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EVERYDAY PRACTICAL ELECTRONICS

APRIL 1998

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FREE 16 page EPE PIC TUTORIAL SUPPLEMENT - 2

The best introduction to using PIC Microcontrollers

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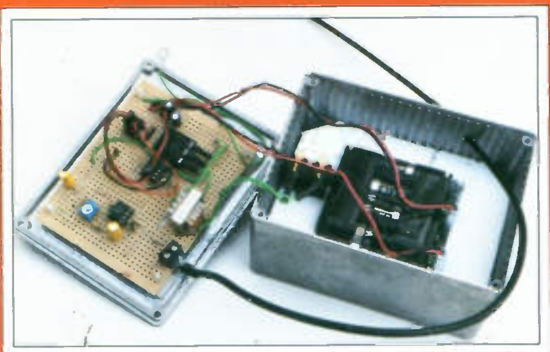

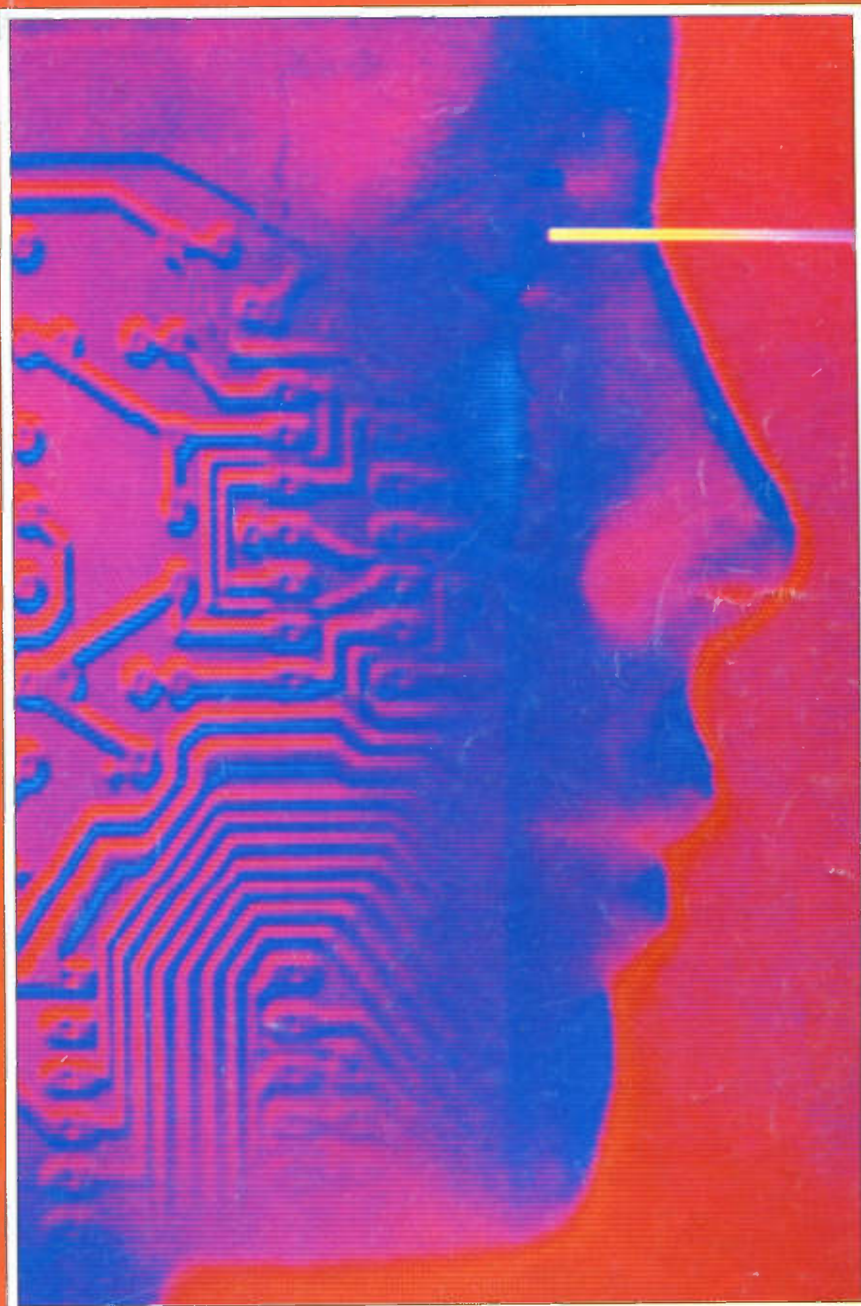

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Ingenuity Unlimited - Net Work - Readout

WIND GENERATORS 380 WATT

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

PLANS

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

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

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

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

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

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

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

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

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

DYNAMO FLASHLIGHT Interesting concept, no batteries needed just squeeze the trigger for instant light apparently even works under water in an emergency although we haven't tried it yet! £6.99 ref SC152

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

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

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

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

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

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

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

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

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

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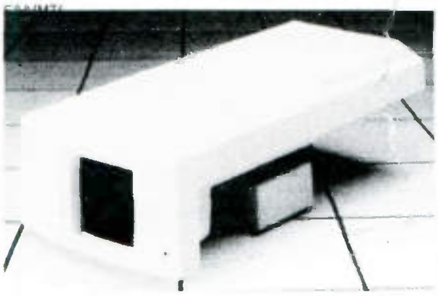

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TZS4 Nightsight £199 ref BAR61

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

VOL. 27 No. 4 APRIL 1998

EVERYDAY PRACTICAL ELECTRONICS

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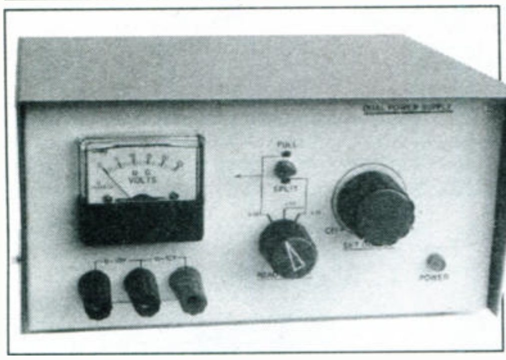
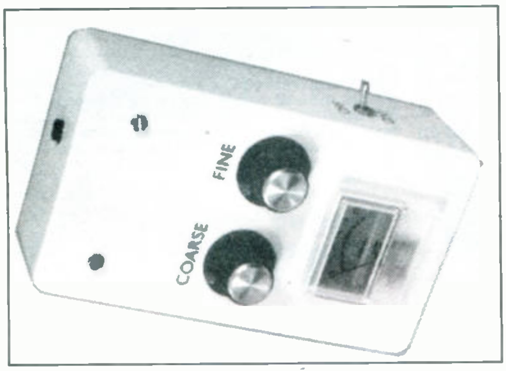
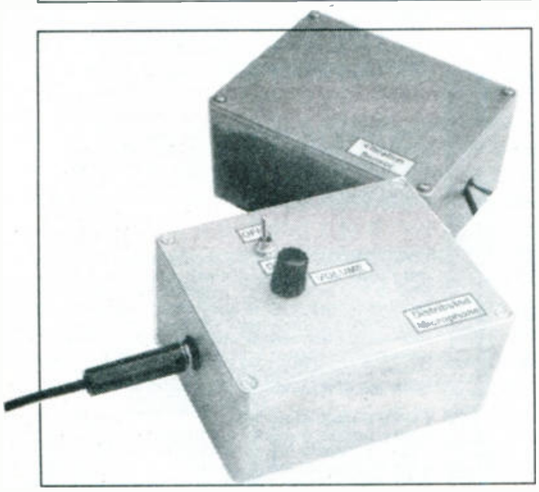
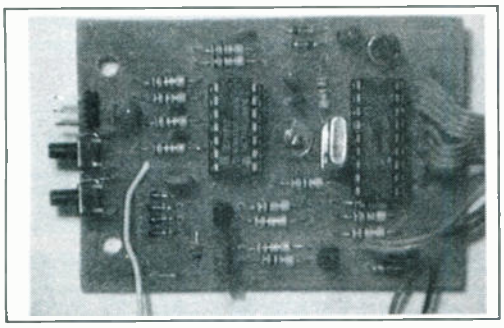
The No. 1 Magazine for Electronics Technology and Computer Projects









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Our May '98 issue will be published on Friday, 3 April 1998. See page 243 for details.

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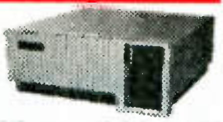
SPECIAL BUY
'AT 286'
40Mb HD + 3Mb Ram



Industrial grade 12Mhz HI GRADE 286 systems Made in the USA to an industrial specification, the system was designed for *total reliability*. The **compact case** houses the motherboard, PSU and EGA **video card** with single **5¼" 1.2 Mb** floppy disk drive & **integral 40Mb hard disk drive** to the front. Real time clock with battery backup is provided as standard. Supplied in good used condition complete with **enhanced keyboard, 640k + 2Mb RAM, DOS 4.01 and 90 DAY Full Guarantee.** *Ready to Run !*
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8" **Mitsubishi M2896-63-02U** DS slimline *NEW*	£295.00(E)
Dual 8" cased drives with integral power supply 2 Mb	£499.00(E)

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Many other drives in stock - Shipping on all drives is code (D)

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Converts your colour monitor into a QUALITY COLOUR TV!!

TV SOUND & VIDEO TUNER
CABLE COMPATIBLE

The **TELEBOX** is 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 computer 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	£36.95
TELEBOX STL as ST but fitted with integral speaker	£39.50
TELEBOX MB Multiband VHF/UHF/Cable/Hyperband tuner	£69.95

For overseas PAL versions state 5.5 or 6 mHz sound specification.
*For cable / hyperband signal reception Telebox MB should be connected to a cable type service. Shipping on all Telebox's, code (B)

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VIDEO MONITOR SPECIALS

One of the highest specification monitors you will *ever* see - At this price - Don't miss it!!

Mitsubishi FA3415ETKL 14" SVGA **Multisync** colour monitor with fine 0.28 dot pitch tube and resolution of 1024 x 768. A variety of inputs allows connection to a host of computers including **IBM PC's** in CGA, EGA, VGA & SVGA modes, **BBC, COMMODORE** (including Amiga 1200), **ARCHIMEDES** and **APPLE**. Many features: Etched faceplate, text switching and **LOW RADIATION MPR** specification. Fully guaranteed, supplied in EXCELLENT little used condition.

Tilt & Swivel Base £4.75 **Only £119** (E) **Order as MITS-SVGA**
VGA cable for IBM PC included.
External cables for other types of computers CALL

As New - Ex Demo
17" 0.28 SVGA Mitsubishi Diamond Pro monitors
Full multisync etc. Full 90 day guarantee. £325.00 (E)

Just in - Microvitec 20" VGA (800 x 600 res.) colour monitors. Good SH condition - from £299 - CALL for info

PHILIPS HCS35 (same style as CM8833) attractively styled 14" colour monitor with **both RGB** and **standard composite 15.625 Khz video inputs** via **SCART socket** and separate phono jacks. **Integral audio power amp** and **speaker for all audio visual uses.** Will connect direct to **Amiga** and **Atari BBC** computers. Ideal for all **video monitoring / security** applications with **direct connection to most colour cameras.** High quality with many features such as front concealed flap controls, VCR correction button etc. Good used condition - fully tested - guaranteed
Dimensions: W14" x H12¾" x 15½" D. **Only £99** (E)

PHILIPS HCS31 Ultra compact 9" colour video monitor with **standard composite 15.625 Khz video** input via SCART socket. Ideal for all monitoring / security applications. High quality, ex-equipment fully tested & guaranteed (possible minor screen burns). In attractive square black plastic case measuring W10" x H10" x 13½" D. 240 V AC mains powered. **Only £79.00** (D)

KME 10" 15M10009 high definition colour monitors with 0.28" dot pitch. Superb clarity and modern styling. Operates from any 15.625 khz sync RGB video source, with RGB analog and composite sync such as Atari, Commodore Amiga, Acorn Archimedes & BBC. Measures only 13½" x 12" x 11". Good used condition. **Only £125** (E)

20" 22" and 26" AV SPECIALS

Superbly made UK manufacture. PIL all solid state colour monitors, complete with composite video & *optional* sound input. Attractive teak style case. Perfect for Schools, Shops, Disco, Clubs, etc.In EXCELLENT little used condition with full 90 day guarantee.

20"....£135 22"....£155 26"....£185 (F)

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MITS. **FA3445ETKL** 14" Industrial spec SVGA monitors	£245
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CSZ VERY Large 3 cavity thermal shock chamber	£POA
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Fujitsu M3041R 600 LPM band printer	£1950
Fujitsu M3041D 600 LPM printer with network interface	£1250
Perkin Elmer 2998 Infrared spectrophotometer	£500
Perkin Elmer 597 Infrared spectrophotometer	£3500
VG Electronics 1035 TELETEXT Decoding Margin Meter	£3750
LightBand 60 output high spec 2u rack mount Video VDA's	£495
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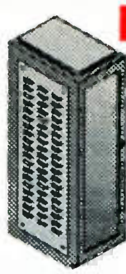
Taylor Hobson Tallysurf amplifier / recorder	£750
System Video 1152 PAL waveform monitor	£485
Siemens K4400 64Kb to 140Mb demux analyser	£2950

19" RACK CABINETS



Superb quality 6 foot 40U
Virtually New, Ultra Smart
Less than Half Price!

Top quality 19" rack cabinets made in UK by **Optima Enclosures Ltd.** Units feature designer, smoked acrylic lockable front door, full height lockable half louvered back door and louvered removable side panels. Fully adjustable internal fixing struts, ready punched for any configuration of equipment mounting plus ready mounted integral 12 way 13 amp socket switched mains distribution strip make these racks some of the ***most versatile we have ever sold.*** Racks may be stacked side by side and therefore require only two side panels to stand singly or in multiple bays. Overall dimensions are: 77½" H x 32½" D x 22" W. **Order as:**

OPT Rack 1 Complete with removable side panels.	£345.00 (G)
OPT Rack 2 Rack, Less side panels	£245.00 (G)

Over 1000 racks, shelves, accessories 19" 22" & 24" wide 3 to 46 U high. Available from stock !!.

32U - High Quality - All steel RakCab

Made by **Eurocraft Enclosures Ltd** to the **highest possible spec**, rack features **all steel construction** with removable side, front and back doors. Front and back doors are **hinged for easy access and all are lockable** with **five secure 5 lever barrel locks.** The front door is constructed of double walled steel with a **'designer style'** smoked acrylic front panel to enable status indicators to be seen through the panel, yet remain unobtrusive. Internally the rack features fully slotted reinforced vertical fixing members to **take the heaviest of 19" rack equipment.** The two movable vertical fixing struts (extras available) are pre punched for standard 'cage nuts'. A **mains distribution panel** internally mounted to the bottom rear, provides 8 x IEC 3 pin Euro sockets and 1 x 13 amp 3 pin **switched utility socket.** Overall ventilation is provided by fully louvered back door and double skinned top section with top and side louvres. The top panel may be removed for fitting of **integral fans** to the sub plate etc. Other features include: fitted castors and floor levelers, prepunched utility panel at lower rear for cable / connector access etc. Supplied in **excellent**, slightly used condition with keys. Colour Royal blue. External dimensions mm=1625H x 635D x 603 W. (64" H x 25" D x 23¾" W)
Sold at LESS than a third of makers price !!

A superb buy at only £245.00 (G)
42U version of the above only £345 - CALL

BATTERY SCOOP - 50% off !!

