220Ω value for the resistor in Fig. 4.12 is actually much lower than calculation would suggest, due to the output resistance within the i.c. Even so, the method by which values are calculated

is fairly straightforward and provides a good starting point in selecting a resistor value. First, though, consider why a series resistor is actually needed.

When a *bulb* is connected to a power supply, as in Fig. 4.14a (in this case a 12V bulb and a 12V battery), the circuit will function satisfactorily. However, if an *l.e.d.* is substituted for the lamp, as in Fig. 4.14b, the l.e.d. will glow briefly and then die. Before it dies, though, it passes so much current that a small battery could quickly run down.

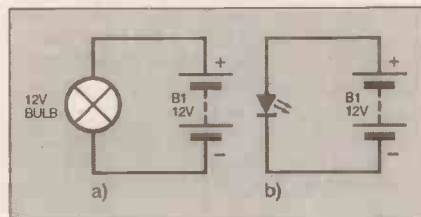


Fig. 4.14. The bulb circuit (a) will work happily but the l.e.d. in the other circuit (b) will die rapidly.

The reason is that a bulb has resistance and will pass an amount of current according to Ohm's Law:

$$I = V / R$$

The formula shows that the amount of current (I) depends up on the resistance (R) of the bulb and the voltage (V) across it. Once the bulb filament has reached its working temperature, its resistance is fairly constant and the current flowing depends only upon the voltage.

An l.e.d. is quite different. It is a diode which, in the direction that current can flow through it, has little appreciable resistance.

As stated in Ohm's Law, when resistance (R) is very small, the current (I) flow through it is very large. Consequently, the 12V battery in Fig. 4.14b causes a great deal of current to flow through the l.e.d., although the current will also be slightly limited by the additional resistance of the wires linking the l.e.d. to the battery, plus the internal resistance of the battery itself.

FORWARD VOLTAGE

There is a complication which arises regarding the calculation of current flow through an l.e.d. Although l.e.d.s can be said to have no appreciable resistance to current flow, a voltage difference, known as the *forward voltage drop*, exists across the l.e.d. when current flows through it.

The forward voltage drop varies slightly with different types of l.e.d., but is typically about 2V. In one sense, then, an l.e.d. does have significant resistance, but only to the first 2V or so of its supply voltage. It is therefore difficult to make a simple statement about its resistance and to apply this conventionally to Ohm's Law.

However, if an l.e.d. has a forward voltage drop of 2V, then the 12V battery in Fig. 4.14b can be likened to a 10V battery connected to a short-circuit. Both components will be very unhappy!

A good catalogue will state the forward voltage drop (V_f) of the l.e.d. being selected. Typically, the V_f for standard red l.e.d.s ranges from about 1.8V to 2V; other colours may range from 2V to 2.2V. However, if a forward voltage of 2V is assumed, calculation results will be accurate enough.

RESISTOR CALCULATION

Since an l.e.d. does not have resistance in the normal sense, a resistor has to be connected in series between it and the power supply to limit the current flow to a safe level, as shown in Fig. 4.15.

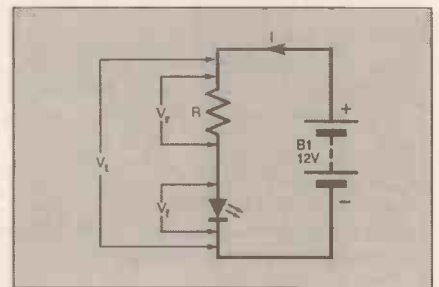


Fig. 4.15. Using a current-limiting resistor in series with an l.e.d.

To calculate the value of the resistor (R) the following information is required:

- Total voltage applied (V_t)
- Forward voltage drop (V_f) across the l.e.d.
- Current required through the l.e.d. (I)

In the example shown in Fig. 4.15, V_t is 12V and V_f is 2V. A catalogue will state the maximum current which can be permitted to flow through an l.e.d. Standard types require around 10mA to 20mA, although low current types are available which typically require 2mA, but these are more expensive. Currents less than the maximum can be used, although the brilliance of the l.e.d. will diminish accordingly. For this example, a current of about 15mA is desired.

Because the resistor in Fig. 4.15 is in series with the l.e.d., the current flow through the l.e.d. will be equal to the current flow through the resistor, in this case, about 15mA.

The forward voltage drop across the l.e.d. (V_f) is taken as 2V, and the voltage across the resistor (V_r) is the total voltage (V_t) less V_f .

$$\text{thus, } V_r = V_t - V_f$$

$$\text{therefore, } V_r = 12 - 2 = 10V$$

So, in the example, the voltage across the resistor is 10V. If the voltage across a resistor and the current flowing through it

are known, the required resistance value can be calculated using Ohm's Law:

$$R = V/I$$

Note that V must be in volts, I in amps, and R in ohms. The current of 15mA should be re-written as 0.015A, therefore:

$$R = 10/0.015 = 667\Omega$$

The standard resistor value nearest to 667Ω is 680Ω. This represents a good choice since the l.e.d. will be quite bright on a total voltage of 12V. Remember, though, that increased brilliance requires more current and results in a shorter battery life.

NON-STANDARD L.E.D.S

The calculations above apply to ordinary cheap l.e.d.s. It is possible to buy l.e.d.s which have a built-in resistor (although they cost more), in which case either a 5V type or 12V type must be selected, as appropriate.

Flashing l.e.d.s have an integral i.c. and are designed for a particular voltage range. Providing the voltage is within that range, the i.c. regulates the current supplied to the l.e.d. without the need for a series resistor.



EXAMPLE PROJECT

The Vari-speed Dice is the example project (elsewhere in these pages) which shows how the modules in *Teach-In Part 4* can be combined in a practical application.

PART FIVE

The modules to be examined in *Teach-In Part 5* are an I.R. receiver, encoder/decoder, bistables and a pulsed Darlington output. The example project is an Infra-Zapper.

Ohm Sweet Ohm

Max Fiddling

Snowbound

I'm often amazed how the United Kingdom grinds to a complete halt when the first seasonal snowflakes land on our island. An inch is enough to close motorways and cause all sorts of national catastrophes and disasters – all of which, though, pale into insignificance compared with the time the Fiddling household experienced a sudden shortage of tinned cat food for you-know-who!

Having received my marching orders from the Boss, I'd ventured out on a treacherous snowy pavement to the nearby corner shop, to purchase some tinned grub for my mange-tout moggie. What I would do for one of those snow scooters I'd seen on the telly! (A funny place to keep a snow scooter, I know.)

The biting wind did nothing to cheer my soul on this wintry day, as I shuffled home carrying a plastic bag of clattering tins of cat food, plus a packet of chocolate biscuits with which I'd decided to treat myself.

Hence, today saw me stuck in the workshop, which had donned a wig of freshly fallen snow. Inside the 'shop, though, the electric fan heater was blasting out three kilowatts of glorious heat, with myself and Piddles (my pesky puss) toasting nicely.

I was slowly thawing out after my expedition while Piddles was scoffing merrily away, clattering his plastic bowl on the floor of the shack oblivious to the fact that I'd nearly succumbed to terminal frostbite purely for his benefit (or so it felt like).

Thermal Contact

Upon my return I had been duly honoured with a mug of tea which I slurped appreciatively, whilst pondering whether there was any similarity between the name of my companion and the flavour of the tea ... Dunking a biscuit in my cuppa, (one of my uncouth habits, I'm

afraid), half of the soggy bikkie suddenly fell into the tea with a "ploop". I polished off the cheering brew with a gulp.

As you'd expect, the electric fan heater had not escaped the attention of my electronic meanderings. I'd recently completed an electronic thermostat project which I'd seen published in the magazine; my new temperature-sensitive gizmo sat there on the bench, with a thermistor probe stuck unceremoniously to the wall with Blu-Tak and the fan heater plugged into a mains socket mounted on top of the housing.

The heater whirred away, providing a handsome level of heat, and an l.e.d. on the panel glowed benignly as a confirmation that all was well with this negative tempco contraption ... Or so I hoped!

The trouble with dinner time is that I have to make it back to the house, leaving the cushy comfort of the snug 'shop, rather an inconvenience but you can't have everything these days, I sighed. At least we had an intercom between the workshop and the kitchen, another project I'd made recently and installed using a part drum of surplus 15A three-core cable. You could probably route a city's entire telephone exchange down the cable but never mind!

The intercom performed magnificently as the Boss summoned me to chow time. I reckoned Piddles would be safe enough in the shack, and I left the heater blazing merrily away so that all would be cosy upon my return.

Taking the Biscuit

About an hour later, and feeling suitably full of scrummy Yorkshire Pudding with gravy, I sneaked out and slithered back to my bolt-hole in the back garden. The menacing moggie had sprung onto the bench and was peering out at me through the window, tail swishing, having spotted some birds pecking away at the bird nut feeder I'd nailed up outside.



Not wanting to see my feathered friends dashed to ribbons at the paws of my marauding moggie, I quickly nipped through the door which I bolted firmly shut behind me! A certain fragrance greeted my nostrils ... a sort of biscuity, chocolatey kind of odour (I always thought I'd make a good wine buff) which I wanted to eat, it smelled so good!

Looking down at the floor, I could see the remains of several of my favourite chocolate biscuits which that dang-nabbing cat had snaffled! Piddles looked at me innocently, with his "Who, Me?" kind of expression: I glared back with my "Yes! You!" evil stare.

Worse still, the cocoa-flavour pong was traced to the pack of biscuits which he'd knocked over in front of the fan heater, where the blow-torch breath of the heater had melted the biscuits together into a chocolate digestive brick!

Undeterred, and not wanting to waste good food, I grabbed the freezer aerosol from the shelf above and I sprayed the outermost packet liberally. Whether it was entirely foodsafe I wasn't sure, but a deft application of a one-inch woodworking chisel separated the amalgamated sweetmeats inside into pieces which Piddles and I started to scoff between us, whilst peering out of the window wondering what we'll do next for entertainment.

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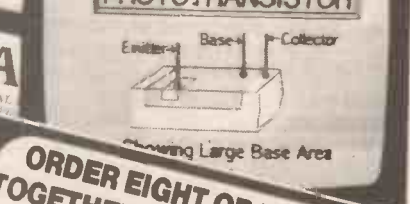
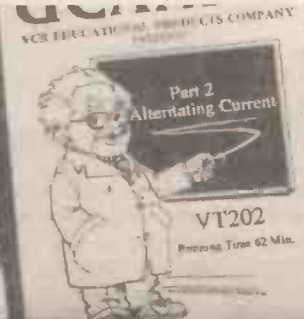
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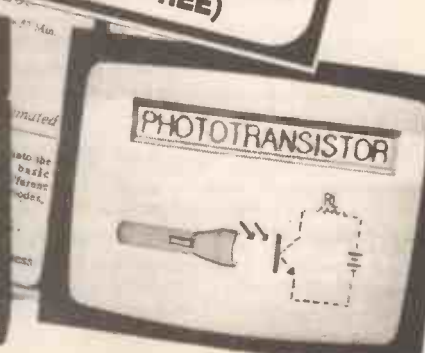
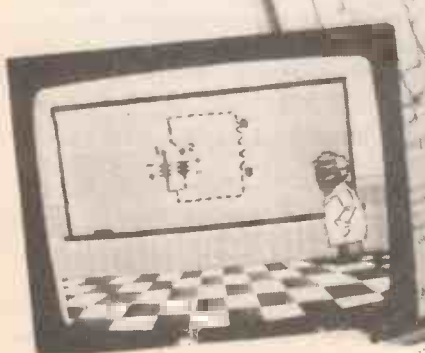
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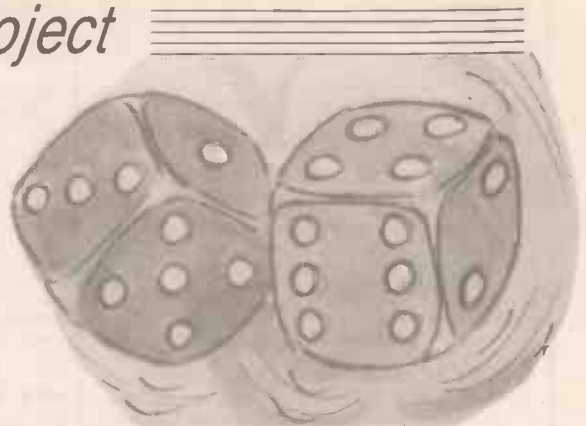
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VARI-SPEED DICE



MAX HORSEY PCB DESIGN BY **ALEX SIMM**

When the chips are down, let them shake, rattle and roll out your fate. Illustrates how Teach-In Part Four might be applied.

THIS project is based on the information provided in *Teach-In Part 4* and shows how modules may be selected and combined to produce a working project.

The Vari-Speed Dice includes a simple l.e.d. display, formed around two rows of six l.e.d.s which "chase" before stopping at "random". A novel feature of the circuit is that instead of the display stopping abruptly it gently slows to a halt, rather like a roulette wheel, thereby adding to the excitement if a particular number is required.

Making electronic circuits "random" is very difficult since any monostable or timer module will use a fixed time sequence. The project therefore relies upon a simple timer, plus the time for which the Start button is held down. The human factor adds the required degree of randomness!

BLOCK DIAGRAM

A block diagram of the modules required to make up the circuit is shown in Fig. 1. When the start button is pressed and held

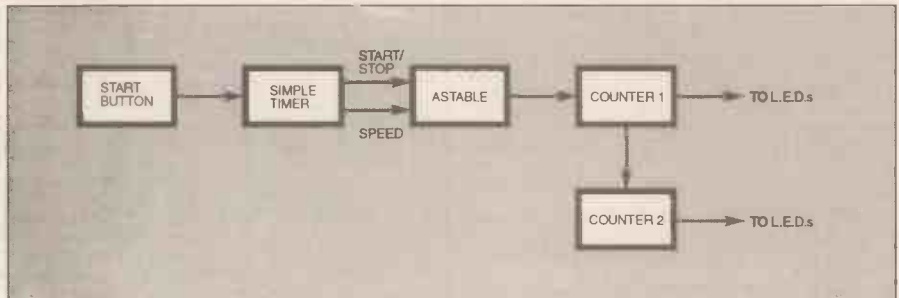


Fig. 1. Block diagram for the Vari-Speed Dice.

down, the timer causes the astable to start at full speed. The square wave from the astable drives the first counter/l.e.d. driver module, which causes six l.e.d.s to flash in sequence.

The same output from the astable could be used to drive the second counter, but this would make the l.e.d.s always stop at the same pairs. A second astable, set at a different speed would solve the problem, but this would necessitate the use of another i.c.

A more obvious way of driving the second counter is from the "carry" output of the first counter. In other words the

second counter moves one step for every six steps of the first. The result is just as random as using two astable modules.

CHOOSING THE MODULES

The complete circuit diagram for the Vari-Speed Dice is shown in Fig. 2.

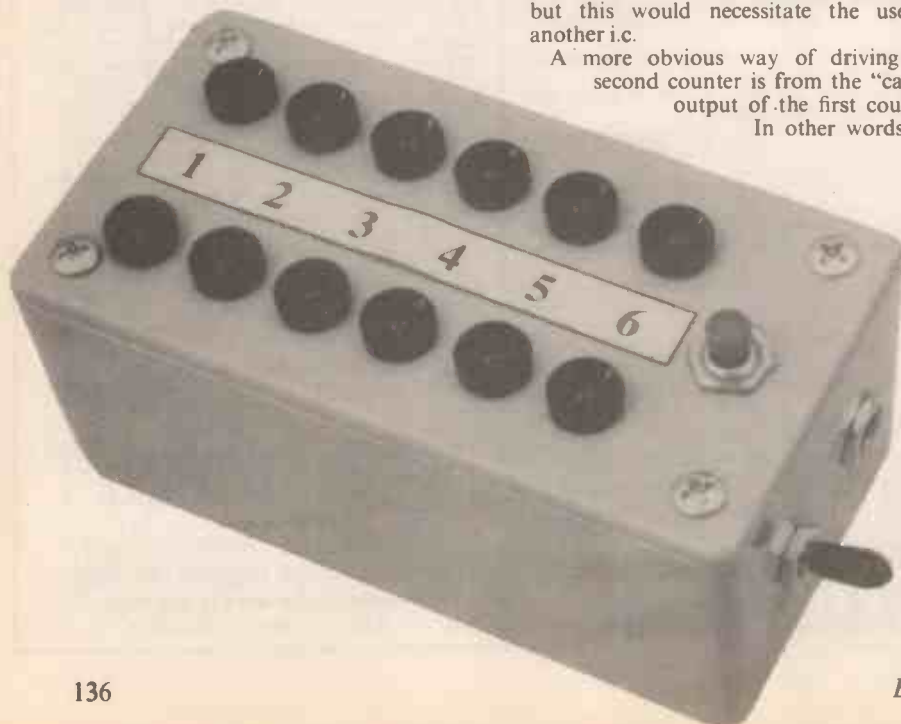
The Timer is based on the Simple Capacitive Delay module described in *Teach-In Part 2* (Fig. 2.3). When the Start switch S1 is pressed, capacitor C1 is discharged. When S1 is released, C1 charges up slowly via resistor R1. The values of R1 and C1 determine the speed with which the voltage across C1 rises – higher values equals longer time.

A slowly changing voltage is often a nuisance in logic circuits, many of which require a sudden change from logic 0 to logic 1. However, in this design the slowly rising voltage is put to good use in controlling the speed of the astable.

VOLTAGE CONTROLLED ASTABLE

A number of astable modules are outlined in *Teach-In Part 4*. The one chosen for use here is the Voltage Controlled Frequency module of Fig. 4.7, which has its frequency (speed) varied by changing the voltage on the two input resistors, R2 and R3 in Fig. 2. This circuit does not provide a "glitch-free" output, but this is of no consequence since any glitches which cause the counter to move one step more than expected will add to the randomness.

In Fig. 2, the astable is formed around two NOR gates, IC1c and IC1d. Its basic frequency is determined by the values of resistors R2 and R3, and capacitors C2 and C3 (larger values = lower frequency). Their values have been chosen to set the



oscillator speed to make it impossible to predict the outcome of the count. (If the value of C2 were to be increased to 100nF the speed would be just slow enough to allow a sharp constant to fix the result by releasing the button at a particular moment.)