A special bulk purchase from a **cancelled export order** brings you the most **amazing savings** on these ultra high spec 12v DC 14 Ah rechargeable batteries. Made by **Hawker Energy Ltd, type SBS15** featuring **pure lead plates** which offer a far superior shelf & guaranteed 15 year service life. **Fully BT & BS6290 approved.** Supplied **BRAND NEW** and boxed. Dimensions 200 wide, 137 high, 77 deep. M6 bolt terminals. Fully guaranteed. Current makers price over £70 each ! ***Our Price £35 each*** (C) ***or 4 for £99*** (D)

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INTEL 'ABOVE' Memory Expansion Board. Full length PC-XT and PC-AT compatible card with **2 Mbytes** of memory on board. Card is fully selectable for Expanded or Extended (286 processor and above) memory. **Full data and driver disks supplied.** RFE. Fully tested and guaranteed. Windows compatible. **£59.95**
Half length 8 bit memory upgrade cards for PC AT XT expands memory either 256k or 512k in 64k steps. May also be used to fill in RAM above 640k DOS limit. Complete with data.
Order as: XT RAM UG. 256k. £34.95 *or* **512k £39.95**

SIMM SPECIALS

1 MB x 9 SIMM 9 chip 120ns		Only	**£8.50**
1 MB x 9 SIMM 3 chip 80 ns	**£10.50**	or 70ns	**£11.95**
1 MB x 9 SIMM 9 chip 80 ns	**£10.50**	or 70ns	**£11.75**
4 MB 70 ns 72 pin SIMM *-with parity-*		Only	**£35.00**
INTEL 486-DX33 CPU	**£19.95**	**INTEL 486-DX66 CPU**	**£59.00**

FULL RANGE OF CO-PROCESSOR'S EX STOCK - CALL FOR £££
MOTOROLA 25 Mhz 68040 (XC68040RC25M) CPU'S £59.00
shipping charges for RAM / CPU upgrades is code B

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NEXT MONTH

FREE PIC TUTORIAL SUPPLEMENT-3

TONE CONTROL + 20W STEREO AMP.

This article describes two projects, a general purpose Stereo Tone Control featuring Bass and Treble controls, and a Stereo 20W per channel amplifier, complete with power supply. The prototype circuits were housed in a single case, but the tone control will work with any amplifier as required.

The amplifier described requires a 12V supply making it suitable for operation on a 12V car battery. However, a mains driven supply is included if required. The Tone Control circuit can be tweeked to meet individual needs and the method of doing this using Electronics Workbench software is described in the text.

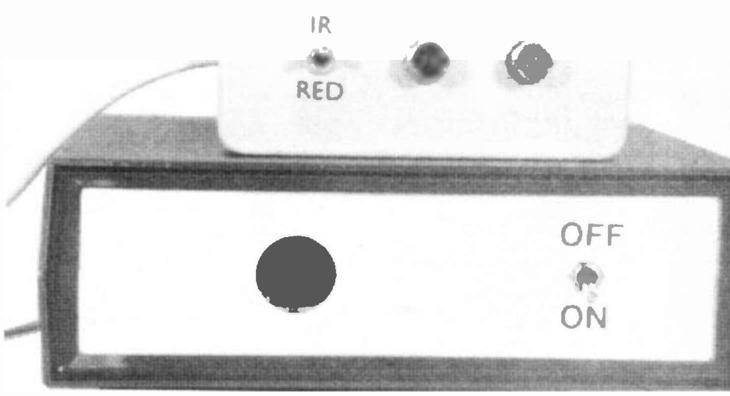
DICE LOTT

There are many random number generators around which simulate dice, or perhaps a bingo machine, or even help you choose your lottery numbers, but this project encompasses all of these and more, including the exclusive Vibe Sensor which means that the numbers it gives you are your own, personal numbers with a special message accompanying the number. It offers five basic modes of operation: 1 to 6 (one dice), 1 to 12 (not two dice, because all 12 numbers are given equal probabilities), 1 to 6 and 1 to 6 (two dice), and finally a lottery mode, which produces your six lottery numbers between 1 and 49, with no repeats.

While your finger is pressing the button to select the numbers, the segments on the displays chase round and round. Furthermore, the device will automatically turn off if left unused for a few minutes, and likewise turn on when the mode select button is pressed. This multitude of options in a simple circuit is made possible through the use of a PIC (the PIC16C71).

IMPROVED IR REMOTE REPEATER

An improved version of the Infra-Red Remote Repeater *published in the July '97 issue. This version will control a satellite receiver, video or audio system in another room, just like the original. But now the remote control receiver is much more sensitive, thus allowing one receiver to work over a greater range.*



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£1 BARGAIN PACKS – List 5

One item only per pack unless otherwise stated.

TEST PRODS FOR MULTIMETERS with 4mm sockets. Good length very flexible lead, Order Ref: D86.
8 OHM PM SPEAKERS, size 8" × 4", pack of 2. These may be slightly rusty and that is why they are so cheap, but are electrically OK, Order Ref: D102.
PAXOLIN PANELS, size 6" × 6", approximately 1/16" thick, pack of 2, Order Ref: D103.
13A SOCKET, virtually unbreakable, ideal for trailing lead, Order Ref: D95.
PIEZO BUZZER with electronic sounder circuit, 3V to 9V d.c. operated, Order Ref: D76.
DITTO but without internal electronics, pack of 2, Order Ref: D75.
LUMINOUS ROCKER SWITCH, approximately 30mm sq, pack of 2, Order Ref: D64.
ROTARY SWITCH, 9-pole 6-way, small size and ¼" spindle, pack of 2, Order Ref: D54.
FERRITE RODS, 7" with coils for Long and Medium waves, pack of 2.
DITTO but without the coils, pack of 3.
SLIDE SWITCHES, SPDT, pack of 20, Order Ref: D50.
MAINS DP ROTARY SWITCH with ¼" control spindle, pack of 5, Order Ref: D49.
ELECTROLYTIC CAP, 800µF at 6·4V, pack of 20, Order Ref: D48.
ELECTROLYTIC CAP, 1000 + 1000µF 12V, pack of 10, Order Ref: D47.
MINI RELAY with 5V coil, size only 26mm × 19mm × 11mm, has 2 sets changeover contacts, Order Ref: D42.
MAINS SUPPRESSOR CAPS, 0·1µF 250V a.c., pack of 10, Order Ref: 1050.
TELESCOPIC AERIAL, chrome plated, extendable and folds over for improved FM reception, Order Ref: 1051.
MES LAMPHOLDERS, slide onto ¼" tag, pack of 10, Order Ref: 1054.
PAX TUBING, ¼" internal diameter, pack of 2, 12" lengths, Order Ref: 1056.
ULTRA THIN DRILLS, 0·4mm, pack of 10, Order Ref: 1042.
20A TOGGLE SWITCHES, centre off, part spring controlled, will stay on when pushed up but will spring back when pushed down, pack of 2, Order Ref: 1043.
HALL EFFECT DEVICES, mounted on small heatsink, pack of 2, Order Ref: 1022.
12V POLARISED RELAY, two changeover contacts, Order Ref: 1032.
PAXOLIN PANEL, 12" × 12", 1/16" thick, Order Ref: 1033.
MINI POTTED TRANSFORMER, only 1·5VA 15V-0V-15V or 30V, Order Ref: 964.
ELECTROLYTIC CAP, 32µF at 350V and 50µF section at 25V, in alulminium can for upright mounting, pack of 2, Order Ref: 995.
PRE-SET POTS, 1 megohm, pack of 5, Order Ref: 998.
WHITE PROJECT BOX with rocker switch in top left-hand side, size 78mm × 115mm × 35mm, unprinted, Order Ref: 1006.
6V SOLENOID, good strong pull but quite small, pack of 2, Order Ref: 1012.
FIGURE-8 MAINS FLEX, also makes good speaker lead, 15m, Order Ref: 1014.
HIGH CURRENT RELAY, 24V a.c. or 12V d.c., 3 changeover contacts, Order Ref: 1016.
LOUDSPEAKER, 8 ohm 5W, 3·7" round, Order Ref: 962.
NEON PILOT LIGHTS, oblong for front panel mounting, with internal resistor for normal mains operation, pack of 4, Order Ref. 970.
3·5MM JACK PLUGS, pack of 10, Order Ref: 975.
WANDER PLUGS, pack of 10, Order Ref: 986.
PSU, mains operated, two outputs, one 9·5V at 550mA and the other 15V at 150mA, Order Ref: 988.
ANOTHER PSU, mains operated, output 15V a.c. at 320mA, Order Ref: 989.
PHOTOCELLS, silicon chip type, pack of 4, Order Ref: 939.
LOUDSPEAKER, 5" 4ohm 5W rating, Order Ref: 946.
230V ROD ELEMENTS, 500W terminal ended, 10" long, pack of 2, Order Ref: 943.
LOUDSPEAKER, 7" × 5", 4ohm 5W, Order Ref: 949.
LOUDSPEAKER, 4" circular, 6ohm 3W, pack of 2, Order Ref: 951.
FERRITE POT CORES, 30mm × 15mm × 25mm, matching pair, Order Ref: 901.
PAXOLIN PANEL, 8½ × 3½ with electrolytics, 250µF and 100µF, Order Ref: 905.
CAR SOCKET PLUG with PCB compartment, Order Ref: 917.
4-CORE FLEX suitable for telephone extensions, 10m, Order Ref: 918.
VERO OFF-CUTS, approximately 30 square inches of useful sizes, Order Ref: 927.
PROJECT CASE, 95mm × 66mm × 23mm with removal lid held by four screws, pack of 2, Order Ref: 876.
SOLENOIDS, 12V to 24V, will push or pull, pack of 2, Order Ref: 877.
2M MAINS LEAD, 3-core with instrument plug moulded on, Order Ref: 879.
TELESCOPIC AERIAL, chrome plated, extendable, pack of 2, Order Ref: 884.
MICROPHONE, dynamic with normal body for handholding, Order Ref: 885.
CROCODILE CLIPS, superior quality flex, can be attached without soldering, 5 each red and black, Order Ref: 886.
BATTERY CONNECTOR FOR PP3, superior quality, pack of 4, Order Ref: 887.
LIGHTWEIGHT STEREO HEADPHONES, Order Ref: 898.
PRESETS, 470 ohm and 220k, mounted on single panel, pack of 10, Order Ref: 849.
THERMOSTAT for ovens with ¼" spindle to take control knob, Order Ref: 857.
12V-0V-12V 10W MAINS TRANSFORMER, Order Ref: 811.
18V-0V-18V 10W MAINS TRANSFORMER, Order Ref: 813.
AIR-SPACED TRIMMER CAPS, 2pF to 20pF, pack of 2, Order Ref: 818.
AMPLIFIER, 9V or 12V operated Mullard 1153, Order Ref: 823.
2 CIRCUIT MICROSWITCHES, pack of 4, Order Ref: 825.
LARGE SIZE MICROSWITCHES, (20mm × 6mm × 10mm) changeover contacts, pack of 2, Order Ref: 826.
MAINS VOLTAGE PUSHSWITCH with white dolly, though panel mounting by hexagonal nut.
POINTER KNOB for spindle which is just under ¼", like most thermostats, pack of 4, Order Ref: 833.

TOROIDAL MAINS TRANSFORMERS

All with 220V/240V primary winding

0V-30V + 0V-30V at 120VA, would give you 30V at 4A or 60V at 2A, price £8, Order Ref: 8PG2.
0V-110V + 0V-110V at 120VA would give you 110V at just over 1A or 220V at 1/2A, price £8, Order Ref: 8PG3.
0V-35V + 0V-35V at 150VA would give you 35V at 4A or 70V at 2A. Price £8. Order Ref: 8PG9.
0V-35V + 0V-35V at 220VA would give you 35V at 6½A or 70V at 3¼A, price £9, Order Ref: 9PG4.
0V-110V + 0V-110V at 220VA would give you 110V at 2A or 220V at 1A, price £10, Order Ref: 10PG5.
0V-45V + 0V-45V at 500VA would give you 45V at 11A or 90V at 5½A, price £20, Order Ref: 20PG7.
0V-110V + 0V-110V at 500VA would give you 110V at 5A or 220V at nearly 3A, price £25, Order Ref: 25PG8.

NORMAL MAINS TRANSFORMERS

5V 45A, £20, Order Ref: 20P16.
6V 1A, 2 for £1, Order Ref: 9.
8V 1A, £1, Order Ref: 212.
9V ½A, 2 for £1, Order Ref: 266.
9V 1A, £1, Order Ref: 236.
9V 3A, £2, Order Ref: 2P408.
10V 1A, £1, Order Ref: 492.
12V ½A, 2 for £1, Order Ref: 10.
12V 1A, £1, Order Ref: 436.
12V 1½A, £1.50, Order Ref: 1.5P41.
12V 2A, £2, Order Ref: 2P337.
12V 3A, £3, Order Ref: 3P181.
15V 1A, £1, Order Ref: 267.
17V 1A, £1, Order Ref: 492.
18V 1½A, £1, Order Ref: 491.
20V 4A, £3, Order Ref: 3P106.
24V ½A, £1, Order Ref: 337.
24V 1A, £2, Order Ref: 2P413.
24V 1½A, £2.50, Order Ref: 2.5P15.
25V 10A, £20, Order Ref: 20P33.
28V 2½A, £4, Order Ref: 4P24.
30V 25VA, £2.50, Order Ref: 2.5P25.
40V 2A, £3, Order Ref: 3P107.
43V 3½A, £5, Order Ref: 5P262.
50V 2A fully shrouded, £5, Order Ref: 5P210.
50V 15A, £20, Order Ref: 20P2.
675V 100mA, £5, Order Ref: 5P166.
4kV 2mA, £5, Order Ref: 5P139.
6V-0V-6V 5VA, 2 for £1, Order Ref: 612.
6V-0V-6V 10VA, £1, Order Ref: 281.
7·5V-0V-7·5V 8VA, £1, Order Ref: D104.
7·5V-0V-7·5V 50VA, £4, Order Ref: 4P98.
8V-0V-8V 8VA, £1, Order Ref: 212.
12V-0V-12V 3VA, £1, Order Ref: 636.
12V-0V-12V 6VA, £1, Order Ref: 811.
12V-0V-12V 30VA, £2.50, Order Ref: 2.5P15.
15V-0V-15V 1VA, £1, Order Ref: 937.
15V-0V-15V 15VA, £2, Order Ref: 2P68.
15V-0V-15V 25VA, £2.50, Order Ref: 2.5P24.
18V-0V-18V 10VA, £1, Order Ref: 813.
20V-0V-20V 10VA, £1, Order Ref: 812.
20V-0V-20V 10VA, £2, Order Ref: 2P85.
20V-0V-20V 20VA, £2, Order Ref: 2P138.
20V-0V-20V 40VA, £3, Order Ref: 3P205.
20V-0V-20V 80VA, £4, Order Ref: 4P36.
25V-0V-25V 40VA, £3, Order Ref: 3P206.
36V-0V-36V 20VA, £2, Order Ref: 2P156.

SPECIAL TRANSFORMERS

15VA gives 1V, 7V, 8V, 9V or 10V, £1, Order Ref: 744.
38V-0V-38V 150VA with regulator winding, £10, Order Ref: 10P36.
230V-115V auto transformer, 10VA, £1, Order Ref: 822.
230V-115V auto transformer, 1kVA, £20, Order Ref: 20P29.
230V-115V auto transformer, 300VA, can be made from our Ref: 4P97. This is a big mains transformer but it has a 115V tapping on its primary, £4.

SUPER WOOFER LOUDSPEAKERS

Two available. The first is a 10" 4 ohm with a power rating of 250W music and normal 150W. Has a very heavy magnet and is beautifully made and finished by Challenger. Normal selling price for this is £55 + VAT, you can buy at **£29 including VAT and carriage,** Order Ref: 29P7.
The second one is a 8" 4 ohm, 200W music, 100W normal. Again by Challenger, price £18, Order Ref: 18P9. Incidentally, as these are so heavy, if you collect, then you make a saving of £2 on the 10" and £1.50 on the 8".