A method of switching an astable on and off by controlling the voltage at one of the pins was also discussed in Part 4 (Fig. 4.3). The technique is used here in the circuit of Fig. 2, IC1c pin 9 being the on/off input, which is controlled by the output from IC1b pin 4. When IC1c pin 9 is held high (made positive) the astable stops oscillating.

Referring to IC1a and IC1b, when the voltage at the junction of R1 and C1 is low, pins 1 and 2 will be low, consequently pins 3, 5 and 6 will be high and pin 4 low. In other words, output pin 4 merely copies the logic on input pins 1 and 2. Using a pair of gates in this way provides a cleaner voltage

change at IC1c pin 9 than would be the case if the pin was connected directly to C1.

When switch S1 is pressed, the voltage at the positive side of capacitor C1 falls to zero and, as a result, IC1c pin 9 also goes low. Since the lower ends of resistors R2 and R3 are also connected to C1, and thus also at 0V, the astable oscillates at its maximum speed (as discussed in Part 4).

As C1 charges, the voltage at its junction with R2 and R3 rises, causing the astable to slow down. When the voltage across C1 reaches half the supply voltage, the astable is at its minimum speed. Then, as this voltage crosses the half way level, the logic at IC1b pin 4 changes from low to high, causing the astable to stop oscillating.

COUNTER/CHASER

The l.e.d. counter/chaser circuits are based on those discussed in Part 4,

Fig. 4.12 and Fig. 4.13, using a CMOS 4017B decade counter. Essentially, both counters are identical and are formed around IC2 and IC3. Each is connected so that it counts from one to six, then resets to one again at the next clock pulse.

Counter IC2 is "Clocked" on its input pin 14 by the output pulses from IC1d pin 11 of the astable. Pulses from the "Carry Out" pin 12 of IC2 provide the clock pulses for counter IC3.

On both IC2 and IC3, Reset pin 15 is connected to output pin 5, which is the seventh output (Q6). Consequently, each i.c. counts from the first output (Q0), through outputs Q1 to Q5, then resetting back to Q0 immediately the count reaches output Q6.

Each output is connected to an l.e.d. Since only one l.e.d. can be on at any one time, a single series resistor, R4 for IC2 and R5 for IC3, is used to control the current. The current available from each output

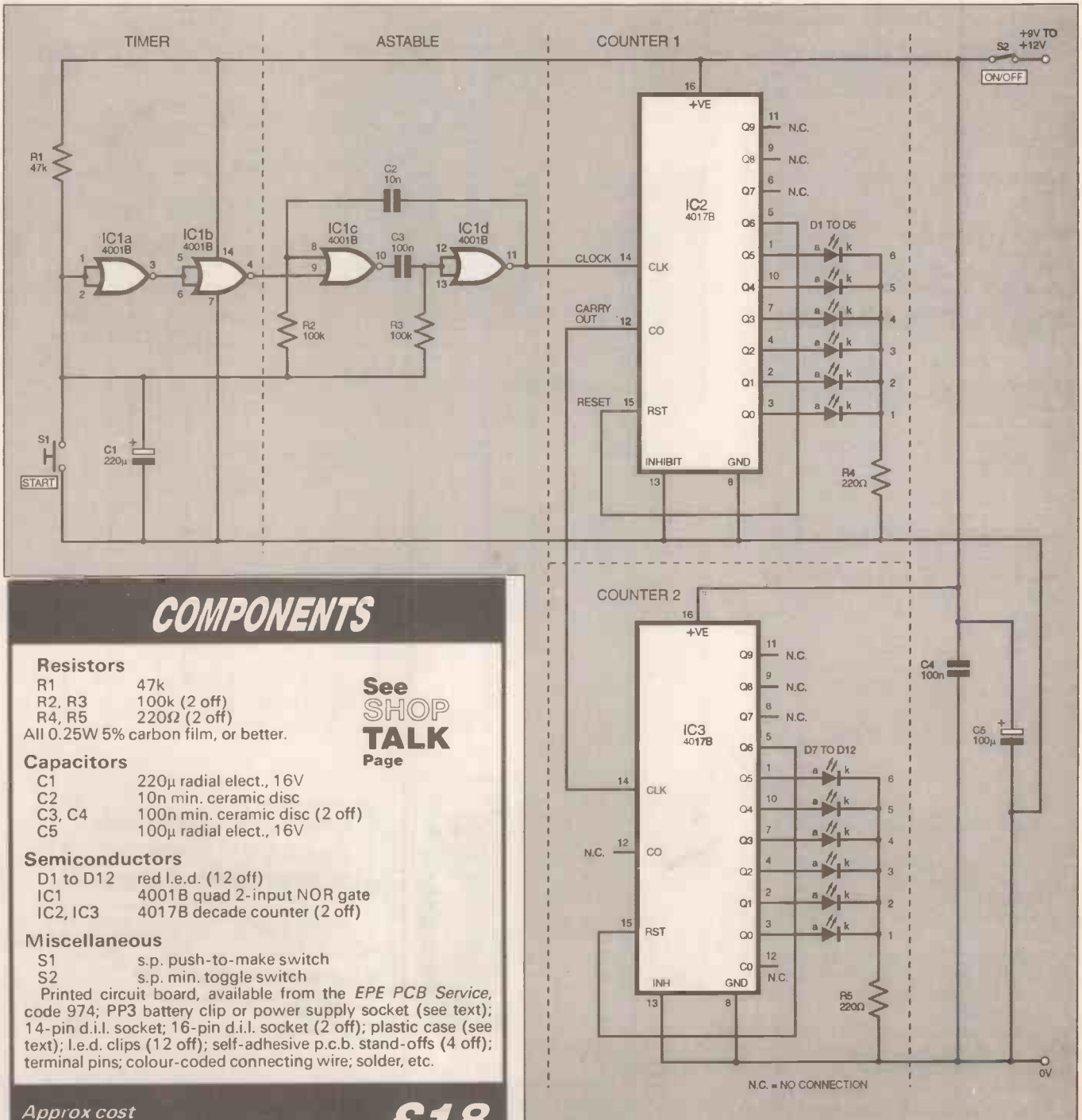


Fig. 2. Full circuit diagram for the Vari-Speed Dice.

COMPONENTS

Resistors

R1 47k
R2, R3 100k (2 off)
R4, R5 220Ω (2 off)

All 0.25W 5% carbon film, or better.

Capacitors

C1 220µF radial elect., 16V
C2 10nF min. ceramic disc
C3, C4 100nF min. ceramic disc (2 off)
C5 100µF radial elect., 16V

Semiconductors

D1 to D12 red l.e.d. (12 off)
IC1 4001B quad 2-input NOR gate
IC2, IC3 4017B decade counter (2 off)

Miscellaneous

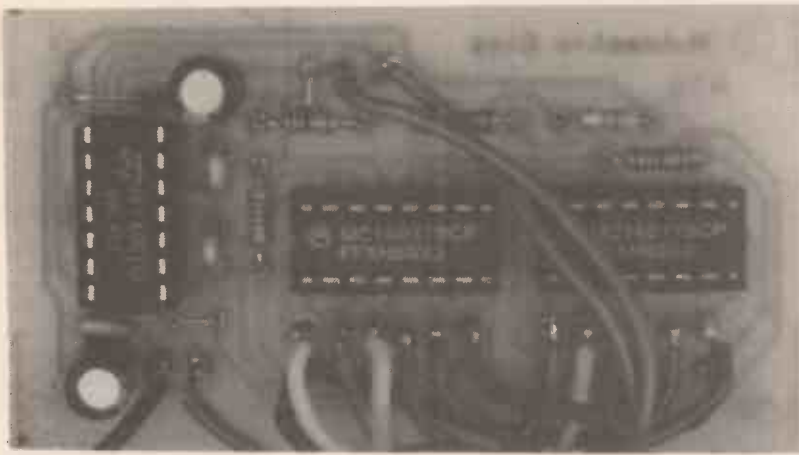
S1 s.p. push-to-make switch
S2 s.p. min. toggle switch

Printed circuit board, available from the *EPE PCB Service*, code 974; PP3 battery clip or power supply socket (see text); 14-pin d.i.l. socket; 16-pin d.i.l. socket (2 off); plastic case (see text); l.e.d. clips (12 off); self-adhesive p.c.b. stand-offs (4 off); terminal pins; colour-coded connecting wire; solder, etc.

See
**SHOP
TALK**
Page

Approx cost
guidance only

£18



Completed printed circuit board.

is rather small, and the i.c. is not really designed for driving l.e.d.s directly. However, with a supply of 9V or 12V (from, say, a mains adaptor) the l.e.d.s are more than adequately lit.

If extra brightness is required, special low-current l.e.d.s are available. Alternatively the CMOS 4017B could be replaced by the 74HC4017 which has a much higher output current, but **MUST NOT** be used on a supply of **MORE** than 6V. The subject of CMOS output currents and l.e.d. series resistors is referred to in Part 4.

Capacitors C4 and C5 provide the required power line decoupling, as discussed in Part 1. Switch S2 is a power supply On/Off switch, particularly important if a battery is used to power the circuit.

CONSTRUCTION

Details of the printed circuit board (p.c.b.) and its connections for the Vari-Speed Dice are shown in Fig. 3. This board is available from the *EPE PCB Service*, code 974.

Fit the two short wire links (not the connecting wires), followed by the i.c. sockets and resistors. Now fit the small ceramic disc capacitors. The labelling of these can sometimes be confusing. Note that if the legend "103" is printed on the capacitor body it means the capacitance value is 10nF (0.01µF) and that "104" means 100nF (0.1µF).

To some readers, this may seem quite illogical. However, "103" actually translates like a resistor colour code, namely, "one", "zero" plus "three" more zeros, i.e. 10,000, measured in picofarads (pF). Clarifying further:

$$1F = 10^6\mu F = 10^9nF = 10^{12}pF$$

Capacitors C1 and C5 are electrolytic and must be fitted the correct way round. The negative end is normally printed on the body; the positive end is indicated by a longer lead.

Solder terminal pins into the p.c.b. for all the external connections.

The p.c.b. allows the l.e.d.s to be mounted directly to it, if preferred. However, in the prototype, the l.e.d.s were mounted on the case lid and linked to the p.c.b. with wires. It is *much* easier to mount the l.e.d.s in the case *before* connecting them to the circuit.

If this is the chosen method, note from Fig. 3 that the l.e.d. anodes (a) have separate wires connecting back to the board. The l.e.d. cathodes (k), however, are soldered to each other in two groups, each group is then connected to the board via a single wire.

HOUSING THE DICE

The prototype was used with a 12V battery eliminator (mains adaptor) and was housed in a plastic case measuring 104mm × 53mm × 44mm. Although the circuit can be powered by a 9V battery, note that a PP3 battery will not easily fit into this size of box.

As seen in the photographs, l.e.d.s were mounted in two straight lines. Alternatively, two circular arrangements could be used. When marking out the positions of the l.e.d.s, allow room for their mounting clips. Although the l.e.d.s could be inserted directly into the case, the use of clips makes the mounting task easier and provides a much neater finish.

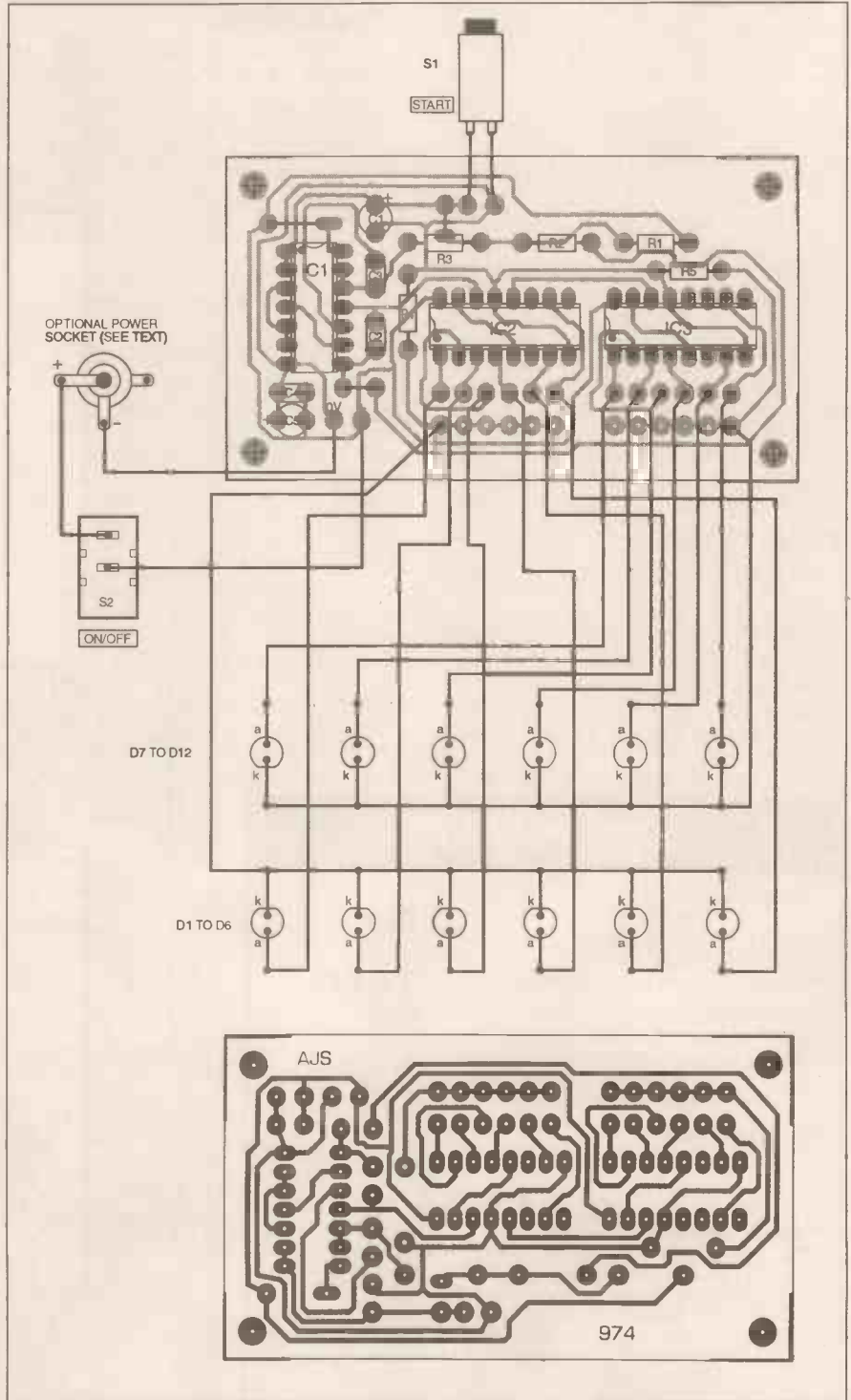


Fig. 3. Printed circuit board component layout, interwiring and full size underside copper foil master pattern. The spare copper pads, below IC2/IC3, can be used for direct board mounting of the l.e.d.s.

Mark the positions of the Start pushbutton switch, On/Off switch and Power Input socket, if required. Drill the holes, taking particular care to get the l.e.d. holes in line – even if just one l.e.d. is not exactly in line the appearance is spoilt. It helps if a very small drill is used first.

Position the l.e.d.s into their clips ensuring that the cathode (k) leads are all facing the same way as shown in Fig. 3. This makes the common cathode (k) connections much simpler to arrange. The cathode side of an l.e.d. is usually the shorter lead. If the leads have been cut, note that the cathode of a round l.e.d. is likely to be denoted by a tiny flat mark at the base of the body.

Now connect and solder the l.e.d. cathodes using a length of bare wire. This common junction is connected to the p.c.b. using a length of insulated wire.

Use colour coded insulated wire to link the l.e.d.s to the terminal pins. In other words, use a black lead for the common cathode connection, a brown lead for l.e.d. D1, red for D2, orange for D3, etc. Using coloured leads in resistor colour code order greatly eases assembly, particularly if fault finding is necessary.

The l.e.d. leads should be shortened before soldering and bent neatly against the plastic body of the case after soldering.

Complete the external wiring. Discharge static electricity from your body before handling the i.c.s, by touching a grounded item first. Then insert the i.c.s into their sockets ensuring that their orientation notches line up as shown.

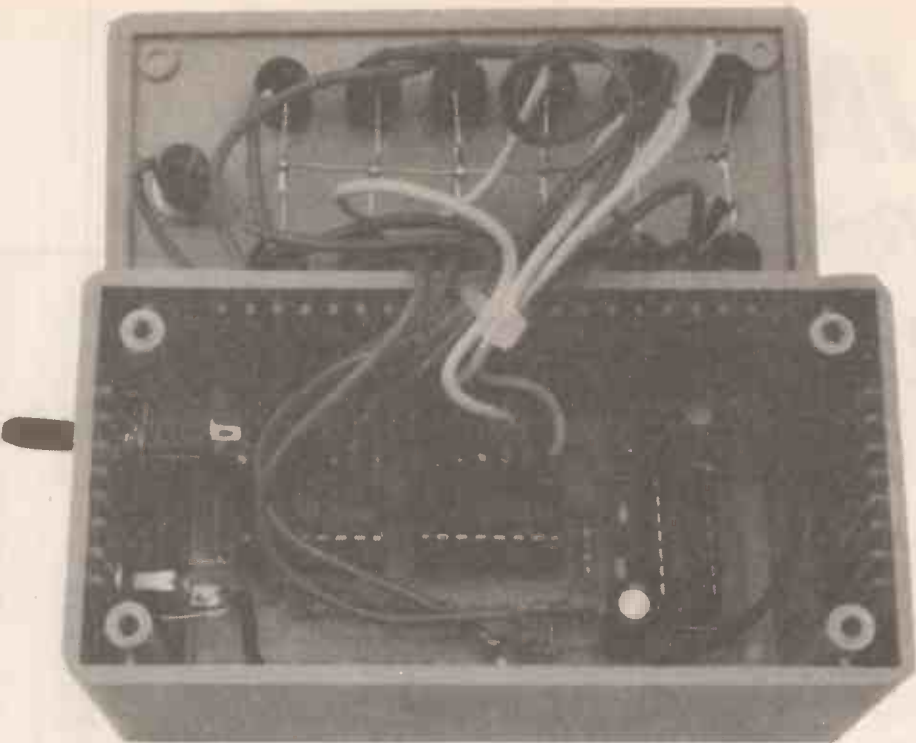
Now thoroughly check the board with a magnifying glass, ensuring that components are correctly positioned and that all solder joints are correctly made.