LOUDSPEAKERS

2" round 50 ohm coil ½W speaker, pack of 2, £1, Order Ref: 908.
2¼" 8 ohm, pack of 2, £1, Order Ref: 454.
2½" 35 ohm, pack of 2, £1, Order Ref: 514.
3½" 8 ohm, pack of 2, £1, Order Ref: 682.
5" 4 ohm, pack of 2, £1, Order Ref: 136.
6½" 4 ohm with tweeter, £1, Order Ref: 895.
6½" 6 ohm, £1, Order Ref: 896.
6½" 8 ohm with tweeter, £1, Order Ref: 897.
6½" 4 ohm 12W (superior make with Hitachi tools), £1, Order Ref: 900.
6" × 4" 4 ohm, £1, Order Ref: 242.
5" × 5" 15 ohm, £1, Order Ref: 906.
5" × 3" 16 ohm, pack of 2, £1, Order Ref: 684.
8" 15 ohm Audax, £1, Order Ref: 504.
3" 4 ohm tweeter, £1, Order Ref: 433.
6½" 4 ohm Sanyo speaker, 10W, £1.50, Order Ref: 1.5P11.
6" × 4" 15 ohm 10W, £2, Order Ref: 2P167.
6½" 4 ohm Hitachi speaker with tweeter, £2, Order Ref: 2P301.
20W tweeter 4ohm, £1.50, Order Ref: 1.5P9.
Tweeter on flange with crossover, £3, Order Ref: 3P86.
Horn speaker, £3, Order Ref: 3P82.
5" 20W loudspeaker by Goodmans for Ford, £3, Order Ref: 3P145.
8" 8 ohm Amstrad 15W speaker with matching tweeter, £4, Order Ref: 4P57.
Midi speaker in cabinet, 4 ohm 5W, £5, Order Ref: 5P137.
Boxed speakers, 4 ohm, £5 each or pair for £8, Order Ref: 8/14L.
Double-wound voice coil 25W speaker, ITT, £7, Order Ref: 7P12.
Bulkhead speaker, metal cased, £10, Order Ref: 10P43.
25W 2-way crossover, pack of 2, £1, Order Ref: 22.
40W 3-way crossover, £1, Order Ref: 23.

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74LS245	£0.60
74LS247	£0.32
74LS251	£0.24
74LS257	£0.24
74LS258	£0.24
74LS266	£0.14
74LS273	£0.32
74LS279	£0.25
74LS365	£0.21
74LS367	£0.21
74LS368	£0.21
74LS373	£0.33
74LS374	£0.34
74LS375	£0.34
74LS377	£0.32
74LS378	£0.62
74LS390	£0.25
74LS393	£0.24
74LS395	£0.26
74LS399	£0.62
74LS670	£0.69

Linear ICs

AD524AD	£23.04
AD548JN	£1.62
AD590JH	£3.65
AD592AN	£4.52
AD595AQ	£12.65
AD620AN	£9.88
AD625JN	£16.20
AD633JN	£8.25
AD648JN	£2.57
AD654JN	£7.25
AD708JN	£5.69
AD711JN	£1.51
AD712JN	£2.38
AD736JN	£8.75
AD797AN	£8.69
AD811N	£6.73
AD812AN	£6.32
AD817AN	£3.85
AD820AN	£3.20
AD822AN	£5.20
AD829JN	£6.41
AD830AN	£5.99
AD847JN	£5.71
AD9696KN	£7.73
ADEL2020A	£5.06
ADM222AH	£3.55
ADM232AA	£3.55
ADM485JN	£2.97
ADM690AN	£5.13
ADM691AN	£6.48
ADM695AN	£6.48
ADM699AN	£3.58
CA741CE	£0.26
CA747CE	£0.39
CA3046	£0.37
CA3059	£1.33
CA3080E	£0.73
CA3130E	£0.87
CA3140E	£0.49
CA3189E	£1.22
CA3240E	£1.12
DG211CJ	£1.55
DG212CJ	£1.55
DG411DJ	£3.11
ICL7106	£2.95
ICL7611DCP	£1.06
ICL7621	£1.70
ICL7660SCP	£1.92
ICL8038	£4.89
ICM7555	£0.32
ICM7556	£0.98
L165V	£2.72
L272M	£1.86
L293E	£4.35
L297	£6.37
L298	£6.99
L6219	£4.48
LF347N	£0.46
LF351N	£0.43
LF353N	£0.40
LF356	£0.84
LM301A	£0.25
LM308N	£0.58
LM311N-8	£0.29
LM318	£0.98
LM319N-14	£0.90
LM324	£0.24
LM335Z	£1.52
LM339N	£0.24
LM348N	£0.31
LM358N	£0.27
LM380N	£0.88
LM381N	£2.64
LM386	£0.79
LM392N	£0.79
LM393N	£0.21
LM709T	£0.79
LM748CN-8	£0.37
LM1458	£0.37
LM1881	£3.92
LM2917N8	£3.10
LM3900N	£0.72
LM3909N	£0.72
LM3914	£2.16
LM3915	£2.70
LM13600	£1.66
LMC660CN	£1.77
LMC6032IN	£1.55
LP311N	£0.74
LP324N	£0.67
LP339N	£0.73
LT1013CN8	£3.94
MAX202CPE	£2.97
MAX208CN	£6.99
MAX220CPE	£5.06
MAX222CPE	£5.06
MAX232CPE	£1.80
MAX483CP	£3.13
MAX485CP	£2.58
MAX631ACP	£4.99
MAX635ACP	£4.99
MAX1232CP	£2.96
MC1488	£0.39
MC1489	£0.39
MC3302	£0.56
MC3340P	£1.60
MC4558P	£0.33
MV601DP	£2.97
NE521N	£6.39
NE555N	£0.21
NE556N	£0.36
NE565	£1.84
NE566N	£0.90
NE567N	£0.39
NE571N	£2.47
NE592	£0.62
NE5532N	£0.45
NE5534N	£0.64
NE5539N	£4.35
NE5560N	£2.31
OP07CN	£1.42
OP27CN	£2.90
OP77GP	£1.99
OP90GP	£3.11
OP97FP	£2.43
OP113GP	£3.44
OP176GP	£2.09
OP177GP	£1.89
OP200GP	£5.60
OP213FP	£5.20
OP275GP	£2.57
OP282GP	£2.27
OP283GP	£5.20
OP290GP	£5.40
OP297GP	£5.74
OP400GP	£11.81
OP495GP	£8.69
RC4136	£1.00
SAA1027	£4.49
SG3524N	£0.96
SG3543	£6.88
SL486	£2.88
SSM2017P	£3.38
SSM2131P	£4.19
SSM2141P	£4.21
SSM2142P	£6.16
SSM2143P	£3.78
TBA120S	£0.90
TBA800	£0.70
TBA810S	£0.64
TBA820M	£0.40
TDA1170S	£2.48
TDA2002	£1.04
TDA2004	£3.11
TDA2030	£1.18
TDA2050V	£3.12
TDA2611A	£1.88
TDA2822A	£0.86
TED3718DP	£5.03
TEA5115	£3.11
TL061CP	£0.35
TL062CP	£0.60
TL064CN	£0.72
TL071CP	£0.39
TL072CP	£0.38
TL074CN	£0.48
TL081	£0.33
TL082CP	£0.54
TL084CN	£0.50
TL494CN	£1.46
TL7705ACP	£1.62
TLC271	£0.54
TLC272	£0.88
TMP01FP	£5.60
ULN2003	£0.52
ULN2004A	£0.48
ULN2803	£0.90
ULN2804A	£1.64
XR2206	£5.37

EPROM's

2716	£4.74
2732	£4.84
2764-20	£4.26
27C64-25	£3.44
27128-20	£4.08
27C128-15	£3.02
27256-20	£4.85
27C256-20	£3.68
27C512	£3.30
27C1001-20	£3.02
27C4001-120	£9.76

RAM

4164-15	£1.90
6116-10	£1.53
6264-10	£3.16
41256-10	£2.80
62256-10	£4.22
514256-8	£6.80

A/D Converters Data Acquisition

AD420AN	£25.38
AD557JN	£8.75
AD574AJN	£18.48
AD775JN	£18.48
AD7528JN	£11.42
AD7545AKN	£14.04
AD7828KN	£20.33
DAC0800	£2.72
ICL7109CPL	£7.75
TLC549IP	£3.04
ZN427E	£9.25
ZN448E	£7.34

PIC Micro's

16C54A04P	£3.07
16C54JW	£12.48
16C71-04P	£4.88
16C71JW	£17.34
16C84-04	£5.92

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7806	£0.32
7808	£0.35
7812	£0.38
7815	£0.38
78L05	£0.23
78L06	£0.32
78L08	£0.23
78L12	£0.23
78L15	£0.24
78L24	£0.39
78S05	£0.70
78S12	£0.70
78S15	£0.98
7905	£0.40
7912	£0.30
7915	£0.38
7924	£0.38
79L05	£0.23
79L12	£0.23
79L15	£0.28
79L24	£0.30
ADM666AN	£3.44
L200CV	£1.30
L296	£6.87
L387A	£3.24
LM2940CT	£2.30
LM317LZ	£0.30
LM317T	£0.48
LM323K	£2.84
LM334Z	£1.35
LM337T	£0.68
LM338K	£5.52
LM723	£0.29
LP2950CZ	£2.70
REF01CP	£3.44
REF02CP	£4.66
REF12Z	£1.28
REF195GP	£4.72
REF25Z	£1.24
REF50Z	£1.22
TL431CP	£0.45
ZN423	£1.00
ZN458B	£1.89

Diodes

1N914	£0.06
1N916	£0.06
1N4001	£0.04
1N4002	£0.04
1N4003	£0.04
1N4004	£0.04
1N4005	£0.04
1N4006	£0.04
1N4007	£0.05
1N4148	£0.05
1N4149	£0.06
1N5400	£0.09
1N5401	£0.08
1N5402	£0.08
1N5404	£0.09
1N5406	£0.10
1N5407	£0.10
1N5408	£0.11
6A05	£0.27
6A1	£0.27
6A2	£0.27
6A4	£0.28
6A6	£0.29
6A8	£0.30
6A10	£0.37
BA157	£0.10
BA158	£0.10
BA159	£0.10
BAT41	£0.24
BAT42	£0.10
BAT46	£0.28
BAT49	£0.36
BAT85	£0.17
BAV21	£0.07
BAW62	£0.07
BAX13	£0.05
BAX16	£0.05
BB405B	£0.26
BB909A	£0.36
BB909B	£0.36
BY126	£0.13
BY127	£0.18
BY133	£0.10
OA47	£0.24
OA90	£0.07
OA91	£0.26
OA200	£0.56
OA202	£0.29

Zeners 2.7 to 33V

500mW	£0.08
1.3W	£0.14

Bridge Rectifiers

1.5A 50V	£0.19
1.5A 200V	£0.20
1.5A 400V	£0.22
1.5A 600V	£0.22
1.5A 800V	£0.27
1.5A 1kV	£0.24
3A 200V	£0.36
3A 400V	£0.40
3A 600V	£0.33
6A 200V	£0.70
6A 800V	£0.59
10A 400V	£1.39
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25A 600V	£1.80

Thyristors

C106D	£0.30
PO102AA	£0.30
TIC116D	£0.66
TIC126D	£0.77

Triacs

ZO105DA	£0.42
TIC206D	£0.65
TIC226D	£0.94
BTA08-600B	£0.88
TIC236D	£1.12

Diac, Si. Switch

DB3, 32V	£0.20
BRY39	£1.30

Transistors

2N1613	£0.31
2N1711	£0.26
2N1893	£0.29
2N2218A	£0.28
2N2219A	£0.25
2N2222A	£0.18
2N2646	£1.12
2N2904A	£0.25
2N2905A	£0.25
2N2907A	£0.17
2N2926	£0.16
2N3053	£0.27
2N3054	£0.85
2N3055	£0.58
2N3439	£0.62
2N3440	£0.50
2N3702	£0.09
2N3703	£0.10
2N3704	£0.10
2N3705	£0.10
2N3706	£0.10
2N3771	£1.44
2N3772	£1.51
2N3773	£1.70
2N3819	£0.42
2N3820	£0.66
2N3904	£0.10
2N3905	£0.10
2N3906	£0.10
2N4036	£0.34
2N5245	£0.80
2N5296	£0.57
2N5322	£0.57
2N5401	£0.11
2N5460	£0.54
2N5551	£0.11
2N6107	£0.60
2N6491	£1.58
2SB548	£0.30
2SD1730	£1.44
AC126	£0.44
AC127	£0.50
AC128	£0.40
AC187	£0.68
AC188	£0.48
ACY17	£3.84
AD149	£1.67
AD161	£0.92
AD162	£0.92
BC107	£0.16
BC107B	£0.17
BC108	£0.14
BC108B	£0.16
BC108C	£0.15
BC109	£0.17
BC109C	£0.16
BC114	£0.19
BC115	£0.41
BC116	£0.41
BC118	£0.41
BC132	£0.36
BC134	£0.36
BC135	£0.36
BC140	£0.25
BC141	£0.27
BC142	£0.34
BC143	£0.38
BC149	£0.21
BC154	£0.36
BC157	£0.12
BC159	£0.21
BC160	£0.28
BC170	£0.16
BC170B	£0.16
BC171	£0.11
BC171B	£0.16
BC172	£0.13
BC172B	£0.13
BC177	£0.18
BC178	£0.18
BC179	£0.18
BC179A	£0.17
BC182	£0.11
BC182A	£0.11
BC182B	£0.12
BC182L	£0.08
BC182LB	£0.10
BC183	£0.08
BC183L	£0.08
BC183LB	£0.08
BC184	£0.08
BC184L	£0.08
BC186	£0.33
BC204C	£0.72
BC206B	£0.72
BC208	£0.72
BC209A	£0.72
BC212	£0.08
BC212L	£0.08
BC212LB	£0.08
BC213	£0.08
BC213B	£0.08
BC213LC	£0.08
BC214	£0.08
BC214L	£0.08
BC225	£0.15
BC237B	£0.09
BC238B	£0.09
BC238C	£0.09
BC239C	£0.10
BC250A	£0.15
BC252	£0.13
BC261B	£0.30
BC262B	£0.24
BC267B	£0.30
BC307	£0.10
BC308	£0.10
BC319C	£0.13
BC327	£0.10
BC327-25	£0.10
BC328	£0.10
BC328-16	£0.10
BC337	£0.10
BC337-25	£0.12
BC338	£0.10
BC338-25	£0.10
BC348B	£0.14
BC357	£0.25
BC393	£0.73
BC441	£0.40
BC461	£0.46
BC463	£0.29
BC478	£0.32
BC479	£0.32
BC516	£0.21
BC517	£0.17
BC527	£0.20
BC528	£0.20
BC537	£0.20
BC546B	£0.08
BC546C	£0.08
BC547B	£0.09
BC547C	£0.09
BC548C	£0.08
BC549C	£0.10
BC550C	£0.10
BC556A	£0.08
BC557B	£0.08
BC557C	£0.08
BC558B	£0.08
BC559C	£0.08
BC560A	£0.09
BC560B	£0.09
BC637	£0.21
BC638	£0.21
BC639	£0.21
BC640	£0.13
BCY70	£0.22
BCY71	£0.20
BCY72	£0.20
BD124P	£6.86
BD135	£0.21
BD136	£0.21
BD137	£0.23
BD138	£0.22
BD139	£0.25
BD140	£0.25
BD150C	£0.82
BD165	£0.42
BD166	£0.35
BD187	£0.39
BD201	£0.40
BD202	£0.70
BD203	£0.40
BD204	£0.40
BD225	£0.42
BD232	£0.50
BD237	£0.32
BD238	£0.44
BD240C	£0.37
BD243B	£0.50
BD244A	£0.53
BD244C	£0.53
BD245C	£1.18
BD246	£1.18
BD246C	£1.18
BD283	£0.61
BD284	£0.61
BD400	£0.79
BD441	£0.41
BD442	£0.37
BD534	£0.47
BD535	£0.50
BD536	£0.65
BD581	£0.62
BD597	£0.92
BD646	£0.52
BD648	£0.52
BD650	£0.53
BD707	£0.42
BD708	£1.04
BD807	£0.80
BDX32	£1.78
BDX33C	£0.56
BDX34C	£0.50
BDX53C	£0.47
BDX54C	£0.50
BF180	£0.31
BF182	£0.31
BF185	£0.58
BF194	£0.31
BF194B	£0.19
BF195	£0.19
BF244	£0.35
BF244B	£0.40
BF244C	£0.35
BF257	£0.33
BF259	£0.33
BF337	£0.40
BF355	£0.38
BF423	£0.13
BF451	£0.19
BF459	£0.33
BF469	£0.36
BFX29	£0.29
BFX84	£0.31
BFX85	£0.32
BFY50	£0.30
BFY51	£0.24
BFY52	£0.28
BS107	£0.21
BS170	£0.23
BSW66	£1.35
BU126	£1.32
BU205	£1.41
BU208A	£1.24
BU326A	£1.40
BU500	£1.54
BU508A	£1.30
BU508D	£0.98
BU526	£1.74
BU806	£1.06
BUT11A	£0.57
BUT11AF	£1.14
BUX84	£0.78
IRF530	£0.76
IRF540	£1.26
IRF740	£1.88
MJ2501	£1.60
MJ3001	£1.80
MJ11015	£2.45
MJ11016	£2.56
MJE340	£0.40
MJE350	£0.48
MPSA05	£0.14
MPSA06	£0.11
MPSA13	£0.12
MPSA42	£0.17
MRF475	£7.28
TIP29C	£0.31
TIP30C	£0.37
TIP31C	£0.41
TIP32C	£0.41
TIP33C	£0.72
TIP41A	£0.44
TIP42C	£0.39
TIP47	£0.48
TIP48	£0.62
TIP50	£0.53
TIP121	£0.45
TIP122	£0.46
TIP125	£0.46
TIP127	£0.40
TIP132	£0.46
TIP137	£0.56
TIP142	£1.30
TIP147	£1.12
TIP2955	£0.97
TIP3055	£0.70
VN10KM	£0.48
ZTX300	£0.16
ZTX500	£0.16