TESTING

A regulated 9V or 12V supply which can be limited to a maximum output current of 100mA is ideal for testing, and will be unlikely to harm the circuit even if major mistakes have been made.

Connect the supply, switch on S2, and check that one l.e.d. of each set lights up. If this does not happen, switch off and recheck for mistakes.

If all is well, press switch S1. The l.e.d.s should chase, with one set chasing six times faster than the other. Release S1. After a brief pause, the chase should slow down and finally stop. The pause length may be shortened by reducing the value of either resistor R1 or capacitor C1.



The p.c.b. is positioned on the base of the box with self-adhesive stand-offs. Take care that the lid mounted components do not short on the p.c.b.

FAULT FINDING

If the circuit does not behave as expected, decide first if the fault affects the whole circuit, or just one module and if so, which one. For example, measure the voltage across pins 7 and 14 of IC1, and across pins 8 and 16 of IC2 and IC3. If a voltage reading equal to that of the power supply is present, and with the correct polarity, check each module as described below. If not, check that the power socket has been connected correctly and that there is a voltage across it.

Read the fault finding guide in Part 1 of the series for general help, and using a voltmeter with its negative side connected to 0V in the circuit try the following tests:

When S1 is pressed, the voltage at IC1 pins 1 and 2 should be 0V. When S1 is released this voltage should rise to the maximum power supply level. The voltage at IC1 pins 3, 5 and 6 should be equal to the positive supply when S1 is pressed, switching to about 0V a few seconds after S1 is released. IC1 pin 4 should do the opposite

of pin 3. Check that the voltage on IC1 pin 9 copies that on IC1 pin 4.

Correct operation of the astable can only be checked with the aid of an oscilloscope: a square wave should be seen at IC1 pin 11 and IC2 pin 14.

Failure of all the l.e.d.s is likely to imply that they are connected the wrong way round or the common connection between their cathodes and the p.c.b. has been forgotten.

INSTALLATION

The p.c.b. may be fastened to the base of the case using self-adhesive p.c.b. supports. Check that when the lid is positioned, a short circuit cannot occur between exposed parts on the p.c.b. and the bare l.e.d. wires. Screw the lid into position, and give the project a final test. □

PART FIVE

Next month an Infra-Red Zapper construction project will be the subject of *Teach-In Part Five*.



Collection of "demonstration" modules used to back up the Teach-In Series.

INTERFACE

Robert Penfold



THIS month we continue with the theme of computers and model railways. This is a popular subject which has been covered spasmodically in *Interface* articles over the years.

In this article we will look at a simple method of providing keyboard control of a signal and the train using hardware that has been covered in previous articles. The circuits and software are designed for use with a PC, and they operate via one of the printer ports.

Provided you have the requisite technical know-how it should be possible to adapt this system to suit other computers. It should also be possible to use them with PCs via some form of parallel input/output card.

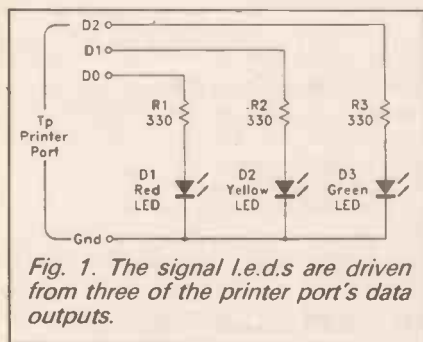


Fig. 1. The signal l.e.d.s are driven from three of the printer port's data outputs.

Key To Success

The function of the system is quite simple, and it is centred on a three aspect (Red - Amber - Green) signal which is controlled from the computer's keyboard. The red, amber, and green signal lights are selected by pressing the "R", "A", and "G" keys respectively.

The train automatically responds to the signal, and stops just in front of the signal if it is set to "red". If the signal is set to "green" or "amber", the train will, where necessary, alter its speed as it passes the signal.

This is essentially the opposite of the system described in the previous *Interface* article. This had manual control of the train, with the signal automatically operated by the train as it passed sensors under the track. In this case the signal is controlled manually, and the train automatically responds to the signal. You take the role of the signaller and the computer drives the train!

On the face of it, the speed of the train simply has to be set at something appropriate when the signal is given a new setting. In practice matters are not quite as simple as this, because the train must only respond to a change in the setting of a signal as it actually approaches the signal. It must not simply change speed as

soon as the signal is altered, regardless of the train's position on the track.

The necessary hold-off is achieved using a track sensor positioned just in front of the signal. Any change in speed dictated by the setting of the signal is not actually implemented until the train activates this sensor.

Light Work

The signal l.e.d.s are driven from data lines D0 to D2, as shown in Fig. 1. This is the same method that was utilized in the signalling system featured last month. If preferred, small filament bulbs can be driven via common emitter switching stages, also described last month.

The same method can be used to drive l.e.d.s at higher currents than the printer port can provide. The red, amber (yellow), and green l.e.d.s are selected by respectively writing values of one, two, and four to input/output address &H378 (port 1) or &H278 (port 2).

Under Control

A circuit diagram for the Train Controller Interface, which is essentially the same circuit that was featured in *EPE* June '95 issue, is shown in Fig. 2. Consult the *Interface* article in that issue for a detailed description of the circuit and the way in which the controller functions.

Note that this version of the controller is driven from bit 2 at input/output address &H37A (port 1) or &H27A (port 2). In the original design it was driven from bit 0 of the main 8-bit output port, but in this system bit 0 of this port is "previously engaged" driving one of the signal l.e.d.s.

This controller functions by having the computer generate a suitable pulse signal, with the interface converting the signal to suitable drive levels for the electric motor

in the train. In this case the computer only has to generate three types of pulse signal.

A signal having a high mark-space ratio provides full speed when the signal is at "green", a one-to-one mark-space ratio provides about half maximum speed when the signal is at "amber", and a low mark-space ratio brings the train to a halt when the signal is at "red."

Forward/Reverse

The forward/reverse switch S1, can be two sets of changeover relay contacts under control of the computer if desired. But the software provided here is not designed to handle this feature though, and having a bidirectional train complicates matters somewhat.

It would be necessary to have a sensor each side of the signal so that the train could be brought to a halt at the correct side of the signal, regardless of which way the train was moving. The signal itself would also need to be bidirectional. This is all quite feasible, but initially it is probably best to settle for a simple one-way system.

Although the controller is a pulsed type, transistor TR1 still has to dissipate a certain amount of power, particularly when the train is set at full speed. TR1 should therefore be fitted with a small bolt-on heatsink. The circuit works well using either a TIP121 or a TIP122 power Darlington transistor for TR1.

The controller circuit requires a reasonably stable 15V supply which must include overload protection, since the controller circuit itself has no form of short-circuit protection. A suitable mains power supply circuit is provided in Fig.3, and this is a conventional design using bridge rectification and a monolithic voltage regulator.

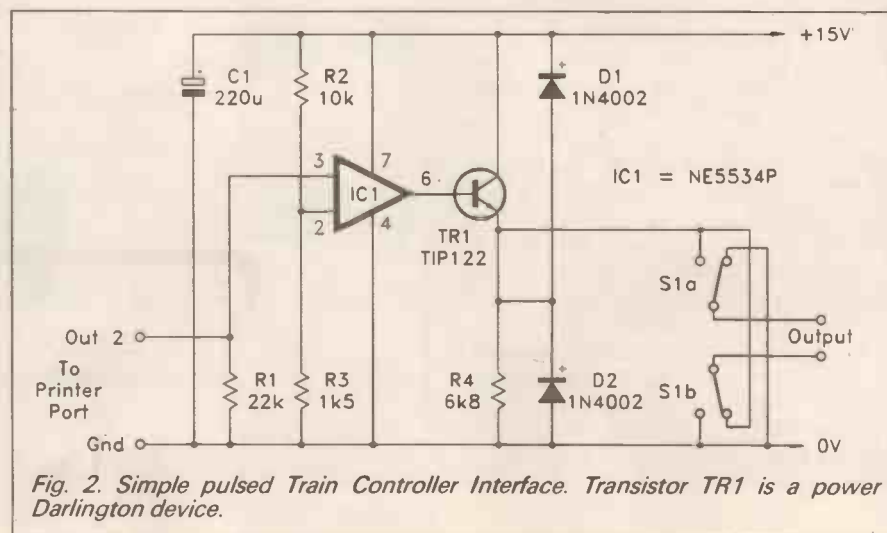


Fig. 2. Simple pulsed Train Controller Interface. Transistor TR1 is a power Darlington device.

This circuit is only included for the benefit of experienced readers, and beginners should not undertake projects which connect to the *dangerous mains supply*. If you lack the necessary experience, power the circuit from a ready-made supply that can provide 15V at 1A or more.

On The Track

The circuit diagram for the Track Sensor Interface is shown in Fig. 4. This is basically the same as the interface used in the automatic signal described last month, but in this case only one sensor switch and pulse stretcher are needed.

The use of reed and microswitches for position sensing in model railways has been covered in previous articles, and is well known to many model railway enthusiasts. Consequently, it is not something we will consider in detail here.

The interface drives bit four of input/output address &H379 (port 1) or &H279 (port 2).

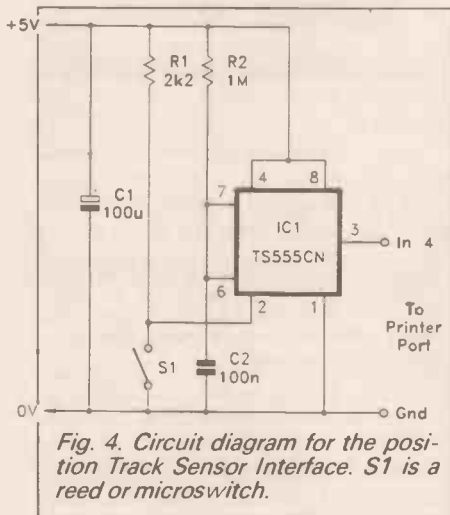


Fig. 4. Circuit diagram for the position Track Sensor Interface. S1 is a reed or microswitch.

Software

The software listing provided here is very simple, but it provides the required combination of manual and automatic control. Note that a reasonably fast PC is needed in order to obtain satisfactory results with this program.

Good results were obtained using a 33MHz 80386DX PC, but anything much slower than this would probably not give good results, with rather jerky movement of the train. The program is for use with printer port 1, but with the appropriate address changes it will obviously work properly with port 2.

Lines 20 to 50 clear the screen and print some on-screen instructions. Line 60 sets the signal initially at "amber", and the next two lines set variables "MARK" and "SPACE" at values of 50.

These two variables set the mark and space periods of the pulsed output signal, and the suggested values give about half speed. Other speeds can be obtained using different values, but they should total about 100. Lines 90 and 130 respectively set the output line high and low, and the two FOR...NEXT loops provide delays that control the mark-space ratio of the output signal.

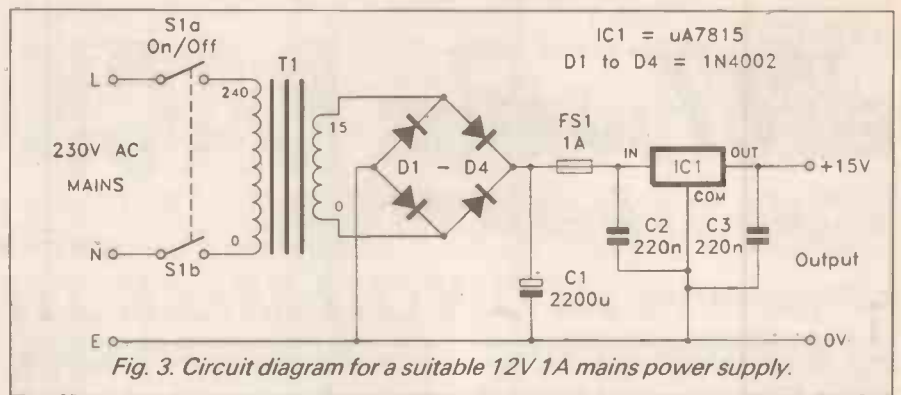


Fig. 3. Circuit diagram for a suitable 12V 1A mains power supply.

Subroutine

The program is taken into the subroutine beginning at line 170 if a key press is detected at lines 110 and 120. The main purpose of this subroutine is to set the state of the signal to match the key that has been pressed.

This is achieved using a series of IF...THEN statements. This subroutine also sets the variable called "SIGNAL" to a value of one, two, or three, depending on whether the signal has been set to "red", "amber", or "green."

Line 150 detects pulses from the track sensor, and each time a pulse is detected it branches the program to the subroutine starting at line 250. A series of IF...THEN statements are used to set variables "MARK" and "SPACE" at appropriate values for the current setting of the signal.

The setting of the signal cannot be determined by reading the 8-bit output port, since this is strictly an output address. The value of the variable "SIGNAL" is therefore used to determine the setting of the signal.

Listing 1: Automatic Model Train Control

```

10 REM AUTOMATIC TRAIN CONTROLLER PROG
20 CLS
30 PRINT "Press 'R' key for RED signal"
40 PRINT "Press 'A' key for AMBER signal"
50 PRINT "Press 'G' key for GREEN signal"
60 OUT &H378,2
70 MARK = 50
80 SPACE = 50
90 OUT &H37A,4
100 FOR DELAY = 1 TO MARK: NEXT DELAY
110 A$ = INKEY$
120 IF LEN(A$) = 1 THEN GOSUB 170
130 OUT &H37A,0
140 FOR DELAY = 1 TO SPACE: NEXT DELAY
150 IF (INP(&H379) AND 16) = 16 THEN GOSUB 250
160 GOTO 90
170 IF A$ = "s" THEN END
180 IF A$ = "r" THEN OUT &H378,1
190 IF A$ = "r" THEN SIGNAL = 1
200 IF A$ = "a" THEN OUT &H378,2
210 IF A$ = "a" THEN SIGNAL = 2
220 IF A$ = "g" THEN OUT &H378,4
230 IF A$ = "g" THEN SIGNAL = 3
240 RETURN
250 IF SIGNAL = 1 THEN MARK = 1
260 IF SIGNAL = 1 THEN SPACE = 100
270 IF SIGNAL = 2 THEN MARK = 50
280 IF SIGNAL = 2 THEN SPACE = 50
290 IF SIGNAL = 3 THEN MARK = 100
300 IF SIGNAL = 3 THEN SPACE = 1
310 RETURN

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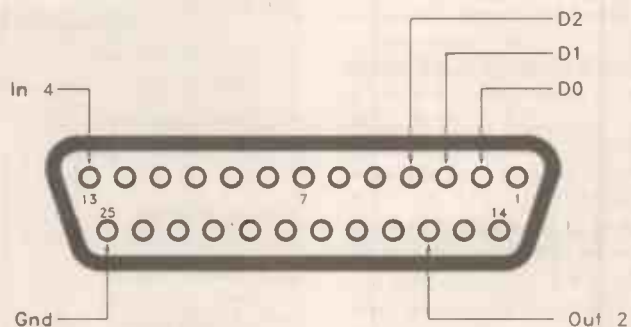


Fig. 5. Details of the connections to the printer port.

We can supply back issues of *EPE* by post, many issues from the past five years are available. An index for each year is also available – see order form. Alternatively, indexes are published in the December issue for that year. Where we are unable to provide a back issue a photostat of any *one article* (or *one part* of a series) can be purchased for the same price.

DID YOU MISS THESE?

AUG. '94

PROJECTS ● Experimental Noise Cancelling Unit ● Dancing Fountains, Part 1 ● Charged-Up (PC battery tip) ● 6802 Development Board ● TV Camera Update ● Stereo HiFi Controller, Part 2.
FEATURES ● Calculation Corner, Part 8 ● Best of British, Part 5 ● I'll Be Seeing You (multimedia communications)

SEPT. '94

PROJECTS ● Protector Plus Car Alarm ● Greenhouse Watering System ● Experimental Seismograph, Part 1 ● Three-Channel Lamp Controller ● Dancing Fountains, Part 2.
FEATURES ● Calculation Corner, Part 9 ● The Invisible Force (magnetic force).



OCT. '94

PROJECTS ● Digilogue Clock ● Visual/Audio Guitar Tuner ● Hobby Power Supply ● Audio Auxilexer ● Experimental Seismograph, Part 2.
FEATURES ● Electronics from the Ground Up, Part 1 with FREE PC Software ● Calculation Corner, Part 10.

NOV. '94 Photostats Only (see below)

PROJECTS ● 1000V/500V Insulation Tester ● Video Modules, Part 1 (Simple Fader, Improved Fader, Video Enhancer) ● Active Guitar Tone Control ● Power Controller ● TV Off-er.
FEATURES ● Electronics from the Ground Up, Part 2 ● Consumer Electronics Show.

DEC. '94

PROJECTS ● Spacewriter Wand ● *EPE* Fruit Machine ● Universal Digital Code Lock ● Video Modules, Part 2 (Horizontal Wiper, Vertical Wiper, Audio Mixer) ● Rodent Repeller.
FEATURES ● Electronics from the Ground Up, Part 3 ● Embedded Controllers ● Index for Volume 23.

JAN. '95 Photostats Only (see below)

PROJECTS ● Magnetic Field Detector ● Moving Display Metronome ● Model Railway Track Cleaner ● Beating the Christmas Lights ● *EPE* Fruit Machine, Part 2 ● Video Modules, Part 3 (Dynamic Noise Limiter, System Mains Power Supply).
FEATURES ● Electronics from the Ground Up, Part 4 ● Electromagnetic Compatibility ● Checking Transistors.

FEB. '95

PROJECTS ● 12V 35W PA Amplifier ● Foot-Operated Drill Controller ● The Ultimate Screen Saver ● MIDI Pedal Board ● Model Railway Signals.
FEATURES ● Electronics from the Ground Up, Part 5 ● Transformerless Power Supplies ● Quickroute 3.0 Review.

MARCH '95

PROJECTS ● Multi-Purpose Thermostat ● Name of the Game-1 Counterspell ● Sound Activated Switch ● Audio Amplifier ● Light Beam Communicator.
FEATURES ● Electronics from the Ground Up, Part 6 ● Understanding PIC Micro-controllers ● Visio Graphics Software Review. FREE Multi-Project PCB with this issue.

APRIL '95

PROJECTS ● National Lottery Predictor ● Auto-Battery Charger ● Light-Activated Switch ● Switch On/Off Timer ● Continuity Tester ● Name of the Game-2 Counterspin.
FEATURES ● Electronics from the Ground Up, Part 7 ● Circuit Surgery ● The Hard Cell (Mobile Telephones).

MAY '95

PROJECTS ● PIC-DATS-1 (PIC Development and Training System) ● R.F. Signal Generator – 1 ● MIDI Pedal ● Club Vote Totaliser ● Name of the Game-3, On Your Marks and Games Timer.
FEATURES ● Electronics from the Ground Up, Part 8 ● Las Vegas Show Report.

JUNE '95 Photostats Only (see below)

PROJECTS ● PIC-DATS-2 (PIC controlled 4-Channel Light Chaser) ● *EPE* HiFi Valve Amplifier – 1 ● R.F. Signal Generator – 2 ● AA to PP3 Converter ● Name of the Game – 4, Star-Struck!, Six-Shot Light Zapper, Wander Wands.
FEATURES ● Electronics from the Ground Up, Part 9 ● Smart Cards.

JULY '95

PROJECTS ● Windicator ● Curtain Winder ● Ramp Generator – 1 ● High Voltage Capacitor Reformer ● *EPE* HiFi Valve Amplifier – 2
FEATURES ● Bridge Rectification Enhanced ● Ingenuity Unlimited.

AUG '95

PROJECTS ● Solar Seeker ● Personal Practice Amplifier ● Infra-Red Remote Control Unit ● Versatile Microcontrolled 3-Digit Timer ● Ramp Generator – 2.
FEATURES ● Static ● Circuit Surgery.



SEPT '95

PROJECTS ● Simple Theremin ● Low Range Ohmmeter Adaptor ● Comprehensive Security System ● Vandata ● Hum-Free Battery Eliminator.
FEATURES ● Cave Radio ● Ingenuity Unlimited.



OCT '95

PROJECTS ● Ginormous VU Meter ● Sound Switch ● Audio Sinewave Generator ● Treble Booster ● Infra-Red Controller/Alarm ● Capacitor Check ● Experimenter's Bargraph Test Board.
FEATURES ● Circuit Surgery ● Security Tagging ● Using Bargraph Displays. FREE ● Multi-Project PCB with this issue.

NOV '95

PROJECTS ● Digital Delay Line ● Video Enhancer ● 50Hz Field Meter ● Temperature Warning Alarm ● Current Tracer ● Distortion Effects Unit.
FEATURES ● Teach-In '96 Part 1 ● Developments in Radio Broadcasting Technology ● Turnpike for Windows Review ● Ingenuity Unlimited.

DEC '95

PROJECTS ● Light Operated Switch ● Stereo "Cordless" Headphones ● *EPE* Met Office – 1 ● Modular Alarm System ● Audio Meter and Amplifier.
FEATURES ● Teach-In '96 Part 2 ● Circuit Surgery ● Index for Volume 24.

JAN '96

PROJECTS ● Printer Sharer ● Mains Signalling Unit ● Automatic Camera Panning System ● Audio Signal Generator ● *EPE* Met Office – 2.
FEATURES ● Teach-In '96 Part 3 ● Ingenuity Unlimited ● European Consumer Electronics Show ● Techniques – Actually Doing It ● Maths Plus Review ● Decibels and dBm Scale.

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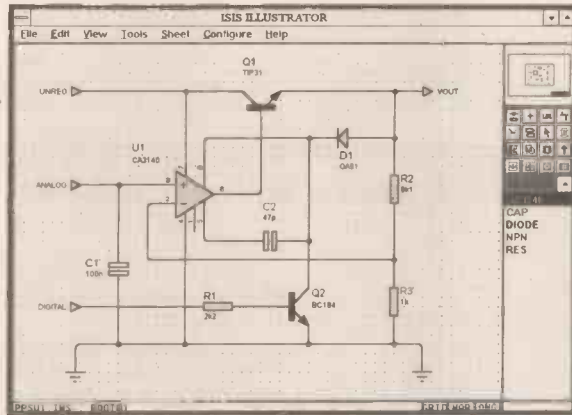
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M2/96

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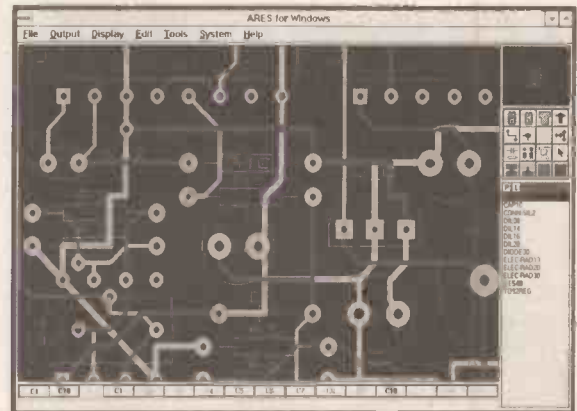
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CIRCUIT SURGERY

ALAN WINSTANLEY



This month's 'clinic' looks at interesting pseudo-random digital signals, plus more on Ni-Cads, a follow-up on cycle l.e.d. flashers and more pointers for Internet users.

WELCOME aboard to *Circuit Surgery* – our two-way column discussing readers' queries and questions on hobby and educational electronics! If you have any topical comments or queries which you think would be of interest to others – or you have anything you'd like to say about any of our constructional projects – then *Circuit Surgery* will strive to help, so please write to us at the address given later.

Random Digital Pulses

A question cropped up in my post bag recently concerning a randomly-activated sequencer. A reader enquired about a method of operating randomly one of a number of loads, after a time period has elapsed.

It brought back memories of one of my own *Everyday Electronics* constructional projects – the *Security Vari-Light* dating back to December 1982, no less. This device operated a table lamp at random-looking intervals, to give the impression that the house was occupied at night, hopefully acting as a deterrent to burglars. (We were never burgled, so I guess it worked!)

The technique of *pseudo-random pulse generation* is an interesting topic to study. Note the phrases "pseudo-random" and "random-looking" – since these methods are never truly random, but they generate a sequence of bits which can be engineered to be "virtually random", as we'll see.

A circuit diagram for a simple 4-bit Shift Register, something like a CD4015 or the 74164 being fine for this application, is shown in Fig. 1. (Both types actually contains two individual registers.) The register has four outputs Q1 to Q4, a D (Data) pin and is edge-triggered by a clock.

A clock pulse enters at pin 9 and could be derived from a standard 555 astable (not shown). Connected to the output is an Ex-OR gate which feeds back to the Data pin.

The register's method of operation is straightforward enough: whenever a suitable clock edge pulse is received then the logic state at the Data pin is toggled

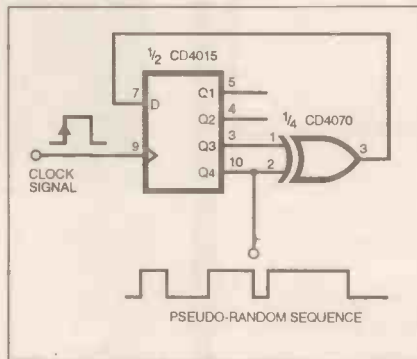


Fig. 1. Simple 4-bit register.

over to the Q1 output. That bit is then carried to the next output Q2 on the next clock edge. Thus a simple bit sequence will be seen rippling along the Q1 to Q4 outputs.

Adding the Ex-OR gate as shown has an extremely interesting effect: it produces a pseudo-random sequence where we can actually "predict" the randomness!

The truth table for a two-input Ex-OR gate (e.g. CD4070) is shown below:

A	B	Q = A + B
0	0	0
1	0	1
0	1	1
1	1	0

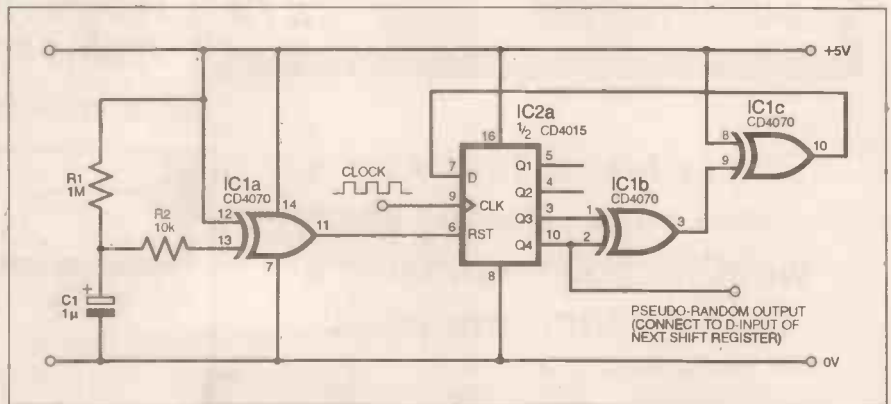


Fig. 2. A simple Pseudo-Random Sequencer.

However Ex-NOR feedback has the effect of making 1111 the forbidden state instead, so this state will never appear in the sequence. An Ex-NOR gate can be formed from an Ex-OR gate followed by an Ex-OR wired as an inverter.

A power-on reset can also be obtained, rather crudely, from a further Ex-OR gate with an RC pair on one input and the other input at Logic 1.

Right Feedback

A simple Pseudo-Random Sequencer, based on a single 4-bit shift register is shown in Fig. 2. It has both a power-on reset (IC1a) to write 0000 to the four outputs, and Ex-NOR feedback (IC1b and IC1c) to start up the sequence with a logic 1.

With only 15 steps available before repeating itself, the circuit isn't terribly useful. By extending the shift register length it's possible to increase the length of the pseudo-random sequence, e.g. by carrying the Q4 output to the D-input of another 4-bit shift register to form an 8-bit type.

An 8-bit register would generate a pseudo-random sequence of 255 steps ($2^8 - 1$) whilst a 16-bit type, say, would generate $2^{16} - 1 = 65,535$ steps. If we are to obtain a "maximal length" sequence, though, everything hinges around hooking up the Ex-OR feedback to the appropriate register outputs, otherwise the entire sequence may not be realised fully.

With some combinations of shift register length, more than one feedback tap is needed: for example an 8-bit register needs to be tapped at Q4, Q5, Q6 and Q8 to get maximal length, whilst a 16-bit register is tapped at Q4, Q13, Q15 and Q16. It isn't compulsory to use the "right" outputs, though – if you don't, you'll simply not obtain the most random-looking sequence.

A high frequency digital sequence can be exploited with further circuitry to provide a source of analogue noise. An excellent in-depth discussion on this topic is found in *The Art of Electronics* by Paul Horowitz and Winfield Hill (2nd Edition, Cambridge University Press, 1,125 pages, ISBN 0-521-37095-7) which is probably one of the world's best books on electronics. Rooting through my library, I also found that the technique is touched on in the *CMOS Cookbook* by Don Lancaster (2nd Edition, Publisher Sams, 512 pages, ISBN 0-672-22459-3) if you want to research it further.

Cycle L.E.D. Flasher

A follow-up concerning my suggested "Cycle L.E.D. Flasher" (October 1995's issue). Mr. J.C. Corfield of Bishop's Castle, Shropshire, who comments:

You proposed at some length how to provide a Cycle L.E.D. Flasher using a battery, switch, p.c.b., i.c. type LM3909 and at least one capacitor. Why didn't you suggest using a battery (3 x AA), switch and a flashing l.e.d. at half the cost?

Is there a reason why flashing l.e.d.s are not suitable? If so, please let us know what it is.

Er, quite. Obviously a single flashing light-emitting diode can be formed

Table 1: 4-bit pseudo-random sequence

Clock Cycle	Q1	Q2	Q3	Q4	D = Q3 + Q4 (Transfer to Q1)
–	(Start Up) Data = Logic 1				1
1	1	0	0	0	0
2	0	1	0	0	0
3	0	0	1	0	1
4	1	0	0	1	1
5	1	1	0	0	0
6	0	1	1	0	1
7	1	0	1	1	0
8	0	1	0	1	1
9	1	0	1	0	1
10	1	1	0	1	1
11	1	1	1	0	1
12	1	1	1	1	0
13	0	1	1	1	0
14	0	0	1	1	0
15	0	0	0	1	1
1	1	0	0	0	0... etc

simply with a ready-made device. However you cannot control the flash rate, and a voltage of about 4V (3.5V absolute minimum) is necessary or they won't operate – so one would make short shrift of three AA cells.

Using a ready-made device isn't necessarily the most "fuel-efficient" way of producing a flashing l.e.d. The LM3909 chip was shown as a way of driving a single l.e.d. from a 1.5V to 3V source. Its party trick is that it has a built-in voltage booster circuit to drive an l.e.d. (forward voltage 2V say), from a single 1.5V supply or even less, although a more useful pulse is obtained by using a couple of pencells instead.

By designing the circuit to give just a short "blink" (mark), using two alkaline AA pencells and one l.e.d. gives approximately nine months of continuous service, from experience. I often use the circuit as a battery-friendly imitation alarm (burglar deterrent).

In the case of a cycle l.e.d. flasher, these use multiple l.e.d.s (three or five, generally) and if the circuit is to be effective they should all flash *simultaneously*. This isn't possible if separate flashing l.e.d.s are utilised since they don't flash at an identical rate and they eventually go out of "sync" – the impression from a distance is that of a steady or irregular lamp.

Furthermore, it is perfectly possible to adjust the flash rate using the "fast" or "slow" pins of the LM3909 and also by adjusting the values of the two or three external components. Overall, I thought the simple circuit was a good compromise.

Incidentally, an old National Semiconductor Data Book from 1977 shows a humungous variety of applications for the LM3909 – everything from an a.m. radio to an electronic trombone, 'scope calibrator and triac trigger! It can be

used as an audio tone generator as well. (NS Application Note AN154, "1.3 Volt i.c. Flasher, Oscillator, Trigger or Alarm.")

Ni-Cads – yet more!

Regular readers may recall my item in the August 1995 issue when I offered a reprint of a "discussion" which took place earlier in the year on the Internet, concerning the performance of Nickel-Cadmium rechargeable cells. Many scores of readers asked for this reprint and we gladly obliged. I have often found that there have been conflicting views as to what constitutes kindness or cruelty to NiCads, but opinions gradually seem to be gelling along the following lines:

The main point is, there's a difference between the *capacity* of a NiCad and its *voltage*. People often confuse the two. The discharge characteristic of a NiCad approximates a flat curve (see Fig. 3) – unlike a zinc carbon cell, for example, its voltage does not gradually tail off but suddenly plummets! A NiCad should be considered as ready for recharging when its (on-load) voltage has fallen to about 1V per cell, though some folks use a potential of 1.1V as the crucial point.

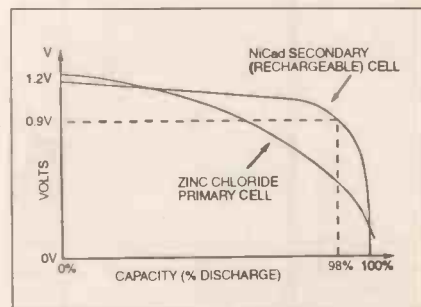


Fig. 3. Discharge characteristics.

Typically, NiCads will have discharged well over 95 per cent of their *capacity* when their voltage has dropped to about 1V on-load. It's bad news to "flatten" a NiCad until its potential is nearly zero volts!