μF	Electrolytic Radial 16v	25v	40v	63v	100v	Electrolytic Axial 16v	25v	40v	63v	100v	250v	450v
0.47	---	---	---	£0.05	---	---	---	---	---	---	---	---
1.0	---	---	---	£0.05	£0.05	---	---	---	£0.13	---	---	£0.22
2.2	---	---	---	£0.05	---	---	---	---	£0.13	---	---	£0.30
4.7	---	---	£0.05	£0.05	£0.05	---	---	---	£0.13	---	---	£0.41
10	£0.05	£0.05	£0.05	£0.05	£0.09	£0.12	---	£0.12	£0.13	£0.17	£0.40	£0.51
22	£0.05	£0.05	£0.05	£0.07	£0.11	£0.12	£0.13	£0.14	£0.15	£0.21	£0.52	£1.06
33	£0.05	---	£0.05	---	---	---	---	---	---	---	---	---
47	£0.05	£0.05	£0.07	£0.10	£0.19	£0.13	£0.13	£0.15	£0.19	£0.32	£0.57	---
100	£0.06	£0.06	£0.10	£0.13	£0.26	£0.14	£0.16	£0.19	£0.26	£0.44	---	---
220	£0.08	£0.09	£0.13	£0.25	---	£0.19	£0.20	£0.27	£0.39	£0.48	---	---
330	£0.09	---	£0.19	---	---	---	---	---	---	---	---	---
470	£0.12	£0.17	£0.24	£0.33	---	£0.24	£0.28	£0.43	£0.53	---	---	---
1000	£0.15	£0.33	£0.34	---	---	£0.33	£0.43	£0.59	£1.08	---	---	---
2200	£0.27	£0.55	£0.70	---	---	£0.53	£0.66	£1.11	£1.55	---	---	---
3300	---	£0.94	---	---	---	---	---	---	---	---	---	---
4700	£0.67	£1.05	---	---	---	£0.86	£1.11	---	---	---	---	---

We carry a large range of capacitors in stock, including: Ceromic Mini Disc, Dipped Ceromic Multiloyer, Dipped & Boxed Polyester, Mylor Film, Polystyrene, MKT Polyester, Tantolum Beod, Sub-miniature Rodiol, 105°C Radial, Law Leakage Radial, Non Polarised Rodiol, PCB Can Electrolytics, Polypropylene & Ceromic Trimmers and Tuning, Dilecon & O Type Variable capacitors. Full technical details available.

Resistors - Please State Value Required

per 100 of one value only

1/8W Carbon Film 5%	E12 Series	10Ω-1M0	£0.02 Each, £0.80 per 100
¼W Carbon Film 5%	E12 Series	1Ω-10M	£0.02 Each, £0.60 per 100
¼W Metal Film 1%	E24 Series	10Ω-1M	£0.04 Each, £1.72 per 100
½W Carbon Film 5%	E12 Series	1Ω-10M	£0.02 Each, £0.95 per 100
2.5W Wirewound 5%	E12 Series	0Ω1-220Ω	£0.23 Each

1W & 2W Carbon Film in stock - selected values only, contact sales dept. for details.

Preset Resistors - Please State Value Required

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Sub-min, 6mm Dia, Horizontal	E3 200Ω-1M0 0.1W	£0.19 Each
Multiturn, 10mm Square, Top Adjust.	E3 100Ω-1M0 0.5W	£0.89 Each
Multiturn, 19mm Long, End Adjust.	E3 50Ω-2M0 0.5W	£0.60 Each

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Single Gang ¼" Shaft, 25mm Dia.	470Ω-2M2 Linear	£0.49 Each
Single Gang ¼" Shaft, 25mm Dia.	4k7,10k,47k,100k,1M,2M2 Log	£0.49 Each
Dual Gang ¼" Shaft, 20mm Dia.	1K0-2M2 Linear	£1.62 Each
Dual Gang ¼" Shaft, 20mm Dia.	1K0-2M2 Logarithmic	£1.71 Each
Switched ¼" Shaft, 20mm Dia.	1K0-2M2 Linear	£1.56 Each
Switched ¼" Shaft, 20mm Dia.	1K0-2M2 Lagarithmic	£1.69 Each
PCB Mount, Splined Shaft, 16mm Dia.	470Ω-1M0 Linear	£0.42 Each
PCB Mount, Splined Shaft, 16mm Dia.	470Ω,4k7,100k,1M0 Log	£0.42 Each
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PATENT PENDING

Fortunately we do not have to apply for a patent each time we produce a new issue of *EPE* – our material is automatically protected by copyright on publication and therefore cannot be reproducd by others. Although we are occasionally ripped-off around the world we can take steps to prevent a recurrence and to get compensation from those responsible. However, if you invent a new widget or gizmo then you need to apply for a patent to prevent others copying your idea and selling similar items around the world.

The trouble is that patenting your invention takes time and can be expensive. In this issue our contributor, Stephen Arnott, tells you just what you can and cannot patent, how to apply and how much it will cost. The article also carries various useful addresses, etc., and has a couple of interesting case histories to show what can happen with patents. It's interesting reading and it could lead to a fortune in royalties if you have an inventive mind.

Mr. Dyson did it (twice!) although the first time he was let down (deflated? – read the article to get the pun) in the States. So now all you need to do is to think up a radical new design for a household appliance – a new mousetrap or steam iron – and the world is your oyster, or maybe your paying customer. But patent it before you spill the beans to anyone.

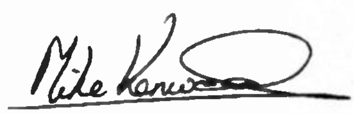
STEVE KNIGHT

It is with great sadness that we have to report the untimely death of a long-standing and highly respected contributor to *EPE*. Steve Knight died after a brief illness in January; he had produced many projects for us over the years and, with his wife's permission, we publish his last design for a PSU in this issue.

Always friendly and helpful, Steve corresponded regularly with a number of readers and, as one reader put it, "he had an outstanding talent for transmitting knowledge by the written word".

Steve's wife, Dulcie, tells us that he had been writing since his army days in the second world war when he was in charge of radio and radar workshops, and he helped write a camp newspaper. He published his first book, on radar, in 1947. His many years in industry, at Murphy Radio before the war, and later at Marconi's in Chelmsford, and BTH/AEI in Leicester, and his many years in teaching, both in this country and in Nigeria, gave him an instinctive feel for what people could understand.

He will be sadly missed and we extend our sympathy to his family and friends.



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COMPONENT SUPPLIES

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

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SIMPLE METAL DETECTOR

ROBERT PENFOLD

Track down those hidden pipes, cables and nails with this low-budget DIY "tracker".

METAL detectors take two general forms, which are either "treasure locator" style units for detecting items buried in the ground, or handheld units for detecting pipes, cables, and pieces of metal in walls. This very simple metal locator is of the second variety, and it should help the do-it-yourself enthusiast to avoid finding cables, etc in walls the hard way! The unit is very easy to use, and a moving coil meter provides a clear indication when metal is detected.

The use of a small detection coil gives the unit good sensitivity to small pieces of metal, and it will quite happily find something like a small screw or nail in a wooden door. The maximum range is about 40mm to 50mm on small items, but is not very much greater than this for very large pieces of metal.

The sensitivity to large objects could be increased by using a larger search coil, but this would make it more difficult to detect small items, and to determine their precise location. For this type of metal detector a small search coil probably represents the most practical choice, because the user is not usually interested in objects more than about 30mm or so into a wall.

SYSTEM OPERATION

Operation of the unit is very simple indeed, and the block diagram of Fig.1 helps to explain the way in which the unit functions. In common with most simple metal detectors, this unit is based on an *L-C* oscillator. Many metal detectors rely on the fact that placing metal near the inductor in the oscillator changes its value slightly, and affects the oscillator's output frequency.

Detecting a very small change in frequency tends to be rather difficult, and with most simple metal detectors it is necessary for the user to have a good sense of pitch. This unit uses a totally different method of detection which provides an unambiguous indication via a moving coil panel meter.

Q-FACTOR

Rather than detecting any change in the output frequency of the oscillator, it detects the affect on the *Q* of the tuned circuit. The tuned circuit is formed by an inductor and a capacitor connected in parallel with it.

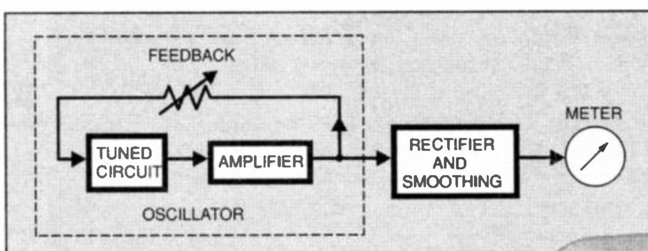


Fig.1. Simple Metal Detector block diagram. The tuned circuit is an L-C parallel type, with the inductor acting as the search coil.

The *Q* value of a tuned circuit is a measure of its efficiency, and placing a piece of metal near the inductor tends to have a dampening effect on the tuned circuit. In the normal course of events this reduction in *Q* value would be too small to be of any significance.

However, in this case the oscillator is adjusted so that it has only just sufficient feedback to sustain oscillation. Placing metal near the search coil therefore produces a reduction in the output level of the oscillator, or in an extreme case it will actually prevent the oscillator from operating at all.

The output of the oscillator is coupled to a rectifier and smoothing circuit which drives the moving coil meter. The d.c. output level from the smoothing circuit is roughly proportional to the output level from the oscillator. Placing metal near the search coil therefore produces a reduction in the reading from the meter, and will reduce the reading to zero if the metal is taken close enough to the coil.

CIRCUIT OPERATION

The full circuit diagram for the Simple Metal Locator is shown in Fig.2. In order to produce oscillation it is necessary to apply positive feedback over an amplifier.

The circuit will oscillate provided the losses through the feedback circuit are less than the gain of the amplifier. In this case the amplifier circuit is a simple non-inverting type based on operational amplifier IC1. Resistors R1 and R2 bias the input of the amplifier and set the input impedance at 50k (kilohms). The voltage gain of the circuit is determined by negative feedback resistors R3 and R4, and these set the gain at just over 3·5 times.

The positive feedback is obtained via a fairly complex looking potential divider circuit, but it is basically quite simple. The feedback path is by way of a variable attenuator based on potentiometers VR1 and VR2, series resistor R7, and the tuned circuit.

In order to obtain good sensitivity from the unit it is essential that the amount of feedback used is barely sufficient to sustain oscillation. The feedback level must therefore be set with a high degree of precision.

Potentiometer VR1 acts as the Coarse feedback level control, and VR2 (which gives only a very limited adjustment range) provides Fine adjustment of the feedback level. VR2 and R8 are connected in parallel with resistor R6, and effectively enable its value to be varied from 1k8 to 2k2. This very limited control range make it reasonably easy to set a suitable feedback level.

TUNED CIRCUIT

The output from the attenuator is coupled to the tuned circuit via resistor R7. The tuned circuit uses inductor coil L1 and capacitor C6 in a standard parallel resonant circuit.

A circuit of this type has a high impedance at and close to its resonant frequency, but a low impedance at other frequencies. This results in high losses through R7 at frequencies other than those near to the resonant frequency. Therefore, the circuit oscillates at the resonant frequency of the tuned circuit as it is at this frequency that maximum feedback occurs.

In theory a tuned circuit has infinite impedance at its resonant frequency, but real-world inductors and capacitors are not perfect, and the impedance at resonance is high rather than infinite. Any metal close to L1 reduces the efficiency of the tuned circuit, giving reduced impedance at resonance. This results in higher losses through R7, and a reduction in the output level from the oscillator.

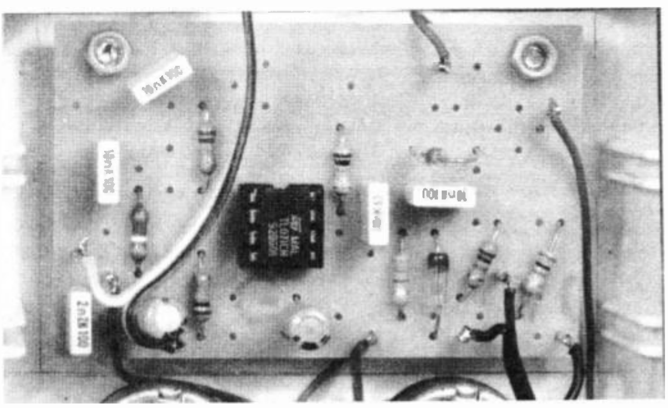
OUTPUT CIRCUIT

The output signal from the oscillator is coupled by capacitor C5 and resistor R9 to a simple rectifier and smoothing circuit based on diodes D1 and D2. Germanium diodes are used in the rectifier circuit as they have lower forward voltage drops than silicon types, giving slightly better results in this application.

The positive d.c. output signal from the rectifier circuit is roughly proportional to the amplitude of the a.c. output signal from IC1. This voltage is registered on a simple voltmeter formed by resistor R10 and meter ME1.

Obviously, in this application the actual output voltage is of no importance, and it is the relative readings that we are interested in. Feedback controls VR1 and VR2 are adjusted to give a reading of about half full scale on ME1, and any reduction in the reading then indicates that there is some metal close to the search coil.

Power is obtained from a PP3 size battery, and as the current consumption of the circuit is only about two milliamps a very long battery life is obtained. The operating frequency of the circuit is about 50 kilohertz, which is well within the *permitted* band of operating frequencies for metal locators. The signal radiated by the unit is extremely weak, and is again well within the permitted limits.



Components mounted on the "multi-project" printed circuit board.

COMPONENTS

Resistors

R1,R2	100k (2 off)	
R3,R8,R10	10k (3 off)	
R4	3k9	
R5	1k	
R6	2k2	
R7	22k	
R9	3k3	

All 0.25W 5% carbon film

See SHOP TALK Page

Potentiometers

VR1	1k rotary carbon, lin
VR2	100k rotary carbon, lin

Capacitors

C1	10µ radial elect. 25V
C2,C4	10n polyester, 5mm lead spacing (2 off)
C3	0·47µ radial elect. 50V
C5, C7	100n polyester, 5mm lead spacing (2 off)
C6	3n3 polyester, 5mm lead spacing

Semiconductors

D1,D2	OA91 germanium signal diode (2 off)
IC1	TL071CP bifet op.amp

Miscellaneous

ME1	200µA moving coil panel meter (see text)
S1	s.p.s.t. min toggle switch
B1	9V battery (PP3 size)
L1	2·2mH radial inductor (see text)

Printed circuit board (multi-project) available from *EPE PCB Service*, code 932; small plastic case, size approx. 150mm × 100mm × 60mm; battery connector; control knob (2 off); multistrand connecting wire; single-sided solder pins; solder etc.

Approx Cost Guidance Only £17 excluding batt.