The NiCad is to all intents fully discharged (~ 98%) when its voltage has dropped below, say, 0.9V and it's pointless draining it any further! Internal damage may be caused which may not be entirely reversible!

Be kind to NiCads by discharging no lower than 1V, then recharge in accordance with the manufacturers' recommended charging times. This means that if they recommend 14 hours, don't leave it to trickle charge afterwards unless they clearly state you can!

The so-called "memory effect" relates to *voltage depression* caused by a poor charging/discharging regime. Voltage depression (increased internal resistance leading to reduced capacity) can quite often be reversed by deliberately discharging the cells, never letting them fall under 1V each on-load, and then recharging them for a full cycle. Do this several times in succession and the NiCad's capacity may be restored.

Bear in mind we're talking about 1V per cell, not per complete battery. A 6V battery will have five cells (1.2V each) – so overall it should not be allowed to drop below 5V. Some say that a slight overcharge (say 30 minutes' worth) is also beneficial during rejuvenation and helps reverse the "memory effect". I showed a simple constant current load for this type of application in the February 1995 issue.

Just a reminder to those who have access to an Internet connection: an interesting document is available by file transfer protocol (ftp) which covers this topic in some depth. The address is [ftp.armory.com/pub/user/rstevev](ftp://armory.com/pub/user/rstevev) and you should download the dozen page document [nicad.faq.zip](#) for more information about how to treat NiCads, plus a detailed look at their chemistry.

We can still reprint it for readers at a cost of 60 pence to cover the copying (cheques, P.O.s payable to *Wimborne Publishing Ltd.*, together with an A4 self-addressed envelope stamped 38 pence). My thanks to all those who have requested the reprint so far – I hope you found it worthwhile.

Auto Battery Back Up

The Auto Battery Charger *constructional project* (April 1995 issue) is indeed very useful. Can you please say if the same design could cater for batteries with higher capacities, e.g. 30Ah to 50Ah perhaps for caravan use. We appreciate your feedback over here! Thanks and regards from Gary M. Leyte, Nizwa, Sultanate of Oman.

The EPE Auto Battery Back Up project was designed to trickle charge a small lead acid battery by monitoring its voltage and switch itself on and off at hysteresis levels which the users sets with two trimmer resistors. It could be used with virtually any 12V (nominal) lead acid accumulator: the designer has used it with batteries up to 8Ah (Ampere-hour) capacity.

The charge current is typically 1A or less: the question is, is this adequate for bigger batteries? Larger and more deeply discharged batteries demand a higher charge current – say 2A or 3A or more. (For example, a deeply discharged car battery may draw some 5A or 6A or more, as I have found on many a winter morning, armed with a battery charger!)

The design at it stands would probably perform adequately with larger batteries *only if they are not used too heavily*, otherwise the 1A nominal maximum charge current could become insufferably (s)low. The only modification you can perform is to increase the transformer rating to, say, 50VA (12V a.c. 4 Amps) and uprate the bridge rectifier to say 3A or more.

Also, omit resistor R6 which limits the current to 1A. The unit will then be able to provide a greater charge current at a level determined by the state of the battery. Extra care is needed to ensure that the power supply current rating is not exceeded, but the rest of the electronics can remain unchanged.

Internet Round-up

Finally this month, for Internet enthusiasts, a few interesting developments in the Newsgroups. A couple of days before you read this, on 2 January 1996 the *sci.electronics* Newsgroup will officially cease to exist – though doubtless it will continue to appear on servers for some time to come.

The group has now been divided into new sub-groups which are already up and running, the charters for which are summarised as follows:

sci.electronics.basics "A forum for discussion of electronics where there is no such thing as a stupid question. Beginners questions. Discussion of electronics education. Requests for other sources of information."

sci.electronics.components "Discussions of electronics at the component level. The use, limitations, and identification of resistors, capacitors, integrated circuits, connectors, enclosures, and so on. Locations and contact information for Manufacturers, Distributors, and other sources for supply and technical information."

sci.electronics.design "Discussions relevant to the design of electronics circuits." The design group is for persons combining components into circuits. Discussion on design solutions and techniques.

sci.electronics.equipment "Discussion of the application and internal operation and relative merits of test equipment, laboratory equipment, and industrial equipment." Not intended as a FS (For Sale) or WTB (Want To Buy) group!

sci.electronics.misc "General discussions on the topic of electronics." Includes gossip, history, trivia, manufacturing, systems, standards, announcements, etc.

sci.electronics.repair continues as a place to ask about (or help with) repairs to electronic equipment – everything from my electric breadmaker to our PC monitor (temporarily deceased) has been in there! Computer equipment, audio, video, TV also.

By posting to the right *UseNet* group, there's more chance of targeting your question at the right kind of people who can answer correctly. Even if they answer wrongly, there's also a good chance that others will jump in with a correction!

Careful posting is always appreciated by regular subscribers, many of whom, like myself, don't have time to sort through hundreds of irrelevant postings.

UK Sources FAQ

My own humble effort to redress our country's balance of payments deficit is my *UK Sources FAQ (Frequently Asked Questions)*. This is a listing of over 150 names and addresses of UK-based mail order electronics specialists, industrial franchised distributors, manufacturer's UK addresses, and more.

This has been combined into a 15-page document available to everyone subscribing to *sci.electronics.components* and which will be regularly updated by your scribe. By the time you read this, it will also hopefully be available by Email from myself upon request. I welcome contributions to this, all of which will be acknowledged in the FAQ!

Circuit Surgery appears bi-monthly. If you have any suggestions for inclusion in a future *Circuit Surgery*, please write to: Alan Winstanley, *Circuit Surgery*, Wimborne Publishing Ltd., Allen House, East Borough, Wimborne, Dorset, BH21 1PF, United Kingdom, or Email to alan@epemag.demon.co.uk.

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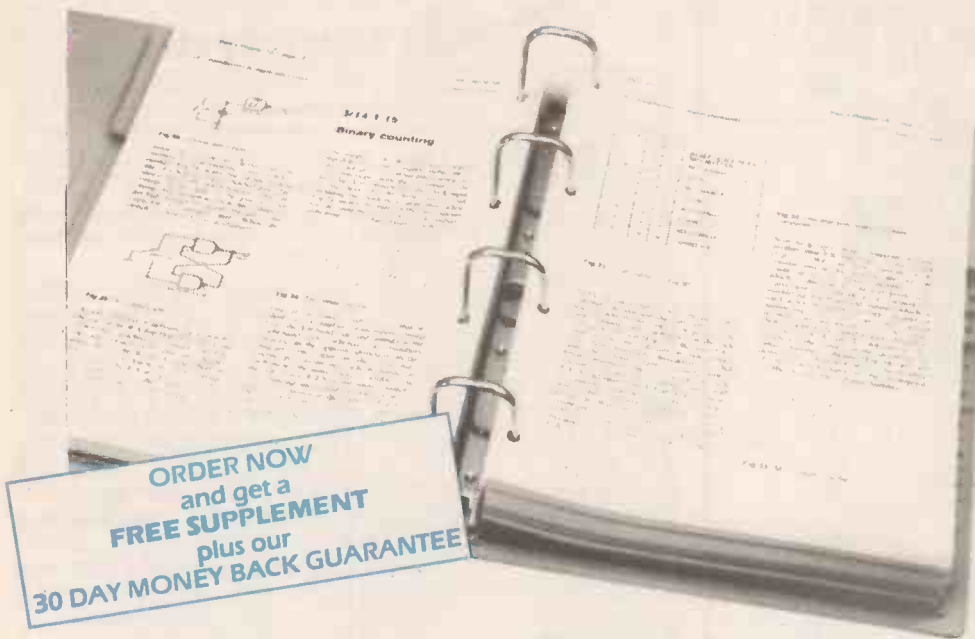
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Techniques

ACTUALLY DOING IT!

by Robert Penfold

AS pointed out at least once previously, letters from readers who are having problems with projects that refuse to work are relatively rare these days. Although the general level of sophistication of published projects has steadily risen over the years, much of this sophistication is handled by complex integrated circuits.

The number of components in the average project has probably changed little over the years. This factor, coupled with increased use of custom printed circuit boards, means that modern projects are generally easier to construct than those of twenty or so years ago.

Beginners Luck

This is good news for beginners at electronic project construction, as they have a relatively good chance of constructing a project that will work first time. Feedback from readers would tend to suggest that the main problem these days is in locating and identifying the right components, and that assembling the components into a finished project is the easy part! In truth there should be no major problems in obtaining and identifying components provided you go about things the right way.

I make no excuse for repeating the much given advice that a couple of the larger component catalogues should be regarded as an essential part of the hobby. They may cost a few pounds to buy, but this is money well spent.

The larger catalogues contain a wealth of useful data and illustrations, and beginners can learn a great deal from them. Obtaining the components you need is always going to be an uphill struggle without the aid of one or two decent component catalogues.

It may be stating the obvious when I suggest reading the articles describing the projects you intend to build, but a certain percentage of queries from readers requests information that is provided in the articles concerned. In the case of projects in *EPE* you should also consult the *ShopTalk* feature, which gives buying advice for any out of the ordinary components used in that month's projects.

With any project it is worthwhile ensuring that you can obtain any unusual components before buying the rest of the parts. With older designs it is essential to do so, as it is quite likely that any components that were out of

the ordinary several years ago will be totally unobtainable now.

It may be possible to track down obsolete semiconductors for an old design, and there are one or two companies amongst the advertising pages that specialise in this type of thing. The problem with many of these components is that their current prices are often quite high, and they can be as much as ten times their original price. They are mainly sold as spares for existing equipment, and are not necessarily a realistic prospect for new projects.

Numbers Game

Semiconductor type numbers seem to cause a certain amount of confusion, and not just to beginners! In fact they are probably the main cause of difficulties when trying to identify and buy the correct components.

The problem stems from the fact that many semiconductors are produced by more than one manufacturer. In an ideal world the type number would be exactly the same regardless of the manufacturer, and with most semiconductors this is indeed the case. A BC549 transistor is always a BC549 transistor, no matter which company manufactured it.

Most of the confusion with transistors and diodes occurs because the actual devices are often marked with a few numbers and letters in addition to the type number. These extra characters are usually of no practical importance, and simply indicate the name of the manufacturer, the date of manufacture in some highly cryptic form, a batch number, or something of this nature. Extraneous numbers and letters are to be found on capacitors and many other components, but you soon get used to sorting out the "wheat from the chaff."

Some transistor type numbers carry a suffix letter, and this can sometimes be of importance. This suffix letter is "A", "B", or "C", and indicates the gain group of the device ("A" is the lowest and "C" is the highest). A BC549C for example, is a BC549 transistor in the highest gain group.

If a particular gain group is specified in a components list, then it is

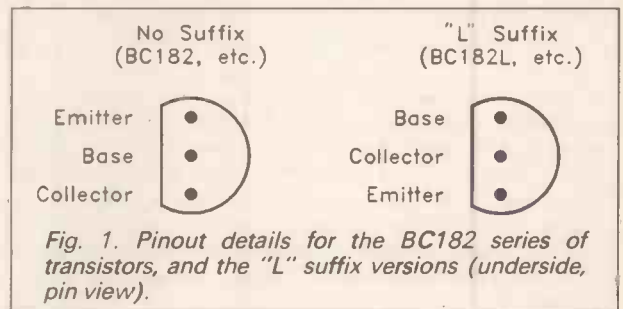
important that a device having the appropriate suffix letter is used. In all other cases it is acceptable to use a device having any suffix letter, or no suffix at all.

It used to be quite common for transistors to have a suffix letter which indicated that a different leadout configuration was used for that particular version of the device. This type of thing is less common these days, and it is now the norm for each version of a device to have its own type number. However, some of the older devices having a suffix letter are still available and in use today.

The only common examples are the BC182/3/4, and BC212/3/4 series, which are available with and without an "L" suffix. Fig.1 shows the leadout configurations for the "L" suffix and non-suffix versions of these transistors.

As is the convention for transistors, thyristors, etc., Fig.1 shows base views (i.e. the device viewed with the leads pointing towards you). The only difference between the two types is the leadout configuration, so they are interchangeable, provided you are careful to get them connected correctly.

On the other hand, mistakes are less likely to be made if you obtain the right



type. There should be no difficulty here, as the "L" suffix and plain versions are both readily available.

Some Confusion

From time-to-time, letters are received from readers who are having difficulty in getting J-f.e.t. transistors connected correctly. The main offenders seem to be the 2N3819, and the BF244. The latter is also available with "A" and "B" suffix letters, but these are equivalent to the gain grouping of some bipolar transistors, and do not indicate a different leadout configuration.

The initial cause of confusion over J-f.e.t. leadouts was caused by the drain (d) and source (s) terminals being transposed on the leadout diagrams in the initial 2N3819 data sheets. Apparently some circuits functioned quite well despite the fact that the 2N3819 was connected around the wrong way!

More recently, confusion has arisen due to the introduction of a different case style having a totally different leadout configuration. Leadout diagrams for both types are shown in Fig. 2.

As the encapsulations are different for the two types, it should be obvious which particular version you have,

even though the type numbers would seem to be exactly the same for both versions.

Integrated Numbers

Probably most of the confusion over type numbers occurs with integrated circuits (i.c.s). Many integrated circuit type numbers are devised by individual manufacturers, and are not standardised in the same way as most transistor and diode type numbers.

This is fine for integrated circuits that are only produced by a single manufacturer, but most devices are produced by two or more manufacturers. This often leads to an i.c. being produced under several similar type numbers.

Many integrated circuit type numbers break down into *three* sections. First there are one, two, or three letters which identify the manufacturer.

For example, devices produced by RCA usually have the letters "CA" at the start of the type number. Table 1 gives details of some of the prefixes used by some of the larger semiconductor manufacturers.

Next there is a three or four digit number, and this is the actual type number.

Finally, there is usually a one or two letter suffix which indicates the type of

Table 1:

PREFIX	MANUFACTURER
AD, OP	Analogue Devices
CA, CD	RCA
HA	Harris Semiconductors
ICL, ICM	Intersil
LM, LF, LH	National Semiconductors
LT	Linear Technology
MAX	Maxim
MC	Motorola
NE, SE	Signetics
SN, TL	Texas
SP, SL	Plessey
TS	Teledyne Components
μ A	Fairchild
Z	Ferranti

Similarly, in component catalogues a 741 might be listed as such, or under a specific type number, or both. This could obviously lead to confusion, with the same basic type number being used for totally different devices.

In practice this is rarely a problem, but it is a potential pitfall. The components lists in *Everyday Practical Electronics* specify the basic function of each semiconductor (Bifet op.amp, quad 2-input NAND gate, etc.).

This should avoid any problems with the wrong device being ordered. If a

component in a catalogue has the right basic type number and function, then you can be fairly certain that it is the device you require.

Logical Numbers

TTL logic devices differ slightly from the standard scheme

of things. The original series of TTL chips conform to the standard setup, and have the 74** number sandwiched between the manufacturer's prefix and what is usually an "N" suffix to denote a plastic d.i.l. encapsulation.

As various series of improved TTL chips were introduced, they had two or three letters added into the middle of the type numbers. These extra letters indicate the logic family of each chip.

For example, the 7408 is the original TTL quad 2-input AND gate, the 74LS08 is the low power Schottky version, and the 74HC08 is the high speed CMOS version.

The compatibility (or lack of it) between TTL logic families is a complex matter, and is something that beginners should not become embroiled with. Only use the exact type specified in a components list, and do not be tempted to a type from the wrong logic family.

Genuine "Duds"

Some readers worry about the type numbers on i.c.s differing slightly from what they ordered. I suppose that strictly speaking if you order (say) an LF351N op.amp, then you should be supplied with a genuine LF351N, and not an exact equivalent such as a KF351N.

Not unreasonably, retailers tend to buy semiconductors from the firm offering the best price, and this can lead to alternatives being supplied. This is of no practical consequence to the consumer. You are getting exactly the same device, but from a different manufacturer and under a slightly different type number.

Where an alternative device is supplied, the retailer should make this clear on the invoice, or in a simple explanatory note supplied with the order. If in doubt, an enquiry to the retailer should soon ascertain whether the devices supplied are proper alternatives to the devices you ordered, or the wrong goods have been supplied in error.

About 25 to 30 years ago there were problems with sub-standard or even totally non-functioning devices being relabelled to look like the "real thing", and sold as such. At one time there was quite a major problem with these so-called "genuine duds."

It would seem that this practice has returned recently, but it only seems to be the more expensive chips, particularly some microprocessors and memory chips, that are the subject of this scam. Most of the semiconductors used in electronic projects cost a few pence when bought in bulk, and there is presumably no point in counterfeiting such low cost items. Any semiconductors you buy will be of good quality and the "genuine article."

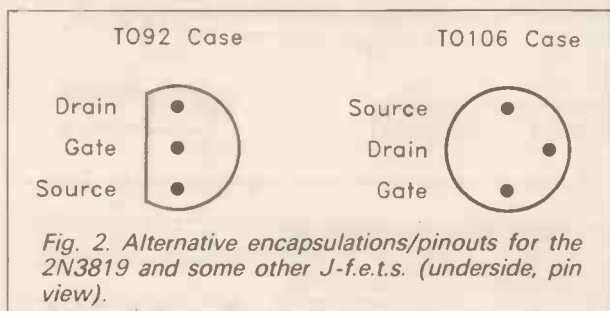


Fig. 2. Alternative encapsulations/pinouts for the 2N3819 and some other J-f.e.t.s. (underside, pin view).

encapsulation. Devices used by the home constructor are generally in a d.i.l. (dual-in-line) plastic encapsulation, and have either a "C", "N", "E", or "P" suffix.

A "Components List" might just give the basic type number, or it could give a full type number. For example, the popular 741 operational amplifier (op.amp) might be specified as a "741", or as something like a μ A741C.

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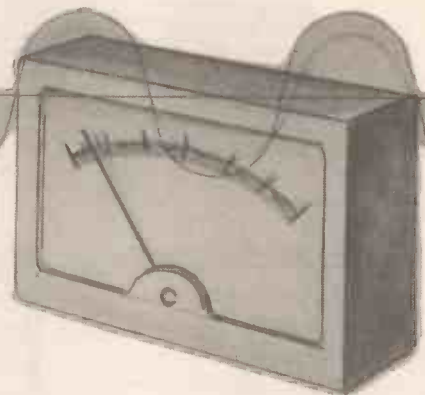
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ANDY FLIND

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AMONGST numerous items of test equipment built over the years, one of the most consistently useful has been an Analogue Frequency Meter. Despite the acquisition of a digital instrument the home-built analogue unit is still preferred in many cases because it is so quick and simple to use.

The six-place accuracy of a digital meter is often unnecessary, whilst the procedure of setting the count period, decoding the decimal position and adjusting input and filtering levels are a hassle one could do without. By contrast the analogue meter is simply connected to the circuit and a suitable range selected to obtain a reading.

Much of the time it is only necessary to know, perhaps, if the circuit is oscillating at two or ten kilohertz, or if its adjustment range is around ten to one, so reduced accuracy is perfectly acceptable whilst speed and ease of taking the reading is a distinct advantage. However, since the original analogue meter was designed over ten years ago, it seemed worthwhile to re-examine its design with a view to improvement. This article describes the construction of the new meter.

HEART OF THE MATTER

The heart of the instrument is a 0 to 100Hz frequency-to-voltage circuit. This is very simple to calibrate because all the constructor has to do is apply a 50Hz mains-derived signal and complete a single adjustment for a half-scale indication. The remaining ranges, extending to a 1MHz full scale, are simply obtained by preceding the basic movement with decade divider stages.

A suitable input circuit for converting various input waveforms to pulses with rapid and jitter-free edges completes the circuit. A block diagram of the complete system is shown in Fig. 1.

One area where worthwhile improvement has been achieved is in the frequency-to-voltage conversion. The original design simply integrated pulses from a timer. A custom i.c., the LM2917N, is now available to perform this task in a much more sophisticated manner, resulting in a simpler circuit with greater accuracy.

An internal block schematic diagram of the frequency-to-voltage converter i.c. is shown in Fig. 2. From this it can be seen

that the chip contains an input amplifier which has some built-in hysteresis although this function is not important in this circuit. The input stage is followed by the heart of the chip, a "charge pump", which transfers a fixed charge to pin 3 for each input pulse. The magnitude of this charge is set by the value of the capacitor connected to pin 2.

Finally, an op.amp and transistor are provided for buffering the output. These can be used in various ways, including the linear driving of meters. As can be seen the chip requires a minimum of external components and a single adjustment is all that is necessary to calibrate its output.

SUPPLY LINES

The power supply arrangement of the LM2917N suggests that it is really intended for use in automotive rev counters. Positive supply is applied to pin 9 and negative "ground" to pin 12. Between these two pins there is an internal 7.6V Zener diode which regulates the voltage for the rest of the internal circuitry.

The manufacturer's information suggests that pin 9 should be supplied from 12V via a current-limiting resistor. Using this feature with a 9V battery supply requires ingenuity, but the feature can be put to good use.

CIRCUIT DESCRIPTION

Moving to the full circuit for the Analogue Frequency Meter, shown in Fig. 3, the power supply will be described first. To ensure an adequate voltage for the internal 7.6V Zener of IC5, bearing in mind that a 9V battery should be able to fall to at least seven volts and preferably six before it has to be discarded, the primary supply is first doubled by the 7660 converter IC4.

This is arranged as a "charge-pump" delivering current to capacitor C10. With a fresh battery, about 17.5V appears across this capacitor, falling to less than 10V as the battery ages.

To avoid current variations that would occur if the Zener in the LM2917N was supplied by a resistor, the constant current source consisting of transistors TR3 and TR4 is used instead. This supplies about 8mA to pin 9 of IC5.

The constant voltage appearing at pin 9 is then buffered by transistor TR5 and used to supply the rest of the circuit, thus avoiding

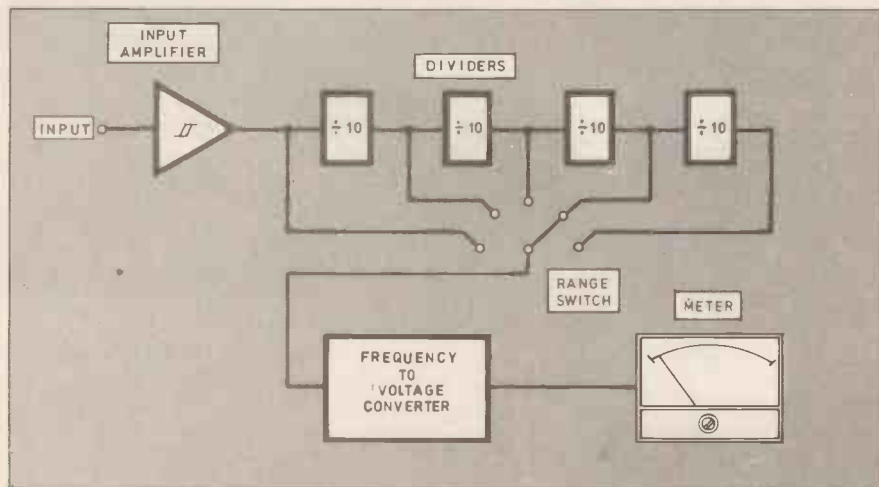


Fig. 1. Block diagram for the Analogue Frequency Meter.

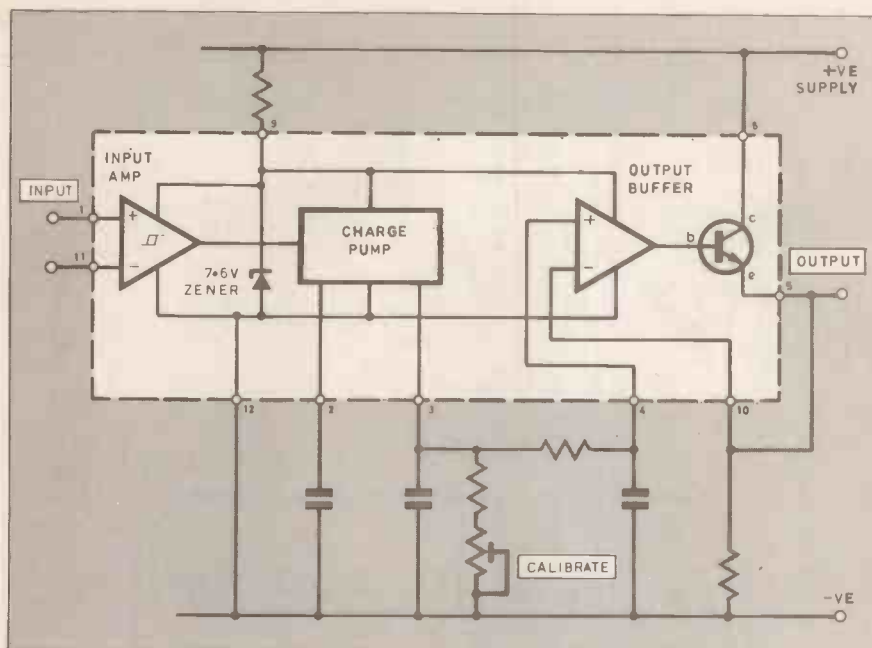


Fig. 2. Internal structure of the LM2917N frequency-to-voltage converter i.c.

the need for a separate regulator. Because of the 0.6V drop across the base-emitter junction of TR5, this supply is about 7V.

INPUT SIGNAL

Moving to the other end of the circuit, the input signal is a.c.-coupled through capacitor C1 to the gate (g) of the f.e.t. buffer TR1. The diode (D1, D2) and resistor (R1 to R3) network clamps the

gate voltage of TR1 to a maximum of about 1.2V peak-to-peak, whilst capacitor C3 compensates for the capacitance of the two diodes at high frequencies.

Transistor TR2 provides a voltage gain of about ten. A *pnp* transistor is used here to maintain correct voltage polarity across the coupling capacitor C4. The output of TR2 is taken to a Schmitt trigger and buffer stage built with IC1.

The design aim was for a circuit that would operate reliably with an input of about 100mV r.m.s., and in fact this begins to respond at about 80mV, well within the objective. The upper voltage limit of the input is dependant mainly upon the voltage ratings of resistor R2 and capacitor C3, so signals up to and possibly beyond 50V r.m.s. should be acceptable without damage. This input circuit operates reliably with no loss of sensitivity to beyond 1.2MHz.

DIVIDERS

Following the input stage, the signal is taken to a group of four CMOS decade dividers contained in the two CMOS 4518B chips, IC2 and IC3. The appropriate output is selected by Range switch S1b and taken to the frequency-to-voltage converter IC5. Switch S1 is a 2-pole 6-way rotary type, with the second half (S1a) serving as the power On/Off switch. It has been arranged so that the highest range is selected first to reduce the chance of over-driving the meter when it is switched on with a high frequency present at the input.

The output from IC5's charge pump is dumped into capacitor C14 with calibration and discharge resistor R18 and pre-set VR1 across it. The voltage on this capacitor, nominally one volt at full scale, is taken through the low-pass filter, made up of R19 and C15, to pin 4 which is the input of the output buffering op.amp. The other input to this op.amp appears at pin 10 and is connected to ground with the one kilohm (1k) resistor R20.

Two possible options are available for

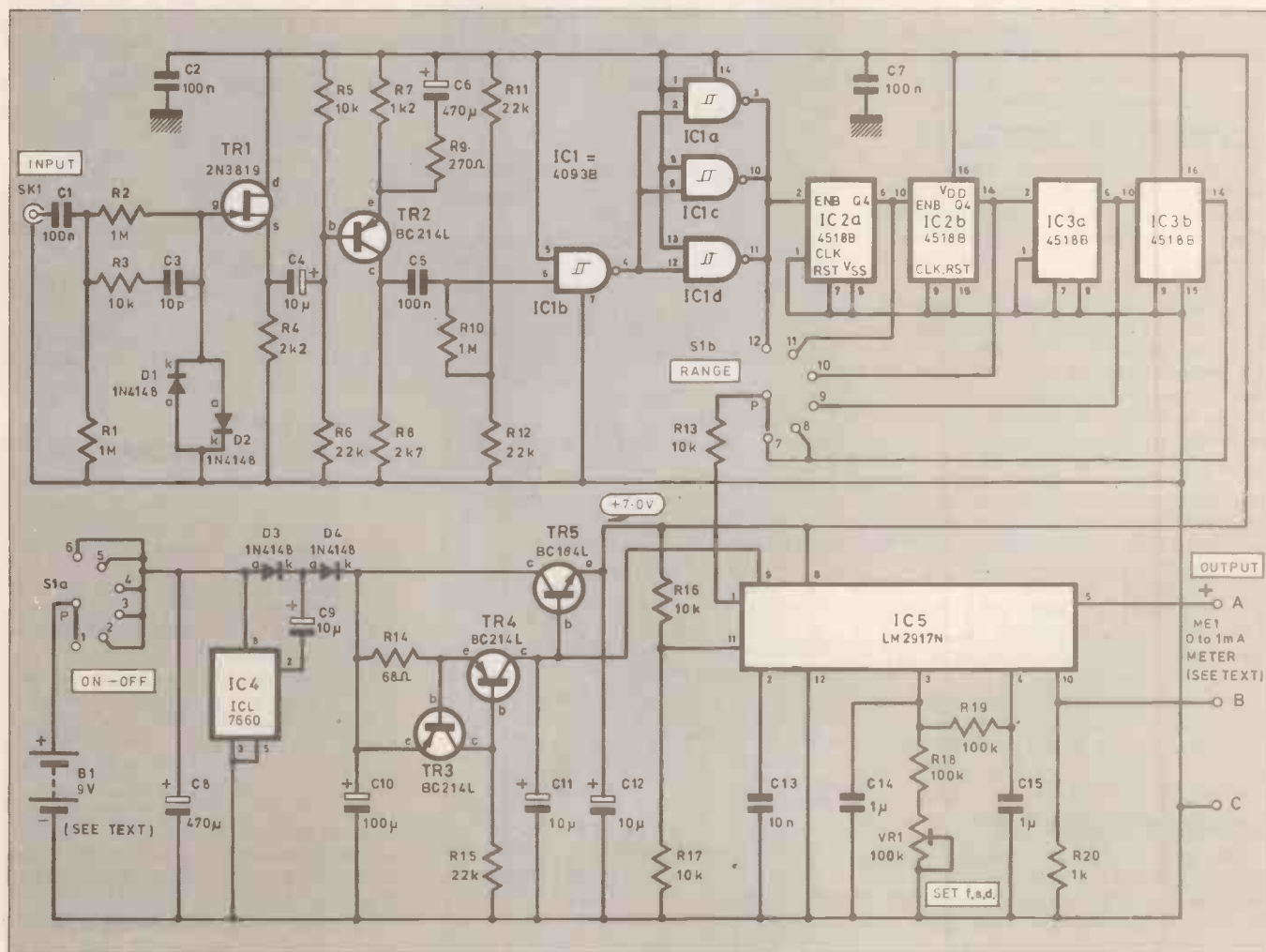
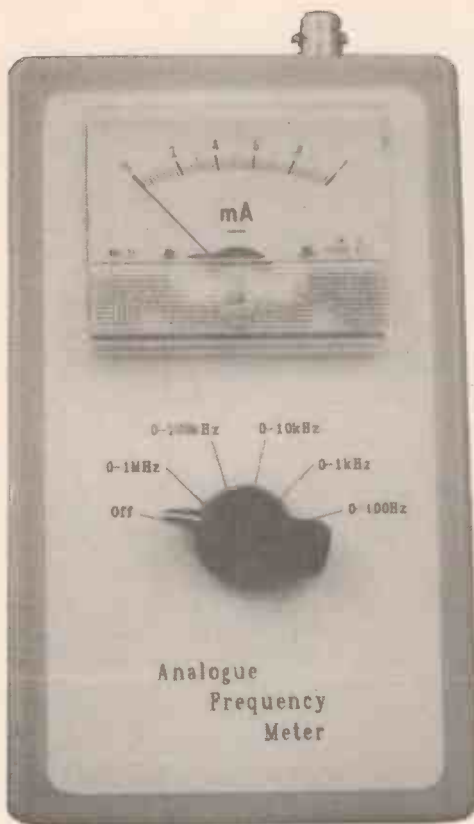


Fig. 3. Complete circuit diagram for the Analogue Frequency Meter.



connecting the meter. The internal output transistor emitter (e), from pin 5, can be shorted to pin 10 and the output will then consist of 0V to 1V at low impedance, which can be used with a one volt meter. Alternatively, where a 1mA movement is to be used as in the prototype, this can be connected between pins 5 and 10, in which case resistor R20 becomes part of a feedback network and the circuit delivers a 0 to 1mA output. This will be described in greater detail later.

CONSTRUCTION

Most of the components for this project are assembled onto a compact printed circuit board, the topside component layout and full size copper foil master is shown in Fig. 4. This board is available from the *EPE PCB Service*, code 957.

To ensure the best chance of successful construction, it is recommended that the following sequence is followed. Firstly, all the passive components should be fitted. This is everything except the transistors and i.c.s, and for ease they should be fitted in order of height.

The twenty resistors can be fitted first, followed by the four diodes, then the small ceramic capacitors, the 10n polyester capacitor C13, and the larger 1 μ polyesters C14 and C15. These should be followed by the electrolytics, starting with the four 10 μ components, then the 100 μ C10 and finally the two 470 μ capacitors C6 and C8. Note that all the electrolytics have their positive connections towards the top of the board.

The calibration cermet preset VR1, can now be fitted, noting that the adjustment screw is at the top. It will still work if it is placed the other way up, but the effect of rotation will be reversed.

FIRST TESTS

The first test can now be carried out. Power leads and the socket for IC4 should be fitted, and IC4 inserted. This, like IC1, IC2 and IC3, is a CMOS component, so precautions against static should be observed whilst handling these.

If the circuit is now powered, there will

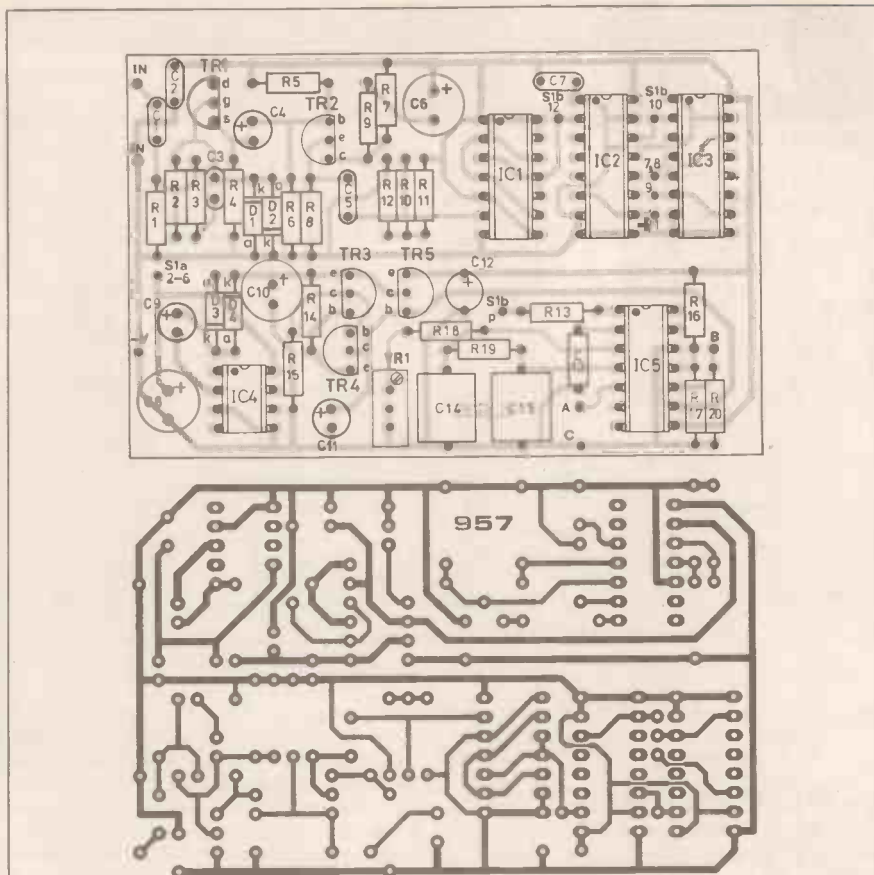
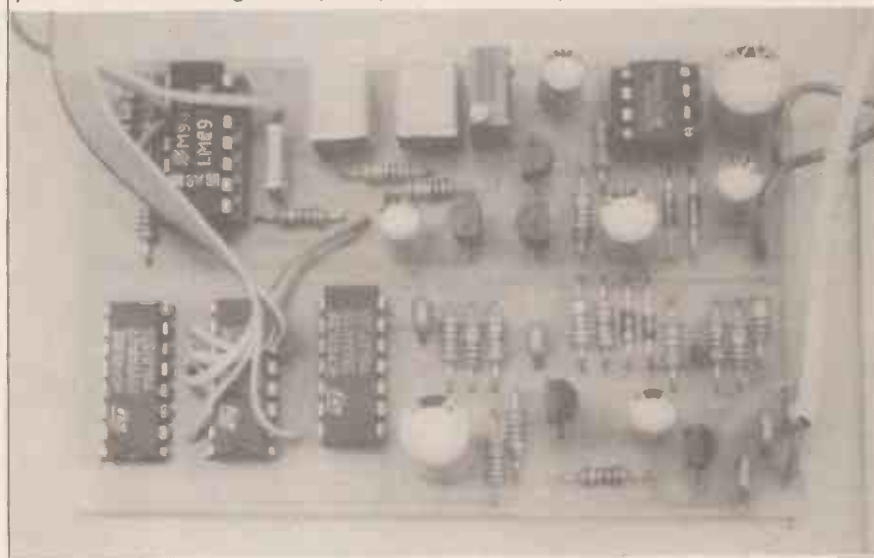


Fig. 4. Printed circuit board component layout and full size copper foil master pattern for the Analogue Frequency Meter. The completed board is shown below.



be a brief surge as the capacitors charge, following which the current drawn from the supply should settle to less than 100 μ A. The exact value will depend on the leakage of the electrolytics, which may take a few minutes to "form". The presence of around 17V across capacitor C10 should be checked, confirming that IC4 is operating.

Following this the socket for IC5 can be fitted along with transistors TR3, TR4, and TR5, taking care with their type and orientation. The p.c.b. should be powered up again and, using a 10mA meter with a one kilohm (1k) resistor in series to protect it, the current between pin 9 of IC5's socket and negative should be measured.

This should read about 8mA to 9mA. If this checks out, IC5 can be fitted and the circuit powered up again. Tests should be

made for the presence of 7.6V at pin 9 of IC5 and 7V at pin 8. The overall current drain, if measured, should now be about 21mA.

Transistors TR1 and TR2 can be fitted next. Static precautions may be advisable whilst fitting the f.e.t. TR1 as a couple of these mysteriously expired during development of this project, suggesting they may be electrically fragile.

If the circuit board is now powered up, the collector (c) voltage of TR2 should be around 3.5V, an easy point to check this being the top of resistor R8. The source(s) voltage of TR1 can be checked at the top of R4. This will vary with the particular f.e.t. in use, but should be somewhere between 0.5V and 2.5V. If a fault occurs in this stage it will usually be zero or nearly full supply, 7V.

Resistors

R1, R2,	
R10	1M (3 off)
R3, R5, R13,	
R16, R17	10k (5 off)
R4	2k2
R6, R11,	
R12, R15	22k (4 off)
R7	1k2
R8	2k7
R9	270Ω
R14	68Ω
R18, R19	100k (2 off)
R20	1k

See
**SHOP
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Page

All 0.6W 1% carbon film

Potentiometer

VR1	100k 22-turn cermet preset, vertical
-----	--------------------------------------

Capacitors

C1, C2, C5,	
C7	100n resin-dipped ceramic (4 off)
C3	10p resin-dipped ceramic
C4, C9, C11,	
C12	10μ radial elect. 50V (4 off)
C6, C8	470μ radial elect. 16V (2 off)
C10	100μ radial elect. 25V
C13	10n polyester layer
C14, C15	1μ polyester layer (2 off)

Semiconductors

D1, D2,	
D3, D4	1N4148 silicon diode (4 off)
TR1	2N3819 <i>n</i> -channel f.e.t.
TR2, TR3,	
TR4	BC214L <i>pnp</i> silicon transistor (3 off)
TR5	BC184L <i>npn</i> silicon transistor
IC1	4093B CMOS quad NAND gate
IC2, IC3	4518B CMOS dual decade divider (2 off)
IC4	ICL7660 voltage converter
IC5	LM2917N frequency-to-voltage converter

Miscellaneous

ME1	0-1mA f.s.d. moving coil meter (see text)
S1	2-pole 6-way rotary switch
SK1	50 ohm BNC socket
B1	9V PP3 battery (or six AA cells in holder - see text)

Printed circuit board available from *EPE PCB Service*, code 957; ABS plastic case, size 90mm × 149.5mm × 52.5mm external; 8-pin d.i.l. socket; 14-pin d.i.l. socket; pointer knob; PP3 type battery clip; multi-strand connecting wire; short piece of screened lead; solder pins; solder etc.