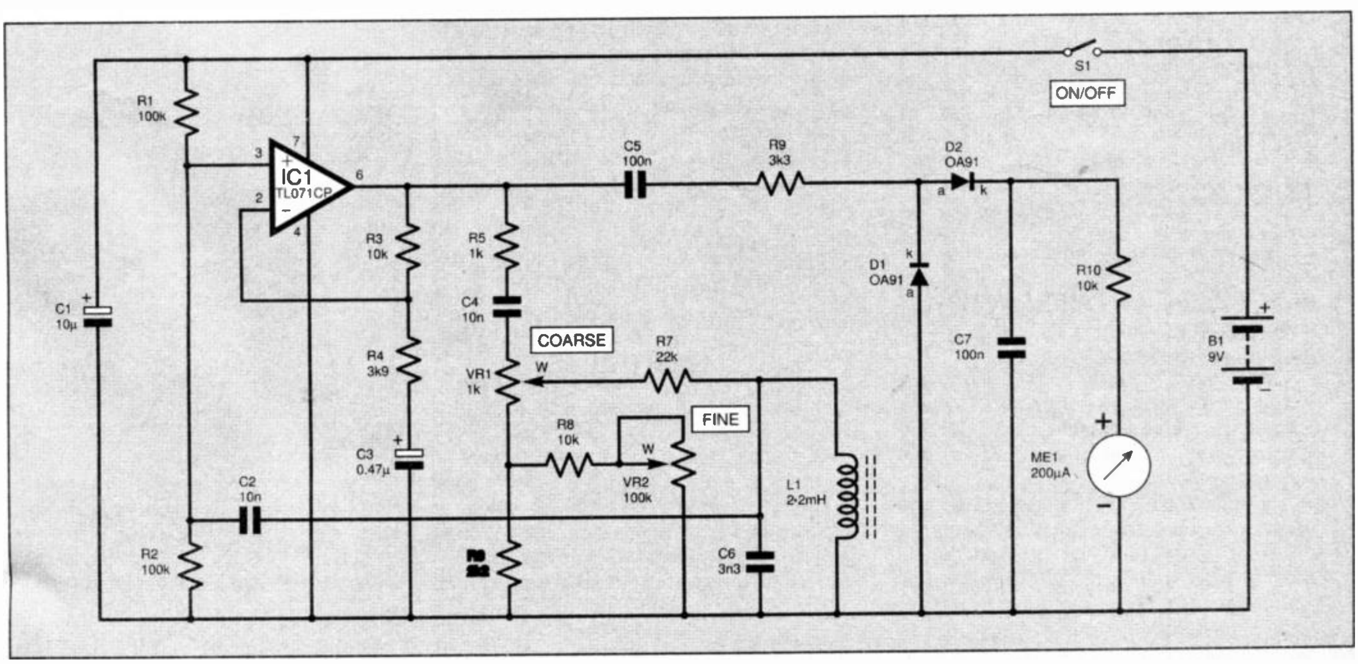


Fig.2. Complete circuit diagram for the Simple Metal Detector.

CONSTRUCTION

This project is constructed on the *EPE* Multi-project printed circuit board (p.c.b.), but it has to be admitted that this circuit is slightly too large to fit onto this board comfortably. Consequently, three of the resistors are mounted directly on the feedback control potentiometers. The circuit then fits on to the p.c.b. reasonably neatly, but the usual warning about this circuit board has to be repeated here.

Some of the holes in the board are left unused, making it relatively easy to fit one of the components in the wrong place. It is therefore necessary to exercise slightly more care when constructing this board as it is not quite as straightforward as using a normal custom printed circuit board.

Details of the component layout together with the actual size foil pattern and hard wiring are provided in Fig.3. Integrated circuit IC1 is not a static-sensitive device, but it is still advisable to fit it in a holder.

TAKE CARE

The germanium diodes used for D1 and D2 are more vulnerable to heat from the soldering iron than the more familiar silicon types. It should not be necessary to use a heat-shunt when fitting these two components, but the soldered joints must be completed reasonably quickly.

Bear in mind that these diodes have a glass encapsulation, and that they are therefore physically quite weak. They must be handled with due care.

There is little space available on the board for the non-electrolytic capacitors, and it will be difficult to construct the board using anything other than printed circuit mounting types having 5mm lead spacing.

Fit single-sided solder pins at the points where connections will be made to the controls, battery, etc. "Tin" the tops of the pins with plenty of solder, and it should then be easy to make reliable connections to them. If the solder is reluctant to flow on to the pins properly, clean the pins by scraping them with the small blade of a penknife.

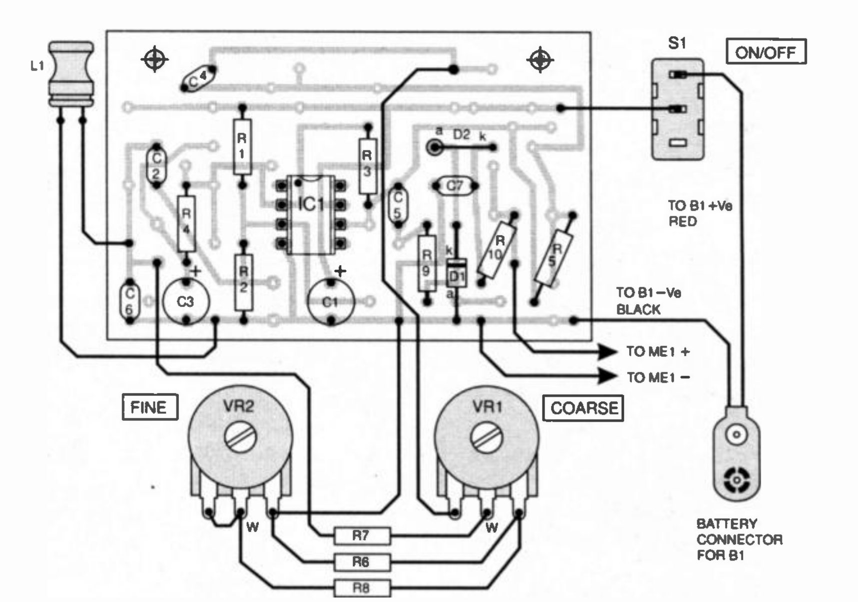
A medium size plastic case, about 125mm to 150mm long, should comfortably accommodate the parts for this project. From the electrical point of view the layout of the unit is not critical, but it is obviously necessary to produce a sensible layout if the finished unit is to be easy to use.

INDUCTOR

Only a radial inductor is suitable for L1 (i.e. one having both leadout wires emanating from the same end). The unit has only been tested using an RS low current inductor and a Toko 8RB type (see *Shoptalk* for buying details).

Performance seems to be much the same whichever of these two inductors is used. Although the circuit should work with any similar inductors of the right value, this cannot be guaranteed.

The inductor L1 is mounted at one end of the case, and this effectively becomes the front of the unit (i.e. the end that is used to scan walls, etc.). Both the specified components are a tight push-fit into an 8mm diameter hole, but it is a good idea to use a small amount of adhesive to ensure that L1 is securely fixed in the case.



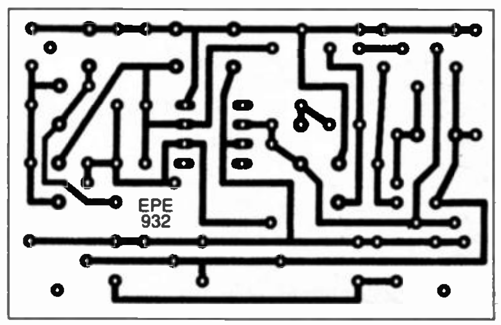


Fig.3. Simple Metal Detector printed circuit board component layout, interwiring and full size copper foil master pattern.

*Check that each component is positioned correctly **before** soldering in position as not all copper pads are used.*

The printed circuit board is mounted under the top panel of the case, close to L1, using metric M3 bolts plus short spacers to prevent the connections on the underside of the board from being crushed against the case.

METER

Meter ME1 is mounted on the top panel of the case, and it is advisable to position it well towards the rear of the unit where it will be clearly visible in use (see photographs). This leaves plenty of space for the two potentiometers and the on/off switch in the middle section of the case.

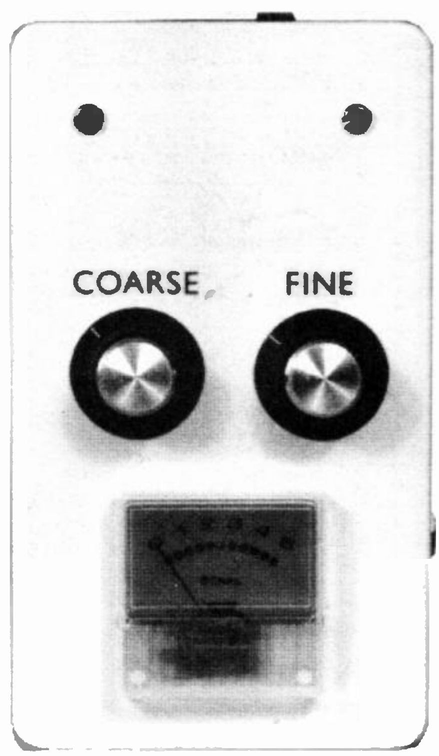
The meter can be a "proper" type if preferred, but a "tuning meter" is much cheaper and is perfectly adequate for this application. A Maplin "tuning meter" is used on the prototype metal detector, but any meter having a full scale sensitivity of about 200µA to 250µA should work just as well.

If you prefer to use a "proper" panel meter it will be necessary to use a type having a full scale sensitivity of 100µA, and the value of resistor R10 will then have to be increased to 18 kilohoms.

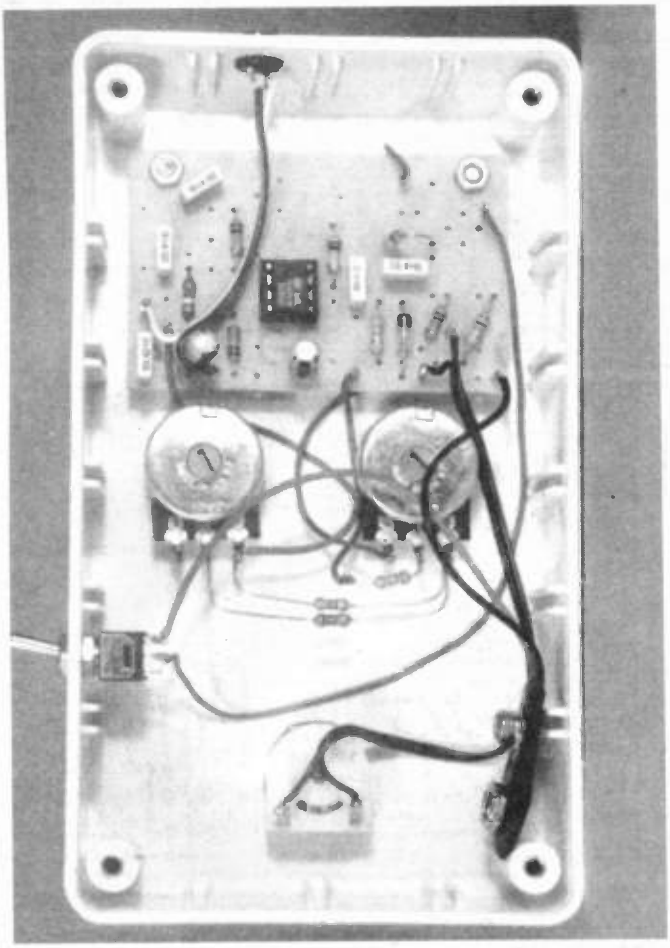
A tuning type meter requires a sort of rectangular cut-out, with two well rounded corners. Probably the easiest way of making this is to first punch a round hole about 15mm to 16mm in diameter and then file it out to precisely the correct size and shape using a miniature flat file. The meter does not have provision for fixing screws, but it can be glued in place using any good quality general purpose adhesive.

WIRING-UP

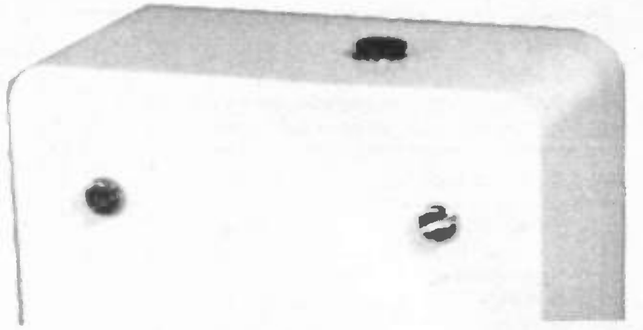
The hard wiring is straightforward apart from mounting the three resistors on controls VR1 and VR2. Start by forming the resistor leadout wires into the correct



The "tuning meter" glued in position on the prototype model.



Layout of components inside the completed Detector. Note the three resistors soldered to the controls.



The inductor "search coil" just protrudes through a push-fit 8mm hole in the top of the plastic case.

shape and cutting them to length. The ends of the leadout wires are then "tinned" with solder, as are the tags of VR1 and VR2.

It should now be quite easy to solder the resistors in place, but it might make things even more simple if some Bostik *Blu-Tack* or Plasticine is used to hold the resistors in position while they are soldered to the tags of the potentiometers. Resistor R7 is only held in place by one leadout wire, but this should be adequate provided its leadout wires are cut quite short.

TESTING, TESTING

After a final check of both the p.c.b. and wiring, set both potentiometers at a roughly middle setting and switch on. With VR1 set well in a clockwise direction the meter should register a fairly high reading. Backing off VR1 in a counter-clockwise direction should result in the reading on the meter falling back to zero.

With VR1 set at this switch-over point, carefully adjust VR2 to produce a meter reading of about half full scale or slightly less. Placing the inductor L1 close to a piece of metal should now produce a reduction in the meter reading.

The Fine control VR2 will almost certainly need periodic readjustment in order to maintain good performance. With slightly too little feedback the circuit will fail to oscillate, and with slightly too much feedback it will exhibit very poor sensitivity. □

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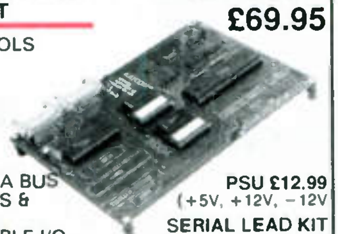

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Mini-Lab & Micro Lab
Electronics Teach-In 7

As featured in *EPE* and now published as Teach-In 7. All parts are supplied by Magenta. *Teach-In 7* is £3.95 from us or *EPE*
Full Mini Lab Kit – £119.95 – Power supply extra – £22.55
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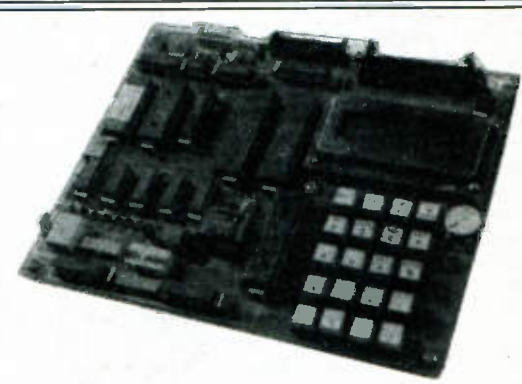

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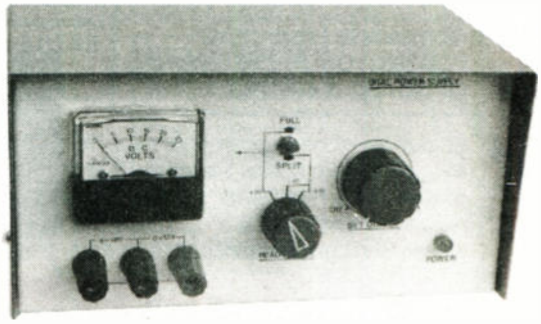


STEVE KNIGHT

A combination power unit that will prove invaluable in the workshop.

THIS easy to build power supply unit will provide a single regulated output of 2V to 20V at 250mA or it can also be switched to provide a dual supply, suitable for most i.c. experimentation and testing, of 1V to 10V on either side of earth. This dual supply automatically tracks each side to the other, so that both positive and negative output rails keep in step throughout the range variation.

To do this a kind of "artificial" earth line is required to divide the normally single output into the split supply; this supply then has both positive and negative terminals relative to this earth. First of all it is necessary to set up a basic regulator.