The quad NAND Schmitt trigger IC1 can be fitted next. Sockets were not used for this or the two divider i.c.s (IC2, IC3) in the prototype in order to avoid any extra capacitance they might introduce into the circuit. Where CMOS i.c.s are soldered directly into circuit, it is sometimes recommended that the *supply pins* should be soldered first, as this enables the internal static protection of these chips to operate correctly.

INPUT/OUTPUT TESTING

A lead for the input signal should be fitted, *screened* lead being preferable. The next test involves applying an input. In many cases touching the input with a finger will be sufficient as the level of "hum" voltage induced in the body is often sufficient to operate the input circuit. In the event that it isn't, a small mains transformer with a few volts output can be used, or a signal generator if one is available.

With an input applied, the output from pins 10 or 11 of IC1 should be checked either with an oscilloscope, where the "squared" waveform should be seen, or with a meter to inspect the average level. The exact voltage will depend on the waveform of the input signal, but it should not be far away from half supply, 3.5V. With the input removed, this point should stop at zero or full supply voltage.

Finally, the dividers IC2 and IC3 can be fitted. If the 50Hz input is re-applied, it will be possible to inspect the output of the first three dividers. The first, at IC2 pin 6, will show an average d.c. level of about 1.4V, and where an analogue meter is used there may be a distinct visible flicker as it is pulsing at 5Hz. The next output, from IC2 pin 14, will be a pulse every two seconds. The third output, from IC3 pin 6, pulses every 20 seconds.

Only very patient constructors will wish to test the last output with a 50Hz input as it pulses only once every 200 seconds! If a signal generator is available a higher in-

put frequency can be used, the last output being from IC3 pin 14.

CASE DETAILS

The prototype instrument was fitted into an ABS plastic case having external dimensions of 90mm × 149.5 × 52.5mm. The layout is not critical in any way, and the general arrangement can be seen from the photographs.

A frequency meter is normally used only for relatively short periods so the prototype is fitted with a PP3 battery. However, the circuit has an overall drain of 25mA, so if extended use is envisaged it might be preferable to use a pack of six AA cells instead. There is ample room for one of these, so long as the Range/On-Off switch is not placed too close to the end of the case.

The connections between the board and other parts are shown in Fig. 5. Although not essential, ribbon cable produces a much neater assembly, particularly for the range switch S1. A BNC socket is recommended for the input, as these are far more reliable than cheaper types such as u.h.f. or phono sockets. They look more professional too.

METER OPTION

Various meter options are available. The unit could be fitted in a case without a meter, and terminals provided for connection to the workshop multimeter. It could even be used with a DVM for a digital readout.

If the points "A" and "B" are shorted together, a 0 to 1V output can be taken from between them and "C" for connection to a meter having a 1V range. If a 1mA meter is used as in the prototype, it is suggested that this is placed between points "A" (positive) and "B", leaving "C" *unused*.

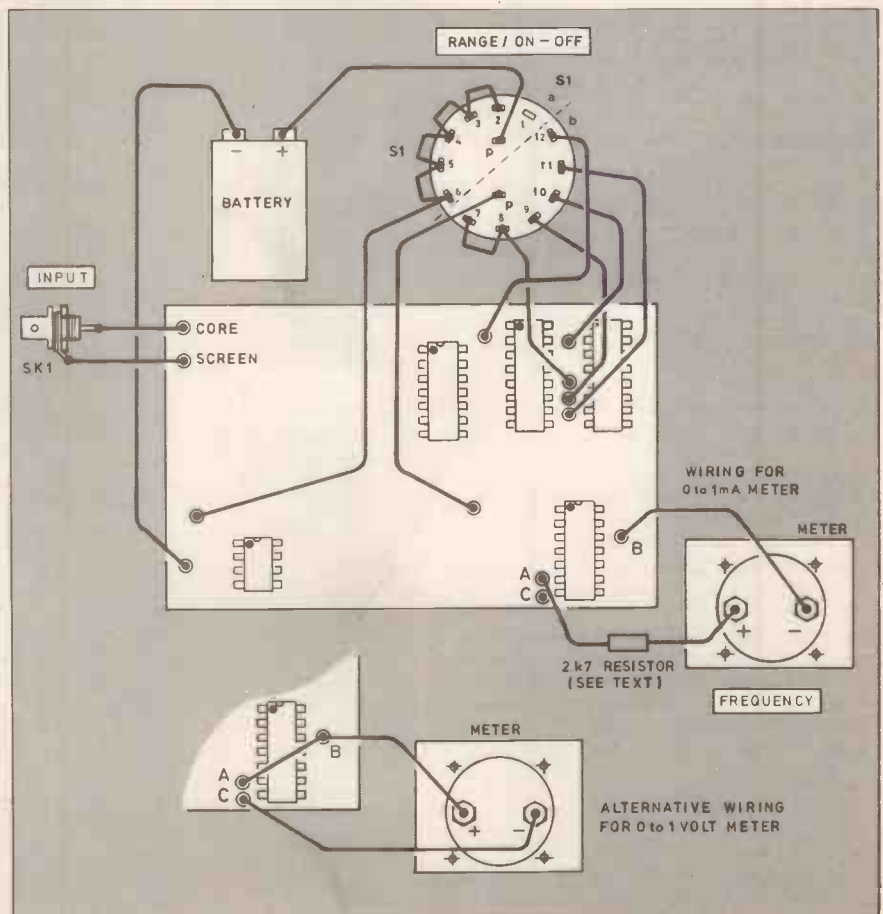
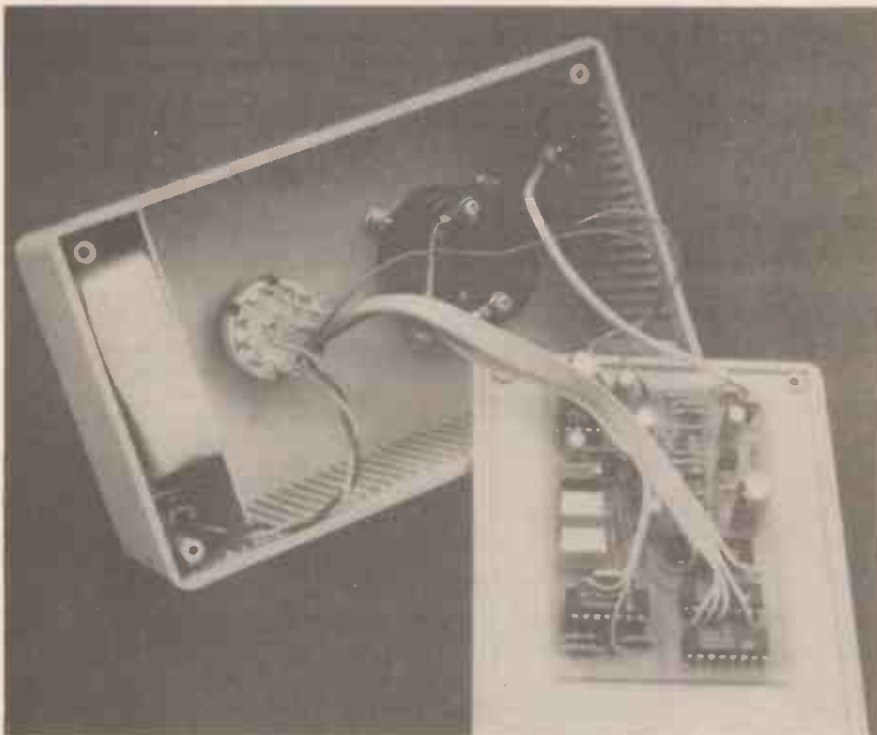


Fig. 5. Interwiring between the p.c.b. and off-board components. Also included are details for wiring to the alternative meter.



Bottom "lid" of the plastic case removed and flipped-over to reveal positioning of the p.c.b. and the layout of components in the "base" of the meter. Note the battery "compartment".

If this is done, some extra resistance can be placed in series with the meter to reduce overloading it when the circuit tries to drive it beyond full scale. This will not affect the reading because the meter is now in a feedback loop and the output op.amp will automatically compensate for the voltage appearing across this resistor. The value will depend on the meter being used, but 2.7k proved about right in the prototype.

CALIBRATION

To calibrate the instrument, it should first be switched on and, with no input, any necessary adjustment to the meter's zero should be made. A 50Hz signal should then be applied, using the basic 0Hz to 100Hz range. A wet finger may suffice, or the output from a small low-voltage transformer may be used. Preset VR1 is then adjusted as accurately as possible to a half-scale reading, following which the instrument is ready for use.

With its custom frequency-to-voltage output i.c. this meter is considerably more accurate and linear than its predecessor. It's less than half the size and displays less flicker at low frequencies, in fact it is perfectly readable down to about 5Hz, a twofold improvement.

Last but not least, it uses only one battery in place of two. With the present high cost of batteries, this improvement alone perhaps justifies the effort. □

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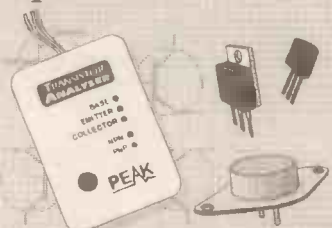
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Various chapters cover: Digital Arithmetic, Electronic Logic, Conversions between Analogue and Digital Structures, Transmission Systems. Several Appendices explain some of the concepts more fully and a glossary of terms is included. Altogether a useful foray into the digital world both for newcomers and also for those who need some revision or updating.

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A REFERENCE GUIDE TO PRACTICAL ELECTRONICS TERMS

F. A. Wilson C.G.I.A., C.Eng., F.I.E.E., F.I. Mgt.

Electronic devices surround us on all sides and their numbers are increasing without mercy. Ours is the problem therefore in keeping up with this relentless expansion. Unfortunately we cannot know it all and most of us do not wish to afford the cost of large reference books which explain many concepts in fair detail. Here is an answer, an inexpensive reference guide which explains briefly (but we hope, well!) many of the underlying electronics features of practical devices, most of which, to a certain extent, control our lives.

This book is in effect more than just a dictionary of practical electronics terms, it goes a stage further in also getting down to fundamentals. Accordingly the number of terms may be limited but the explanations of the many which are included are designed to leave the reader more competent and satisfied - and this is without the use of complicated mathematics which often on first reading can be confusing.

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R. A. Penfold

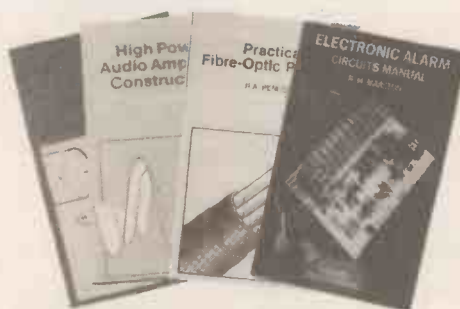
The Musical Instrument Digital Interface (MIDI) is surrounded by a great deal of misunderstanding, and many of the user manuals that accompany MIDI equipment are quite incomprehensible to the reader.

The Practical MIDI Handbook is aimed primarily at musicians, enthusiasts and technicians who want to exploit the vast capabilities of MIDI, but who have no previous knowledge of electronics or computing. The majority of the book is devoted to an explanation of what MIDI can do and how to exploit it to the full, with practical advice on connecting up a MIDI system and getting it to work, as well as deciphering the technical information in those manuals.

128 pages

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Owen Bishop

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The subjects covered include:- Magnetic field detector, Basic Hall effect compass, Hall effect audio isolator, Voice scrambler/descrambler, Bat detector, Bat style echo location, Noise cancelling, LED stroboscope, Infra-red "torch", Electronic breeze detector, Class D power amplifier, Strain gauge amplifier, Super hearing aid.

138 pages

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While fibre-optic cables may have potential advantages over ordinary electric cables, for the electronics enthusiast it is probably their novelty value that makes them worthy of exploration. Fibre-optic cables provide an innovative interesting alternative to electric cables, but in most cases they also represent a practical approach to the problem. This book provides a number of tried and tested circuits for projects that utilize fibre-optic cables.

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R. A. Penfold

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R. A. Penfold

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166 pages

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V. Capel

Feedback is the bane of all public address systems. While feedback cannot be completely eliminated, many things can be done to reduce it to a level at which it is no longer a problem.

Much of the trouble is often the hall itself, not the equipment, but there is a simple and practical way of greatly improving acoustics. Some microphones are prone to feedback while others are not. Certain loudspeaker systems are much better than others, and the way the units are positioned can produce or reduce feedback. All these matters are fully explored as well as electronic aids such as equalizers, frequency-shifters and notch filters.

The special requirements of live group concerts are considered, and also the related problem of instability that is sometimes encountered with large set-ups. We even take a look at some unsuccessful attempts to cure feedback so as to save readers wasted time and effort duplicating them.

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R. A. Penfold

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R. A. Penfold

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This book will help you learn the basics of computing, running applications programs, wiring up a MIDI system and using the system to good effect, in fact just about everything you need to know about hardware and the programs, with no previous knowledge of computing needed or assumed. This book will help you to choose the right components for a system to suit your personal needs, and equip you to exploit that system fully.

174 pages

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R. A. Penfold

This book contains a collection of guitar effects and some general purpose effects units, many of which are suitable for beginners to project building. An introductory chapter gives guidance on construction.

Each project has an introduction, an explanation of how it works, a circuit diagram, complete instructions on strip-board layout and assembly, as well as notes on setting up and using the units. Contents include: Guitar tuner; Guitar preamplifier; Guitar headphone amplifier; Soft distortion unit; Compressor; Envelope waa waa; Phaser; Dual tracking effects unit; Noise gate/expander; Treble booster; Dynamic treble booster; Envelope modifier; Tremolo unit; DI box.

110 pages

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R. A. Penfold

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Owen Bishop

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The book also presents a dozen filter-based projects with applications in and around the home or in the constructor's workshop. These include a number of audio projects such as a rhythm sequencer and a multi-voiced electronic organ.

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R. M. Marston

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Ian R. Sinclair

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Ian R. Sinclair

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A. Penfold

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The circuits covered in this book are mainly concerned with analogue signal processing and include: Audio

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Over 150 circuits are provided, which it is hoped will be useful to all those involved in circuit design and application, be they professionals, students or hobbyists.

182 pages **Order code BP321** £4.95

CIRCUIT SOURCE BOOK 2

R. A. Penfold

This book will help you to create and experiment with your own electronic designs by combining and using the various standard "building blocks" circuits provided. Where applicable, advice on how to alter the circuit parameters is provided.

The circuits covered are mainly concerned with signal generation, power supplies, and digital electronics.

The topics covered in this book include: 555 oscillators; sinewave oscillators; function generators; CMOS oscillators; voltage controlled oscillators; radio frequency oscillators; 555 monostables; CMOS monostables; TTL monostables; precision long timers; power supply and regulator circuits; negative supply generators and voltage boosters; digital dividers; decoders, etc; counters and display drivers; D/A and A/D converters; opto-isolators, flip/flops, noise generators, tone decoders, etc.

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E. A. Parr

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R. A. Penfold

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Radio, TV, Satellite

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R. A. Penfold

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The circuits covered include:- An aerial tuning unit; A simple active aerial; An add-on b.f.o. for portable sets; A wavetrap to combat signals on spurious responses; An audio notch filter; A parametric equaliser; C.W. and S.S.B. audio filters; Simple noise limiters; A speech processor; A volume expander.

Other useful circuits include a crystal oscillator, and RTTY/C.W. tone decoder, and a RTTY serial to parallel converter. A full range of interesting and useful circuits for short wave enthusiasts.

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AN INTRODUCTION TO AMATEUR RADIO

I. D. Poole

Amateur radio is a unique and fascinating hobby which has attracted thousands of people since it began at the turn of the century.

This book gives the newcomer a comprehensive and easy to understand guide through the subject so that the reader can gain the most from the hobby. It then remains an essential reference volume to be used time and again. Topics covered include the basic aspects of the hobby, such as operating procedures, jargon and setting up a station. Technical topics covered include propagation, receivers, transmitters and aërials etc.

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R. A. Penfold

The subject of aërials is vast but in this book the author has considered practical aerial designs, including active, loop and ferrite aërials which give good performances and are relatively simple and inexpensive to build. The complex theory and mathematics of aerial design have been avoided.

Also included are constructional details of a number of aerial accessories including a pre-selector, attenuator, filters and a tuning unit.

96 pages **Temporarily out of print**

SIMPLE SHORT WAVE RECEIVER CONSTRUCTION

R. A. Penfold

Short wave radio is a fascinating hobby, but one that seems to be regarded by many as an expensive pastime these days. In fact it is possible to pursue this hobby for a minimal monetary outlay if you are prepared to undertake a bit of d.i.y., and the receivers described in this book can all be built at low cost. All the sets are easy to construct, full wiring diagrams etc. are provided, and they are suitable for complete beginners. The receivers only require simple aërials, and do not need any complex alignment or other difficult setting up procedures.

The topics covered in this book include: The broadcast bands and their characteristics; The amateur bands and their

characteristics; The propagation of radio signals; Simple aërials; Making an earth connection; Short wave crystal set; Simple t.r.f. receivers; Single sideband reception; Direct conversion receiver.

Contains everything you need to know in order to get started in this absorbing hobby.

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AN INTRODUCTION TO AMATEUR COMMUNICATIONS SATELLITES

A. Pickford

Communications and broadcast satellites are normally inaccessible to individuals unless they are actively involved in their technicalities by working for organisations such as British Telecom, the various space agencies or military bodies. Even those who possess a satellite television receiver system do not participate in the technical aspects of these highly technological systems.

There are a large number of amateur communications satellites in orbit around the world, traversing the globe continuously and they can be tracked and their signals received with relatively inexpensive equipment. This equipment can be connected to a home computer such as the BBC Micro or IBM compatible PCs, for the decoding of received signals.

This book describes several currently available systems, their connection to an appropriate computer and how they can be operated with suitable software.

102 pages **Order code BP290** £3.95

A GUIDE TO THE WORLD'S RADIO STATIONS (1995/96)

P. Shore

Provides the casual listener, amateur radio DXer and the professional radio monitor with an essential reference work designed to guide him or her around the ever more complex radio bands. This new edition has been completely revised and rewritten and incorporates much more information which is divided into the following sections:

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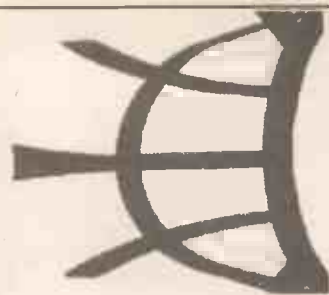
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REPORTING

AMATEUR RADIO

Tony Smith G4FAI



MORSE - NO CHANGE!

The ITU World Radio Conference (*WRC-95*) which ended in Geneva on November 17, decided not to accept New Zealand's proposal for the abolition of the amateur Morse test. During discussion of the proposal most delegates thought the issue needed further study within the amateur community. To give time for such consideration, it was decided the matter should be included on the agenda of a future conference, possibly *WRC-99*.

As a result, the International Amateur Radio Union, recognised by the ITU as the organisation representing national radio societies around the world, has disbanded its "Ad Hoc Committee on Roaming License Qualifications", mentioned last month, and has set up an alternative committee to consider the future of the amateur service.

This committee will prepare proposals for discussion by all member societies, including the need or otherwise for a compulsory Morse test. Once agreed internationally, recommendations on the future of the amateur radio service will be presented for consideration by the appropriate *WRC*.

As a result of the decision of *WRC-95*, the Morse test will continue, until 1999 at least, as a necessary qualification for amateurs wishing to operate on the HF bands below 30 MHz.

RSGB OPEN LETTER

The President of the Radio Society of Great Britain, Clive Trotman GW4YKL, has published an "Open Letter" addressed to the 1300 members and non-members of the Society who wrote to him following the recent exchange of letters between the RSGB and the Radiocommunications Agency. This related to the RA's decision to support the abolition of the Morse test without discussing the matter with the RSGB.

Mr Trotman stresses how important it is that there be no major change in direction without consultation between the administration and the amateur radio fraternity. He reports that the exchange of correspondence has had the desired effect and there now has been consultation.

Questions that immediately spring to mind, he says, include "what are we going to replace the test with?" and "Are we going to replace it?, both of which give rise to a whole new set of questions."

He concludes, "The decision has been postponed to 1999, now we must work in collaboration with other societies and administrations to achieve a feasible and workable system that will be acceptable across the whole amateur radio fraternity... we must start to make moves to find a solution immediately, four years is but a short time."

RSGB ANNUAL REPORT

The Annual Report of the RSGB for 1994/95 records a successful year. It has achieved a modest increase in membership, and has maintained a good relationship with the Radiocommunications Agency (apart from the furore over the Morse test).

It has been represented at many international meetings and conferences; and its "Intruder Watch" now has a full complement of monitors dedicated to protecting exclusive amateur frequency allocations from illegal transmissions.

The Data Communications Committee has been concerned with the day to day management and development of the UK datacomms network; the Repeater Management Group performed much the same function for the repeater network; while an Emergency Communications Officer co-ordinated the work of various emergency networks nationwide.

During the year, the competitive side of the hobby was well catered for with a comprehensive program of operating contests and awards. The QSL bureau sorted and distributed over two million cards for UK amateurs and shortwave listeners; the audio visual library hired out 168 videos to 101 clubs; and the society organised, or was represented at, various rallies, conventions and other events throughout the year.

The HQ library houses the largest collection of English language amateur radio books in Europe, and is available to members and *bona fide* researchers on request. Several new titles were added to the list of books published by the society, and the major success of the year was the long-awaited 6th edition of the *Radio Communication Handbook*. This was published in October, sold out in May, and subsequently reprinted.

SCHOOLS LINKS STRENGTHENED

The society's Training and Education Committee has been restructured to take account of the growing need to involve schools in amateur radio. This need has been highlighted by the activities of the STELAR Group (Science and Technology through Educational Links with Amateur Radio), with which liaison has been strengthened.

It is reported that since the Novice Licence training scheme began in 1991 almost 4,500 students have satisfactorily completed the course. In a large number of cases they have upgraded to the full licence immediately, or after a very short spell as Novice licensees.

Despite all these activities, and many more not mentioned, only about 50 percent of UK amateurs are members of the RSGB. If there were more the society would be that much stronger, more influential, and could provide even better services.

Membership is open to anyone interested in amateur radio, whether licensed or SWL, and full details can be obtained from: *RSGB, Dept EPE, Lambda House, Cranborne Road, Potters Bar, Herts EN6 3JE*.

CRASH COURSE FOR TEACHERS

The next STELAR crash course for teachers who wish to take the radio amateur's examination will be held on April 8 to 13 at Rickmansworth, Herts. The course, sponsored by Trio-Kenwood UK Ltd, provides free hotel accommodation and meals, free course materials, free tuition, and one year's subscription to STELAR.

Places are allocated to teachers who work in schools where there is no amateur radio activity at present, or where the licensed member of staff is about to leave. Full information can be obtained from the *STELAR RAE Course Organizer, Dept EPE, 115 Marshalswick Lane, St Albans, Herts AL1 4UU*. Please mention that you read about the course in *EPE*.

For teachers new to the subject, AMRED (Amateur Radio in Education) the journal of STELAR, carries very informative introductory articles relating to all aspects of amateur radio.

The current issue covers slow scan television (and includes a free SSTV disk); a continuing history of amateur radio; "easy-match" wire antennas; and transmitters. Such good quality back-up and encouragement is essential if schools are to continue to take up, and benefit from amateur radio. STELAR are to be congratulated on their efforts.

SATELLITE LAUNCH ARRANGED

The launch of the eagerly awaited *Phase 3-D* international amateur radio satellite has been arranged to take place in September 1996. The launch by the European Space Agency will cost about \$1 million US, and its primary launch opportunity will be via the second test flight of ESA's new *Ariane 5* booster (*Ariane 502*).

If, for some reason, ESA decides that a launch via *Ariane 502* is not possible, the contract calls on ESA to exercise their "best efforts" to orbit *Phase 3-D* on an *Ariane 4* booster no later than mid-1997. This possibility had been anticipated, and the satellite has been constructed to be easily compatible with either booster.

The final negotiated price is somewhat reduced from earlier estimates. Through the generous contributions of individuals and organisations around the world, \$800,000 is already available to pay the first instalment of the launch bill. Another \$200,000 is still needed to complete the satellite and prepare it for launch (*W5YI Report*).

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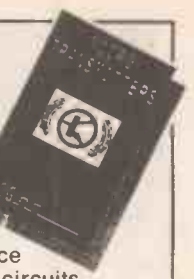
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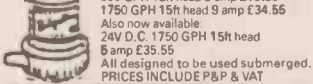
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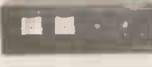
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ADVERTISERS INDEX

N. R. BARDWELL	167
B.K. ELECTRONICS	Cover (iii)
BRIAN J. REED	168
BULL ELECTRICAL	Cover (ii) / 135
CHATWIN GUITARS (JCG)	165
CIRKIT DISTRIBUTION	147
COMPELEC	167
COOKE INTERNATIONAL	167
CRICKLEWOOD ELECTRONICS	94
CR SUPPLY COMPANY	168
CUSTOM ELECTRONIC SERVICES	157
DIRECT CCTV	165
DISPLAY ELECTRONICS	90
ELECTRONICS SERVICE MANUAL	110
EPT EDUCATIONAL SOFTWARE	97
ESR ELECTRONIC COMPONENTS	100
GREENWELD ELECTRONICS	95
HART ELECTRONIC KITS	93
IE	157
INFOTECH & STREE	167
INTERCONNECTIONS	94
J&N FACTORS	158
JPG ELECTRONICS	168
LABCENTER	143
LENNARD RESEARCH	165
MADLAB	156
MAGENTA ELECTRONICS	98/99
MAPLIN ELECTRONICS	Cover (iv)
MAURITRON	167
MINICRAFT (DELIC ASSOCIATES)	151
MODERN ELECTRONICS MANUAL	148
NATIONAL COLLEGE OF TECHNOLOGY	94
NICHE SOFTWARE	151
OMNI ELECTRONICS	94
PEAK ELECTRONIC DESIGN	156
PICO TECHNOLOGY	109
QUASAR ELECTRONICS	147
QUICKROUTE SYSTEMS	92
SEETRIX CAE	157
SERVICE TRADING	165
SHERWOOD ELECTRONICS	165
STEWART OF READING	165
SUMA DESIGNS	96
THE SECURITY CENTRE	168
TSIEN	117
WILLIAM STUART SYSTEMS	167

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POWER AMPLIFIER MODULES-TURNABLES-DIMMERS-LOUDSPEAKERS-19 INCH STEREO RACK AMPLIFIERS

★ PRICE INCLUDE V.A.T. ★ PHOTO DELIVERIES ★ FREIGHTY SERVICE ★ LARGE (A4) S.A.E. 60p STAMPED FOR CATALOGUE ★

OMP MOS-FET POWER AMPLIFIERS HIGH POWER, TWO CHANNEL 19 INCH RACK

THOUSANDS PURCHASED BY PROFESSIONAL USERS



THE RENOWNED MXF SERIES OF POWER AMPLIFIERS
FOUR MODELS:- MXF200 (100W + 100W) MXF400 (200W + 200W)
MXF600 (300W + 300W) MXF900 (450W + 450W)
 ALL POWER RATINGS R.M.S. INTO 4 OHMS, BOTH CHANNELS DRIVEN

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★ ECHO & SOUND EFFECTS ★

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TYPE 'D' (KSN1025A) 2"x6" wide dispersion horn. Upper frequency response retained extending down to mid-range (2KHz). Suitable for high quality Hi-Fi systems and quality discos. **Price £9.99 + 50p P&P.**
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 Delivery £6.00 per pair

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PRICES: 150W £49.99 250W £99.99
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THREE SUPERB HIGH POWER CAR STEREO BOOSTER AMPLIFIERS
 150 WATTS (75 + 75) Stereo, 150W Bridged Mono
 250 WATTS (125 + 125) Stereo, 250W Bridged Mono
 400 WATTS (200 + 200) Stereo, 400W Bridged Mono
ALL POWERS INTO 4 OHMS

Features:
 ★ Stereo, bridgable mono ★ Choice of high & low level inputs ★ L & R level controls ★ Remote on-off ★ Speaker & thermal protection.

OMP MOS-FET POWER AMPLIFIER MODULES

SUPPLIED READY BUILT AND TESTED.

These modules now enjoy a world-wide reputation for quality, reliability and performance at a realistic price. Four models are available to suit the needs of the professional and hobby market i.e. Industry, Leisure, Instrumental and Hi-Fi etc. When comparing prices, NOTE that all models include toroidal power supply, integral heat sink, glass fibre P.C.B. and drive circuits to power a compatible Vu meter. All models are open and short circuit proof.

THOUSANDS OF MODULES PURCHASED BY PROFESSIONAL USERS



OMP/MF 100 Mos-Fet Output power 110 watts
 R.M.S. into 4 ohms, frequency response 1Hz - 100KHz
 -3dB, Damping Factor >300, Slew Rate 45V/uS,
 T.H.D. typical 0.002%, Input Sensitivity 500mV, S.N.R.
 -110 dB. Size 300 x 123 x 60mm.
PRICE £40.85 + £3.50 P&P



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.
PRICE £259.00 + £12.00 P&P



NOTE: MOS-FET MODULES ARE AVAILABLE IN TWO VERSIONS:
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10" 100 WATT R.M.S. ME10-100 GUITAR, VOCAL, KEYBOARD, DISCO, EXCELLENT MID. PRICE £33.74 + £2.50 P&P
RES. FREQ. 71Hz, FREQ. RESP. TO 7KHz, SENS97dB.
10" 200 WATT R.M.S. ME10-200 GUITAR, KEYB'D, DISCO, VOCAL, EXCELLENT HIGH POWER MID. PRICE £43.47 + £2.50 P&P
RES. FREQ. 65Hz, FREQ. RESP. TO 3.5KHz, SENS 99dB.
12" 100 WATT R.M.S. ME12-100LE GEN. PURPOSE, LEAD GUITAR, DISCO, STAGE MONITOR. PRICE £35.64 + £3.50 P&P
RES. FREQ. 49Hz, FREQ. RESP. TO 6KHz, SENS 100dB.
12" 100 WATT R.M.S. ME12-100LT (TWIN CONE) WIDE RESPONSE, P.A., VOCAL, STAGE MONITOR. PRICE £36.67 + £3.50 P&P
RES. FREQ. 42Hz, FREQ. RESP. TO 10KHz, SENS 98dB.
12" 200 WATT R.M.S. ME12-200 GEN. PURPOSE, GUITAR, DISCO, VOCAL, EXCELLENT MID. PRICE £46.71 + £3.50 P&P
RES. FREQ. 58Hz, FREQ. RESP. TO 6KHz, SENS 98dB.
12" 300 WATT R.M.S. ME12-300GP HIGH POWER BASS, LEAD GUITAR, KEYBOARD, DISCO ETC. PRICE £70.19 + £3.50 P&P
RES. FREQ. 47Hz, FREQ. RESP. TO 5KHz, SENS 103dB.
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RES. FREQ. 46Hz, FREQ. RESP. TO 5KHz, SENS 99dB.
15" 300 WATT R.M.S. ME15-300 HIGH POWER BASS, INCLUDING BASS GUITAR. PRICE £73.34 + £4.00 P&P
RES. FREQ. 39Hz, FREQ. RESP. TO 3KHz, SENS 103dB.

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RES. FREQ. 40Hz, FREQ. RESP. TO 5KHz, SENS. 99dB.
10" 100WATT EB10-100 BASS, HI-FI, STUDIO. PRICE £30.39 + £3.50 P&P
RES. FREQ. 35Hz, FREQ. RESP. TO 3KHz, SENS 96dB.
12" 100WATT EB12-100 BASS, STUDIO, HI-FI, EXCELLENT DISCO. PRICE £42.12 + £3.50 P&P
RES. FREQ. 26Hz, FREQ. RESP. TO 3 KHz, SENS 93dB.
FULL RANGE TWIN CONE, HIGH COMPLIANCE, ROLLED SURROUND
5 1/2" 60WATT EB5-60TC (TWIN CONE) HI-FI, MULTI-ARRAY DISCO ETC. PRICE £9.99 + £1.50 P&P
RES. FREQ. 63Hz, FREQ. RESP. TO 20KHz, SENS 92dB.
6 1/2" 60WATT EB6-60TC (TWIN CONE) HI-FI, MULTI-ARRAY DISCO ETC. PRICE £10.99 + 1.50 P&P
RES. FREQ. 38Hz, FREQ. RESP. TO 20KHz, SENS 94dB.
8" 60WATT EB8-60TC (TWIN CONE) HI-FI, MULTI-ARRAY DISCO ETC. PRICE £12.99 + £1.50 P&P
RES. FREQ. 40Hz, FREQ. RESP. TO 18KHz, SENS 89dB.
10" 60WATT EB10-60TC (TWIN CONE) HI-FI, MULTI ARRAY DISCO ETC. PRICE £16.49 + £2.00 P&P
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PHOTO: 3W FM TRANSMITTER

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