BASIC REGULATION

The circuit diagram for the Single/Dual-Tracking Power Supply is shown in Fig.2. Regulation is carried out quite conventionally and uses the 723 regulator chip after the bridge rectifier REC1 and reservoir capacitor C1.

The 723 regulator is a basic circuit having an internal component arrangement as depicted in Fig.1. This is a familiar example, in integrated form, of a standard regulator system which appeared in discrete transistor form in many power supplies over a number of years, and in many cases still does so. So although it has been around for some while, the 723 is still a useful and convenient way of getting virtually the whole of a stabilised supply under one roof as it were.

An internal Zener reference source (D1), an error amplifier (IC1), a 150mA series pass transistor (TR_a) and current limiting are all provided for in this 14-pin d.i.l. package. The reference voltage, which is derived from a constant current source, is brought out at pin 6. By connecting this pin to pin 5, either directly or by a voltage divider arrangement of resistors, the required reference level is applied to the non-inverting (+) input of the error amplifier.

The inverting (–) input of this amplifier is brought out at pin 4. This point is normally controlled by a voltage derived from an external potentiometer connected across the output (pin 10) of the package.

Any difference between the inputs will be detected by the error amplifier and its output will correspondingly control the series pass transistor TR_a. This transistor may be used directly in the positive supply rail from the reservoir capacitor as the output control or, because of the current limitation of the 723, additional external pass elements may be employed (as they are in this design) when a larger current than the basic 150mA is required.

As a current of 250mA is the target here, the pass transistor of the 723 is not used directly, therefore, because the power rating of this component is derated with a rise in temperature. The output current capability of the device is consequently boosted by using TR_a as a driver to an external Darlington regulator transistor (TR1 in the main circuit).

CURRENT LIMITING

A second internal transistor, TR_b (see Fig.1 again) and an external resistor, R4, provide current limiting. Output current from the 723 flows through R4 and the voltage developed across this is applied between base (pin 2) and emitter (pin 3) of TR_b. When this voltage exceeds about 0·65V, TR_b is switched on and control is removed from TR_a.

Taking a maximum current of 250mA, therefore, $R4 = 0{\cdot}65V/0{\cdot}25A = 2{\cdot}6$ ohms, and a 2·7 ohms preferred value resistor will serve here. If 250mA is exceeded or an output short-circuit develops (accidentally or otherwise!), the output voltage will drop to near zero until the excess or fault condition is corrected.

TRACKING REQUIREMENTS

With the circuit so far described, and switch S2 set to Full function mode, it will produce an output voltage range covering 2V to 20V (after setting up). This section of the circuit can be used on its own as a relatively simple stabilised supply.

However, the usefulness of the unit can be considerably enhanced if a system can be added which will divide this output into two separate supplies effectually connected in series. The centre point of these dual outputs appears as a zero or earthed point, and the voltages developed on either side of this earth line keep in step (or track) as a positive or negative output.

When switch S2 is changed over to the Split position, an additional output circuit system is introduced which sets up an artificial zero line between the positive and negative terminals of the single supply,

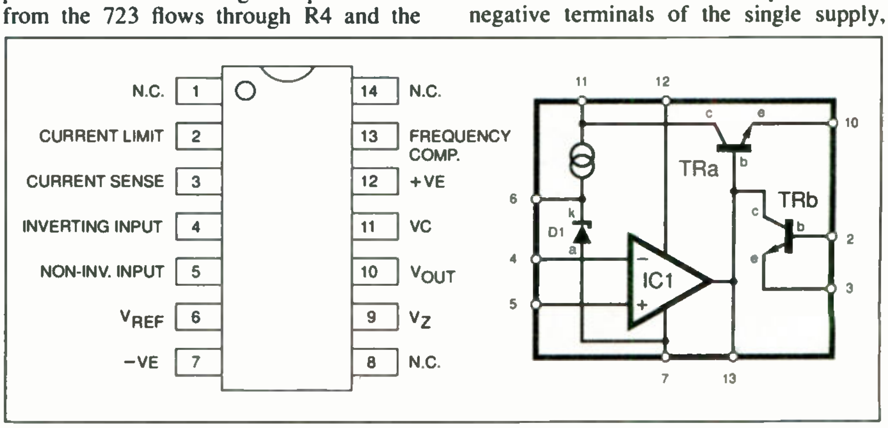


Fig.1. Pinout details and internal circuit for the 723 regulator.

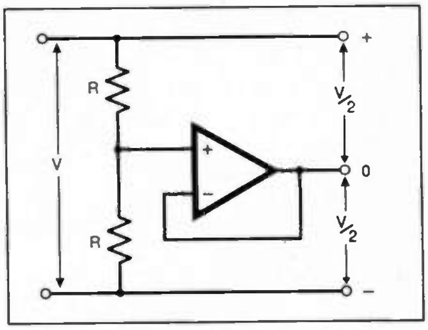


Fig.3. The basic voltage divider.

and so creates a split supply operating on either side of this line. The principle is based roughly on the circuit of Fig.3 which uses an op.amp as a voltage splitter device. When the non-inverting input is held at the mid voltage of the supply by equal resistor values, then the output is also held about a reference point which represents the zero line centred between the normal positive and negative output terminals.

Although the double-pole double-throw (d.p.d.t.) switching, via S2, at first appears to be a bit "weirdo", the idea is to cut off the tracking part of the circuit when the single 20V supply is being used. It is still necessary to retain the +V line, however, when the dual stage is switched in, hence the curious switching arrangement.

The dual part could be left in circuit, of course, when the full 20V was in use, but this way saves the additional drain. The Full and Split modes then operate separately.

The Supply can be built with or without an output voltage meter. If a meter is required this is wired as shown in Fig.4 – more details are given regarding this arrangement later in the text.

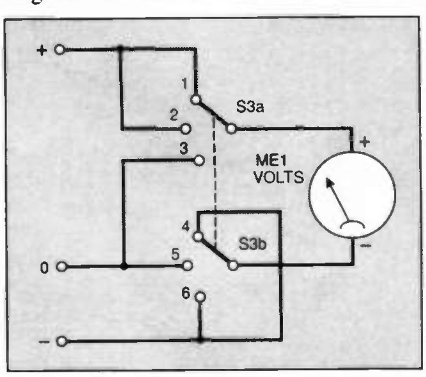


Fig.4. Switching at the output if a voltmeter is used.

OUTPUT BOOSTING

We now want some additional transistors to do the job of boosting the output of the op.amp IC2 and provide a low impedance output for both of the tracking lines. From Fig.2, by adjustment of preset VR3, the voltage on pin 3 of IC2 can be set to exactly one half of the supply rail voltage, although, if you wish, you can replace R7 and VR3 with a 22 kilohm one per cent resistor to match up with R6.

The output of op.amp IC2 is fed to the input bases of transistors TR2 and TR3. The transistor pair TR2 and TR4 are connected as a Darlington emitter follower, while the transistor pair TR3 and TR5 form another complementary pair having unit gain as have the Darlington pair. Notice that TR3 is a *pnp* transistor.

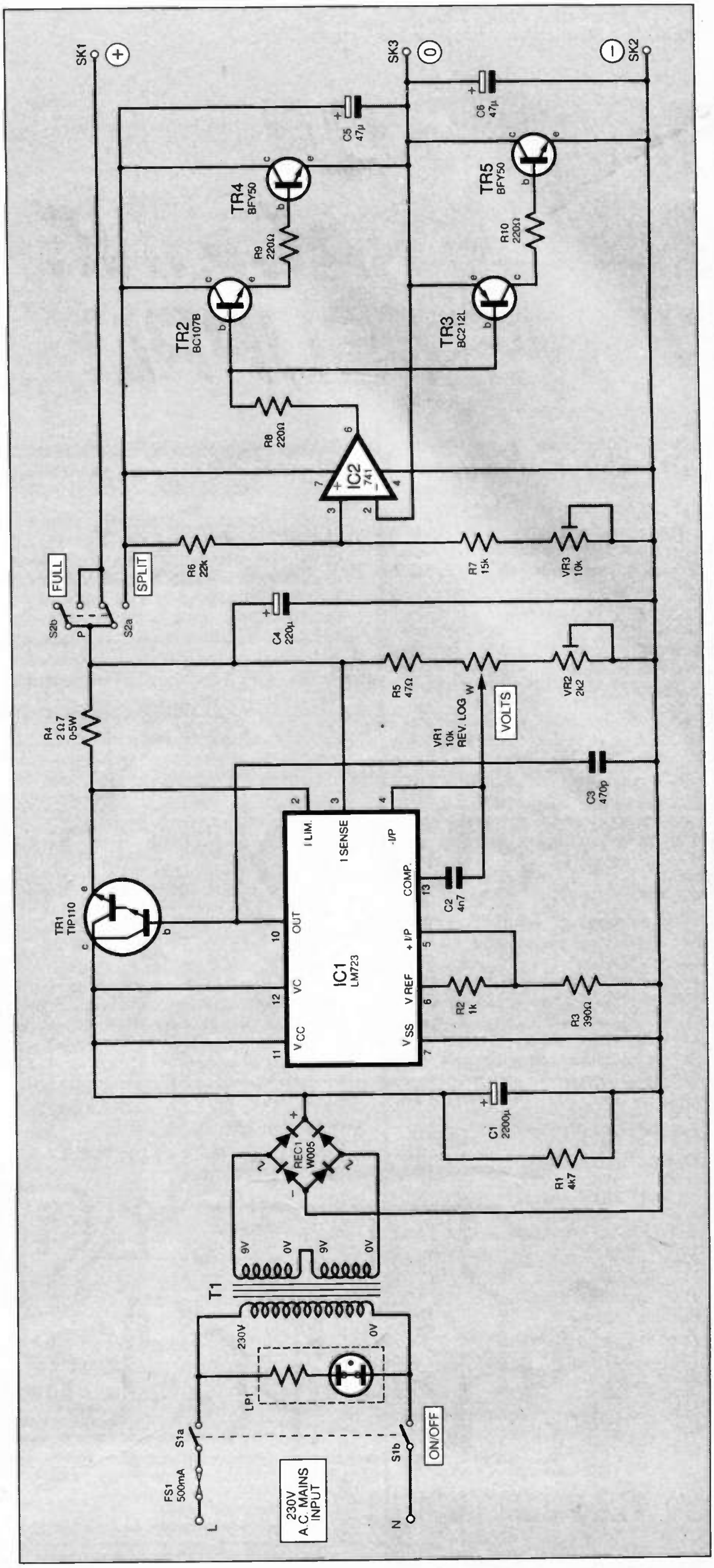
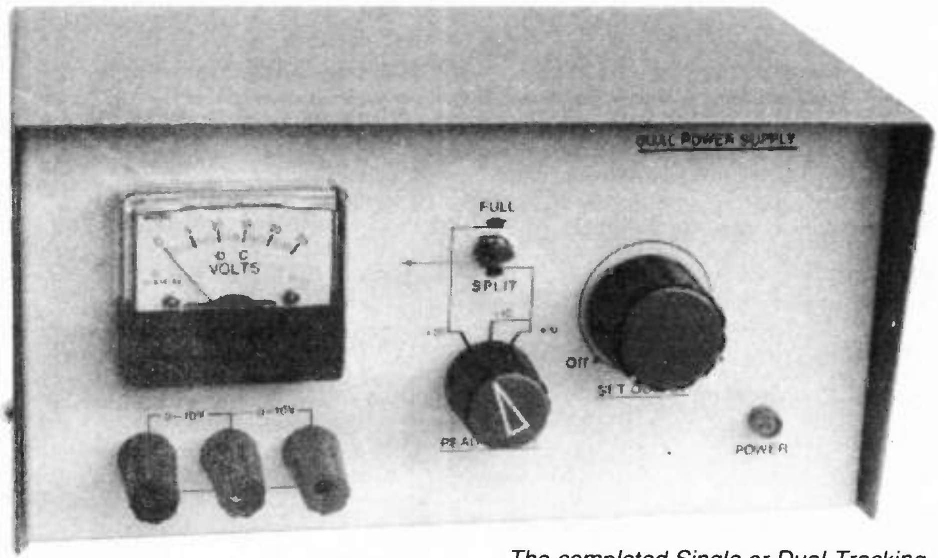


Fig.2. Circuit diagram for the Single or Dual-Tracking Power Supply.



The completed Single or Dual-Tracking Power Supply, incorporating the output voltage meter.

The common outputs of the transistor pairs are fed back to the inverting input of IC2, so making the i.c. and the transistors as a composite voltage follower whose output will be the same as that on the non-inverting input. The common line of the two transistor pairs then represents a zero output pin centred between the positive and negative rails.

CONSTRUCTION

All components, with the exception of the mains transformer T1, function switch S2, the voltage control VR1, mains neon, output sockets, and the optional voltmeter, are assembled on a single, uncomplicated printed circuit board (p.c.b.). This board is available from the *EPE PCB Service*, code 187.

The component layout and the full-size copper foil master pattern are given in Fig.5. The interwiring details to the off-board components are shown in Fig.6.

No problems are likely to arise in the assembly of the board, but the following points should be observed. The 2·7 ohm ½W current limiting resistor R4 should not be mounted hard against the p.c.b. surface, but spaced above it by about 3mm.

The Darlington pass transistor TR1 is attached to a small finned heatsink which is designed to fit into the board at the positions indicated by X-X and then soldered to the isolated board pads at these points. Drill the holes for the heatsink to 2·8mm (7/64in.) to make a snug fit.

No insulation is necessary between TR1 and the heatsink, but it *must* remain out of contact with any other parts of the board copper foil or components. Small "crinkle" type heatsinks are also fitted to transistors TR4 and TR5 and, although not strictly required, it is comfortable to have a "belt" as well as "braces" here.

There are two fixing holes on the board, one at each end, marked Y-Y. Drill these out 3mm (1/8in.) or to suit the size of fixing screws you will be using.

METER MONITORING

It is possible to calibrate the front panel control knob of VR1 to indicate the output voltage, taking half of the indicated value

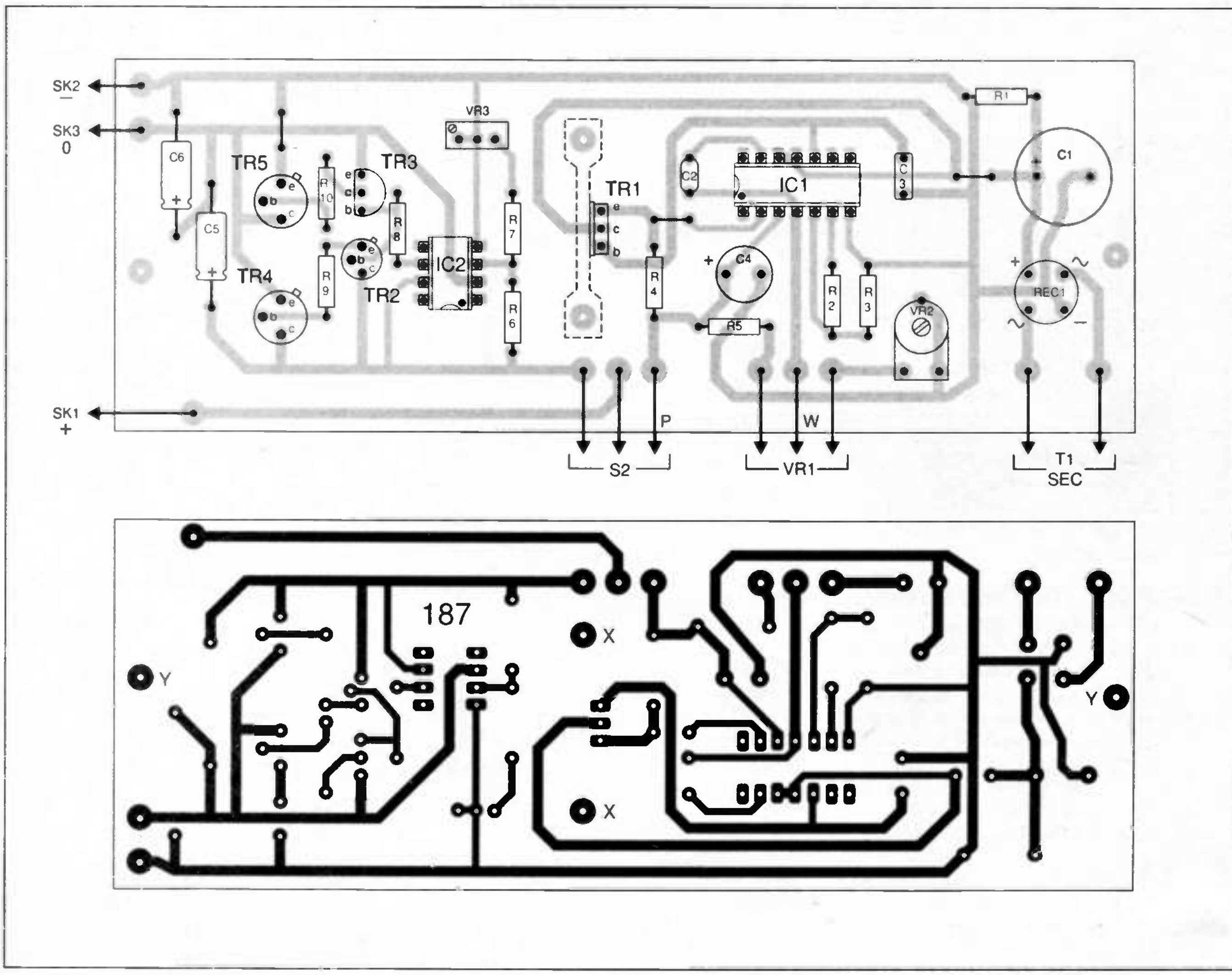
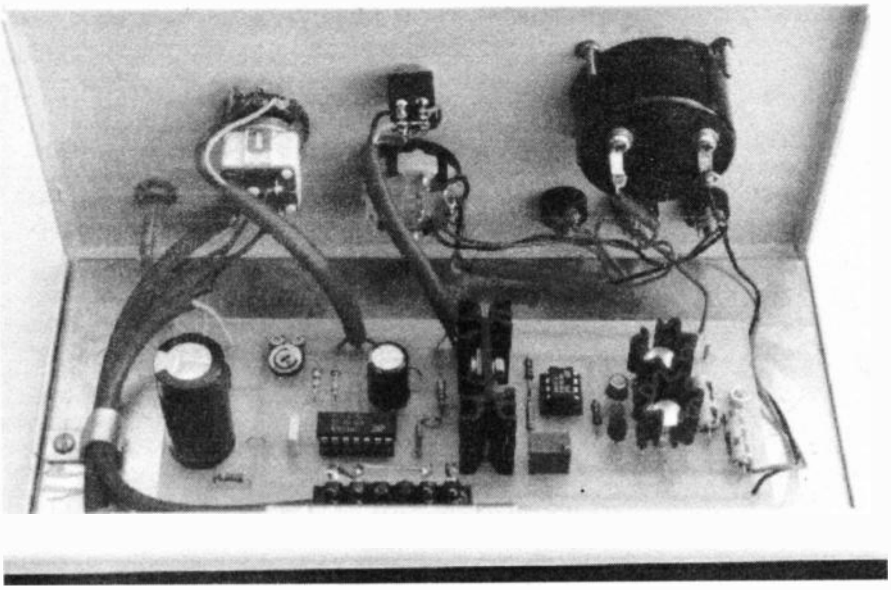


Fig.5. Printed circuit board component layout and full size underside copper master pattern. The dashed outline on the top view represents the finned heatsink for the voltage regulator.



Wiring to the front panel mounted components.

when using the dual outputs. It is better, however, to employ a small moving-coil meter, calibrated 0V to 20V (or with a range capable of covering up to 20V), in conjunction with a switch so that both the Single and Dual outputs can be checked directly.

A 0V to 25V panel meter is available from a number of suppliers and this will do very well. The alternative is to use, say, a 1mA movement and, with the scale suitably readjusted, fitted with an appropriate multiplying resistor in series with it.

In the model, this optional meter readout is operated through a 4-pole 3-way miniature rotary switch (although only two poles are used) and the circuit is shown in Fig.4. The three switch positions then give us: (1) Single 20V output; (2) Positive dual output; and (3) Negative dual output respectively. Both switch and meter are separate from the circuit board.

BOXING UP

The metal case used for the prototype was a Newrad two-piece, measuring 200mm × 150mm × 100mm. This box is actually a bit on the large size, but the next size down is just too small for comfort.

Any type of metal case with about these dimensions will do, but it is best, from an assembly point of view, to have a type with a separate base section and cover so that the components that are external to the p.c.b. do not have to be wired across to some other section of the box, entailing long connecting leads and the resultant difficulty in bunching these back into the case when the lid is replaced.

With the suggested box there is adequate room for everything and the actual

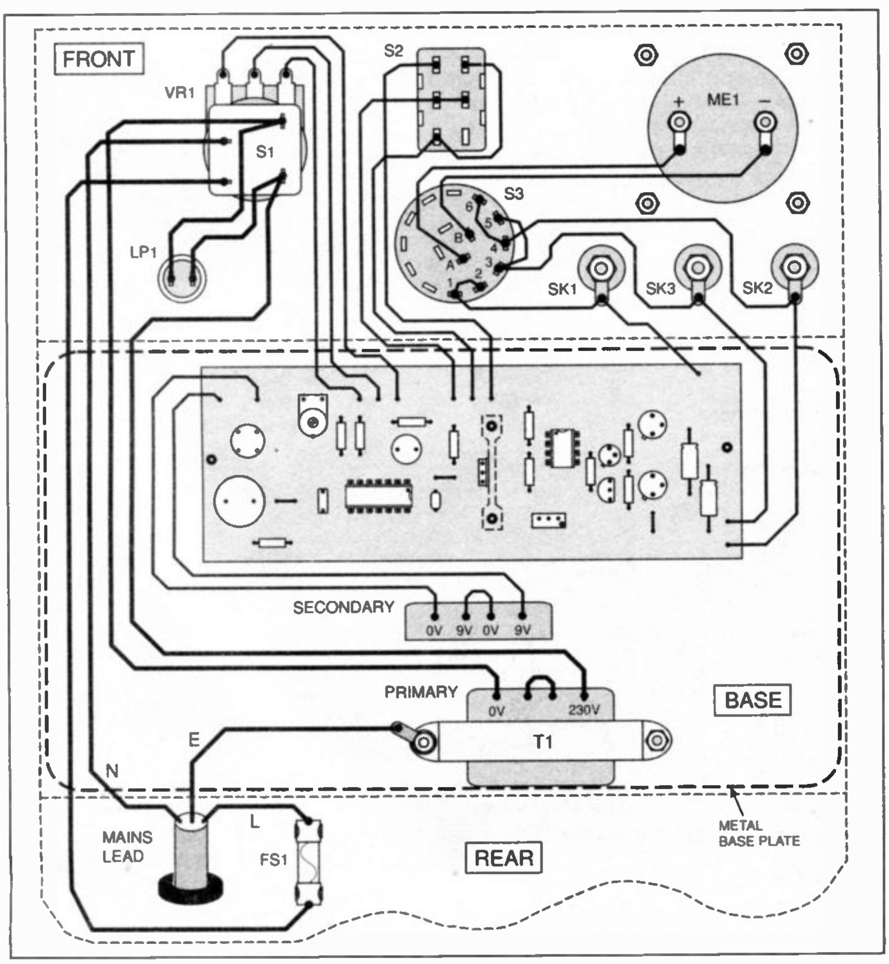


Fig.6. Interwiring details to off-board components, including the optional meter.

COMPONENTS

Resistor

R1	4k7
R2	1k
R3	390Ω
R4	2Ω7 0·5W
R5	47Ω
R6	22k
R7	15k
R8, R9, R10	220Ω (3 off)

All 0·25W 5% or better metal film, except where stated

See SHOP TALK Page

Potentiometers

VR1/S1	10k rotary carbon, *reverse log*, with d.p. mains rated switch (see text)
VR2	2k2 min. preset, horizontal
VR3	10k multiturn preset, top adjust

Capacitors

C1	2200μ radial elect. low impedance 35V
C2	4n7 polyester
C3	470p polyester
C4	220μ radial elect. 25V
C5, C6	47μ axial elect. 25V (2 off)

Semiconductors

REC1	W005 50V 1A bridge rectifier
TR1	TIP110 Darlington *npn* transistor
TR2	BC107B *npn* transistor
TR3	BC212L *pnp* transistor
TR4, TR5	BFY50 *npn* medium power transistor (2 off)
IC1	LM723 100mA adjustable regulator
IC2	741CN op.amp

Miscellaneous

S1	mains d.p.d.t. toggle switch (unless fitted to VR1)
S2	double-pole changeover toggle switch
S3	miniature 4-pole 3-way rotary switch
SK1-SK3	4mm screw terminal block, red, yellow and black
T1	6VA mains transformer, 0V-9V, 0V-9V sec. (clamp mounting)
LP1	230V mains neon indicator
ME1	0V to 25V moving coil meter (see text)

Printed circuit board available from *EPE PCB Service*, code 187; metal case, 200mm × 150mm × 100mm (Newrad or similar); heatsinks, finned for TR1, TO5 crinkle type for TR4 and TR5 (2 off); 500mA cartridge fuse, with mains fuseholder; connecting wire; solder, etc.

Approx Cost Guidance Only £25 excluding meter

layout of the parts is not particularly important. An internal view of the prototype layout and the front panel assembly and markings are shown in the photographs. The panel positions are not critical and can be modified to suit your own requirements if necessary.

It is *essential* that the case is correctly earthed, as shown in Fig.6.

TESTING PROCEDURES

The necessary checks on the operation of this unit can be made with the assembly boxed up as described in the previous section, but if you prefer to try things out before finalising this can be done with the bare assembly set out on the bench. If you prefer this you will require the leads to the potentiometer VR1 and switch S2 to be connected to the appropriate pads on the board.

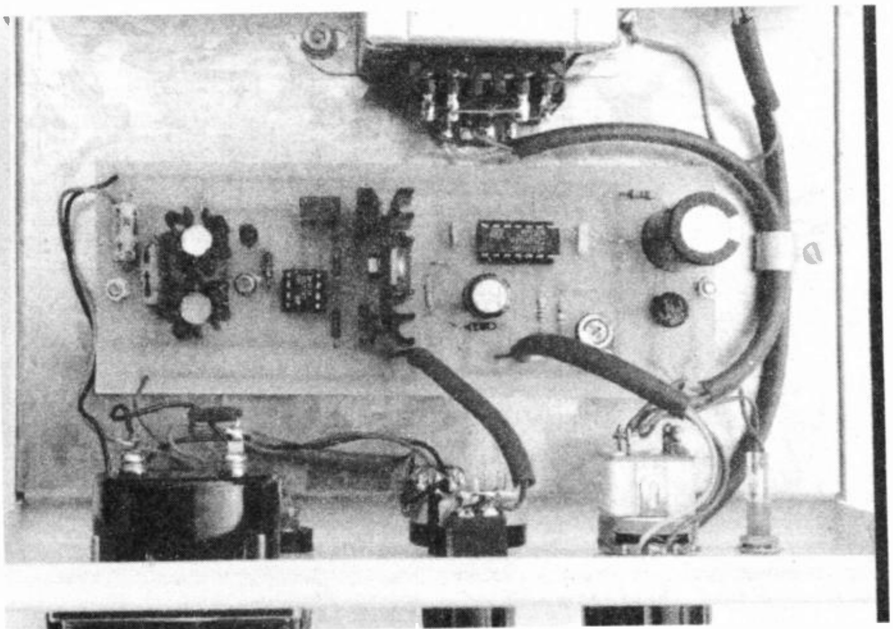
Make sure that all the mains input wiring is totally insulated if you are working on the bench in this way; feed the (safe) secondary transformer winding through fairly long leads to the input copper pads on the board, taking great care that you can't accidentally touch the primary winding contacts.

Set preset VR2 fully anticlockwise and VR3 to about mid travel. This last component is a multiturn pot. and if you have an ohmmeter handy, set it to about 7 kilohm before you begin.

With the unit now switched on, and with switch S2 in the Full position, connect a voltmeter to the +V output (SK1) and the negative rail (SK2). With the Output control VR1 fully clockwise adjust VR2 until the output reading is 20V. Now take VR1 fully anticlockwise and check that the output falls to about 2V.

You may have to go over this drill once or twice to allow for component tolerances, but it does not particularly matter, with the lowest output at 2V, that the higher output goes a bit above 20V. What you want is a swing of at least 2V to 20V over the range of VR1 and small variations from these limits at either end can be tolerated.

If there is any problem about this procedure, resistor R5 may need a small adjustment one way or the other, perhaps down to zero if the 2V end is elusive. Preset VR2 will take care of the 20V end by a slight readjustment in this case.



The completed circuit board bolted in position, using spacers, on the base of the case and wiring to the mains transformer. Note the mains on/off switch attached to the potentiometer on the right.

DUAL VOLTAGE TRACKING

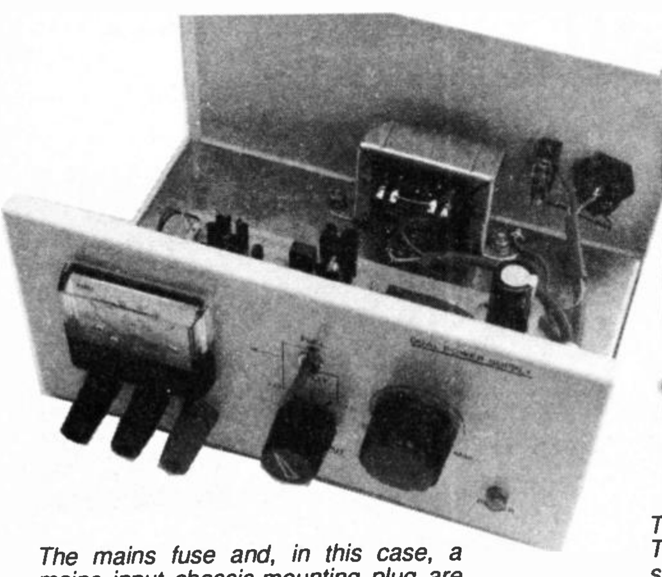
Having set up the single 2V to 20V range, the dual tracking outputs can now be set up. Remember that each of these will track from about 1V to 10V and stay in step with each other.

Set Output control VR1 to give about 10V output and change switch S2 over to the Split position. This energises the splitting part of the circuit (IC2, TR2 to TR5). If you have two voltmeters, you can connect these to SK1 and SK3 pads to read off the *positive* part of the split output and to SK3 and SK2 pads to read off the *negative* part of the split output. With one voltmeter you must take the readings separately.

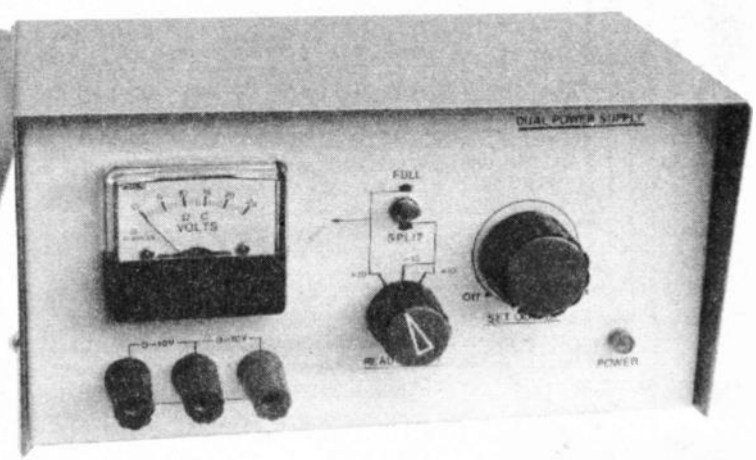
Now preset potentiometer VR3 sets the negative side of the output, since it adjusts the voltage on the inverting pin of IC2. If you are using two voltmeters, adjust VR3 until both positive and negative readings are identical; this will be *one-half* of whatever output VR1 has been set to provide as a FULL output. Over the full travel of VR1 you should now get a range of 1V to 10V over both tracking outputs.

If you have only one voltmeter, set VR1 to give you any convenient voltage at the positive half of the split output; then transfer the meter to the negative half and set VR3 to give you the same reading. Recheck these settings if necessary.

There remains one last note: it may not be possible to obtain a *reverse-log* pot for VR1 with an incorporated double-pole mains switch. In this case use a separate miniature "toggle" type, double-pole changeover as the mains switch, rated at 230V a.c., of course. This can be easily positioned an inch or so above the neon indicator on the front panel. □

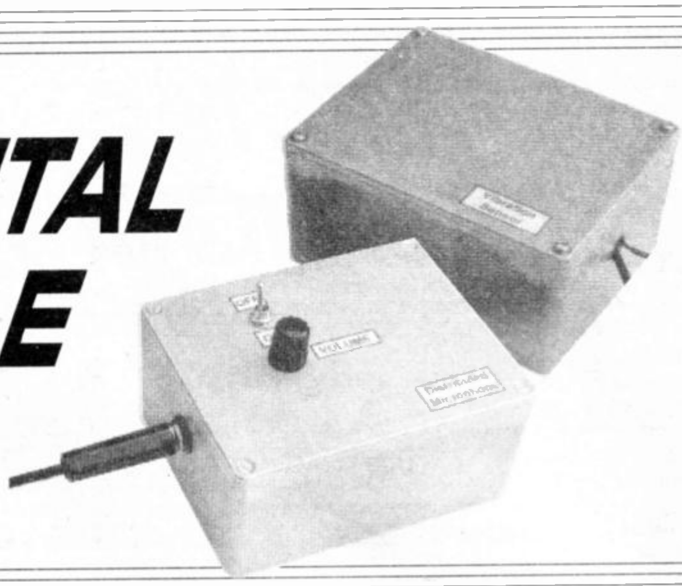


The mains fuse and, in this case, a mains input chassis-mounting plug are mounted on the rear panel.



The finished unit showing the front panel components and legends. The 2V to 20V output is taken from across the two outer sockets. If a separate mains on/off switch is used it can be mounted on the front panel just above the neon indicator.

EXPERIMENTAL PIEZO-CABLE PROJECTS



PETER SOMERVILLE

A practical introduction to the "magical" properties of piezoelectric sensor cables. Plus, two everyday projects for the experimenter who wants to try something different.

PIEZOELECTRIC materials have the property of converting mechanical energy into electrical energy and vice versa. Such materials are used in the manufacture of a wide range of products, for example:

- Gas Igniters
- Electromechanical actuators and micropositioning devices
- Microphones and hydrophones
- Accelerometers
- Miniature loudspeakers and tweeters
- Microprocessor clock crystals

The main types of piezoelectric material in everyday use are:

- Crystalline quartz
- Various ceramics, such as lead titanate zirconate (PZT)
- Certain thermoplastics, such as polyvinylidene fluoride (PVDF)

Thermoplastic PVDF is of particular interest, as it can readily be formed into sheets, thin films or cable. One of the most successful applications for piezoelectric PVDF is in acoustic sensor cables, which effectively act as extended microphones or dynamic pressure transducers. Such sensor cables find many uses in perimeter security systems, either attached to fences or walls or buried in the ground.

PIEZOELECTRIC SENSOR CABLES

A piezoelectric sensor cable attached to a fence or wall allows the entire structure to act as a "microphone", picking up the sounds generated by an intruder as they attempt to gain access. When buried in the ground, the cable picks up the low frequency pressure variations caused by someone walking on the ground over or near the cable.

When connected to suitable circuitry, the microphonic signals can be analysed automatically and the decision taken as to whether the noise was caused by an intruder or was merely a product of the environment. Although there are several types of sensor cable available for use with perimeter security systems, the piezoelectric product is widely acknowledged to be one of the most effective.

Piezoelectric cable is also quite widely used as a traffic sensor, by encapsulating it in a synthetic rubber strip which is then mounted in a channel cut into the carriageway at right angles to the direction of traffic flow. Each time the axle of a vehicle passes over the cable an electrical signal is generated. Depending on the circuitry used, these signals can then be analysed to provide information on the number and type of vehicles, and even to determine the speed of the traffic.

VIBETEK

The *Vibetek™ range of piezoelectric sensor cables uses PVDF as the piezoelectric element. Vibetek cable is configured as a lightweight, small diameter (3·5mm) coaxial cable, with a tough weather and solvent resistant outer jacket. The cable effectively behaves as an extended microphone, which can be hundreds of metres long, and converts sound, vibration, impact, pressure, stress or strain into an electrical signal which is linearly proportional to the strain induced.

The cable is available in a range of sensitivities, namely:

Vibetek 3 – (Low sensitivity)
Vibetek 5 – (Low/Medium sensitivity, no triboelectric noise)
Vibetek 13 – (High sensitivity, no triboelectric noise).

Note: Triboelectric noise is noise generated by static due to movement of the copper braid in the cable.

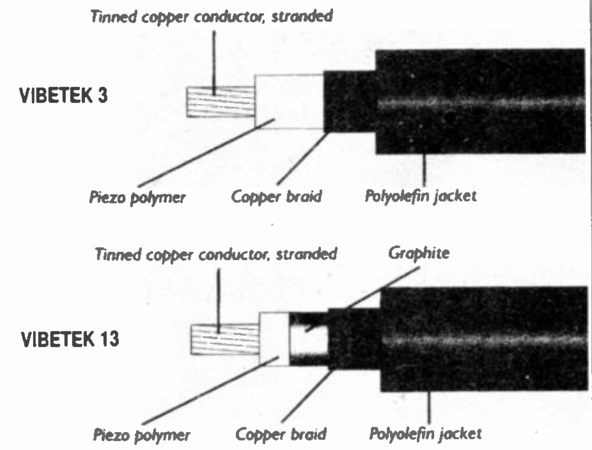
The characteristics of Vibetek may be summarised as follows: Available in long lengths – Flexible and lightweight – Different sensitivities to suit most applications – Output voltage linearly proportional to strain – Self screening – Robust.

SOME APPLICATIONS

Although perimeter security and traffic sensor applications account for most of the piezoelectric cable that is manufactured, other applications include: • vibration sensing • fluid flow monitoring • acoustic pickups for musical instruments • safety sensors for automatic doors and windows.

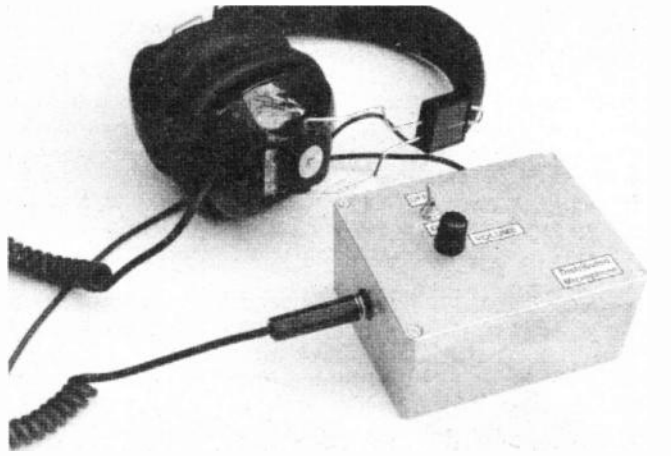
Having briefly outlined piezoelectric cable and what it does, the remainder of this article describes two circuits which will allow a practical exploration of the properties of Vibetek piezoelectric sensor cable.

***Vibetek is a trademark of Ormal Ltd.**



Typical construction of piezoelectric sensor cable.

DISTRIBUTED MICROPHONE



Use a pane of glass or an instrument sound board as a microphone.

THIS first project uses Vibetek 13 cable as a simple acoustic transducer, providing an amplified output to low impedance headphones or a small loudspeaker, although the latter may suffer from problems with acoustic feedback. The full circuit diagram of the Distributed Microphone amplifier is shown in Fig.1.

CIRCUIT DESCRIPTION

The equivalent electrical circuit of the piezo-cable is simply a voltage source in series with a capacitor. The capacitor is equivalent to the total capacitance of the cable, which in the case of Vibetek 13 is about 700pF per metre. The series capacitance effectively means that any electronic interface must have a high input impedance if it is a voltage amplifier, or to be a sensitive charge amplifier.

In the case of the circuit in Fig.1, IC1 provides two high gain inverting voltage amplifier stages. The first inverting op.amp provides a high input impedance interface to the sensor cable, with a voltage gain of 330; the capacitor C3 provides some high frequency roll-off.

The second amplifier stage, IC1b, has a gain variable from 2·2 to 24, using a preset cermet trimmer VR1. The overall closed loop gain provided by IC1 thus ranges from 730 to 7900.

A 741 op.amp, IC2, drives mono headphones or a small loudspeaker, via a minature impedance matching transformer T1. Potentiometer VR2 provides a Volume control.

CONSTRUCTION

The Distributed Microphone is built up on a piece of 0·1in. matrix stripboard, size 29 holes × 34 copper strips. The board component layout, wiring and underside details of breaks required in the copper tracks are shown in Fig.2. The completed circuit board is housed in a diecast metal box to provide screening from mains pick-up.

Before mounting any components on the board, carefully make all breaks in the copper tracks using a special track cutter or a small handheld twist drill bit. Next you should drill out the four board corner mounting holes and the two holes for the audio transformer mounting tags.

The next task is to drill the board for the Volume control VR2 and to provide a cutout for the On/Off toggle switch S1. VR2 is mounted directly on the board, but the switch is mounted on the box lid.

The cutout for the switch will, of course, depend on the shape of its body, but can easily be produced by "linking" together a series of holes and smoothing down the resulting rough edges of the cutout with a small flat file.

At this stage, it is a good idea to offer the unpopulated board up to the underside of the lid and mark out and drill the holes for the control spindle and the switch mounting bush. Once the two holes have been drilled the lid can be put aside for later. Note that the board is fixed to the lid by four self-adhesive stand-off nylon mounting pillars.

CIRCUIT BOARD

Now commence mounting components on the circuit board. Begin construction with the numerous wire links, double-checking before soldering in place. This can be followed by the resistors (some vertically mounted) and capacitors, checking the polarities of the electrolytics as they are inserted on the board.

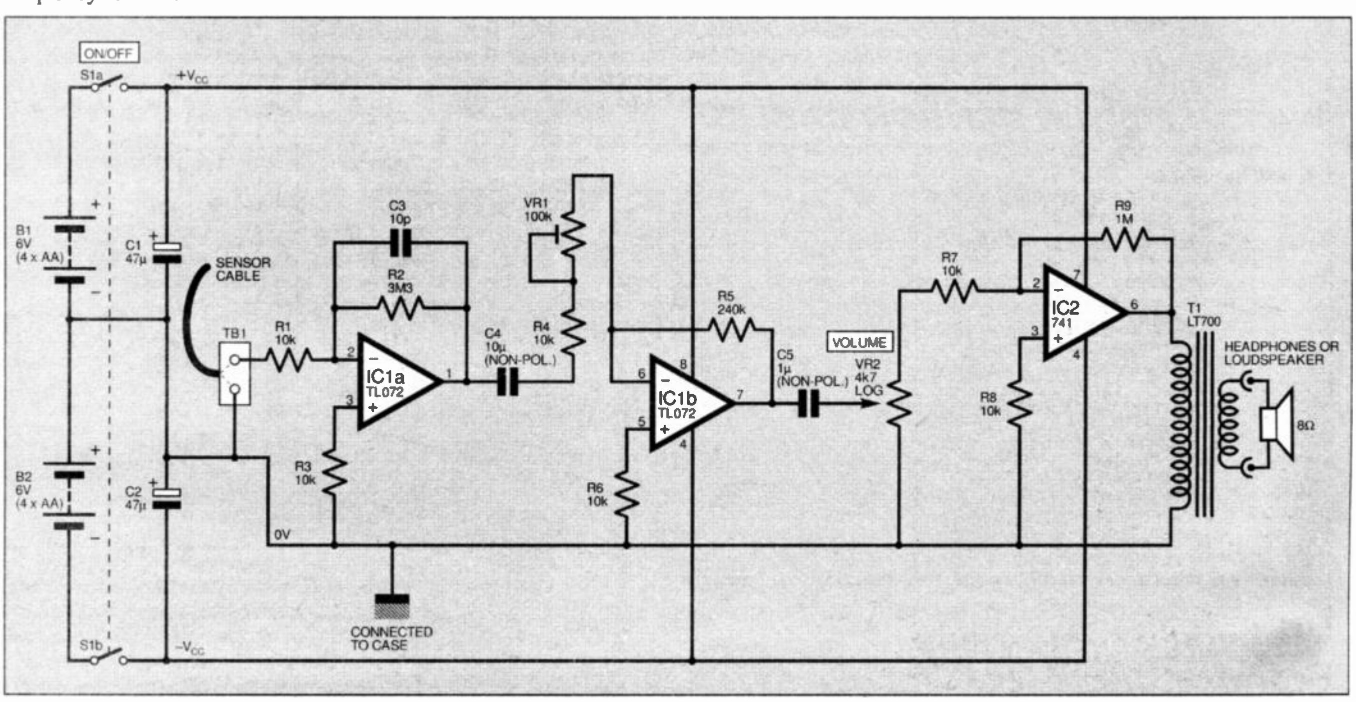


Fig.1. Complete circuit diagram for the Distributed Microphone.

Next start mounting the d.i.l. sockets (without the i.c.s.), cermet trimmer VR1, p.c.b. mounting screw-terminal block, potentiometer VR2 and the audio output transformer T1. Finally, lengths of lead-off wires for the headphone socket SK1, battery packs (with clips) and case "common" connection should be soldered in position. The free end of the common lead should be terminated with a solder tag.

Returning to the box lid, bolt the switch in position, and then mount the circuit board on the underside of the lid using four self-adhesive mounting pillars. Now start soldering the interwiring leads in place. The headphone socket is mounted in one side panel and the two battery holders are taped togther and sited in the bottom of the case, recessed into a slab of polystyrene.

All that remains is to drill a small hole in the side of the box, push the sensor cable through the hole and connect it up to the terminal block. Having first removed the black graphite coating from the dielectric, the inner conductor is connected to resistor R1 via terminal block TB1/1.

The graphite is there to prevent the generation of triboelectric noise and can easily be wiped off with a small piece of tissue paper soaked in a solvent such as methylated spirit, surgical spirit or nail varnish remover. If all else fails, gin works quite well!

SPOT CHECK

Before we close up the box, a couple of spot checks can be made. Insert the i.c.s into their holders and, with the sensor cable connected, power up the circuit board.

Touching the cable should produce a noise in the headphones; VR2 will allow the volume to be adjusted. If the signal sounds distorted, IC1 is probably overloaded, in which case reduce the gain by adjusting preset VR1.

It is possible to separate the Vibetek sensor cable from the amplifier by using a length of coaxial cable. The cable is easy to solder, the conductors are tinned copper. Care should be taken to avoid overheating

COMPONENTS

DISTRIBUTED MICROPHONE

Resistors

R1, R3, R4 R6 to R8	10k (6 off)	See SHOP TALK Page
R2	3M3	
R5	240k	
R9	1M	

All 0·25W 5% metal film

Potentiometers

VR1	100k cermet preset, lin.
VR2	4k7 rotary carbon, log.

Capacitors

C1, C2	47µ radial elect. 35V (2 off)
C3	10p disc ceramic, 50V
C4	10µ radial non-polarised elect. 16V
C5	1µ radial non-polarised elect. 16V

Semiconductors

IC1	TL072 dual low-noise op.amp
IC2	741 op.amp

Miscellaneous

T1	LT700 transistor output transformer
S1	2-pole 2-way min. toggle switch
SK1	6·35mm (¼in.) mono jack socket
B1, B2	6V battery pack (4 × AA cells in holder) (2 off)

Stripboard, 0·1in. matrix 29 holes × 34 copper strips; 1 metre Vibetek 13 piezoelectric cable; 8-pin d.i.l. socket (2 off); 2-way, p.c.b. mounting, screw terminal block, 5mm lead spacing; diecast metal box, size 120mm × 95mm × 60mm; plastic knob; low impedance headphones (preferred) or miniature loudspeaker; multistrand connecting wire; single-core link wire; self-adhesive p.c.b. stand-off pillars (4 off); solder, etc.

Approx Cost Guidance Only £26
excl. headphones & batts.

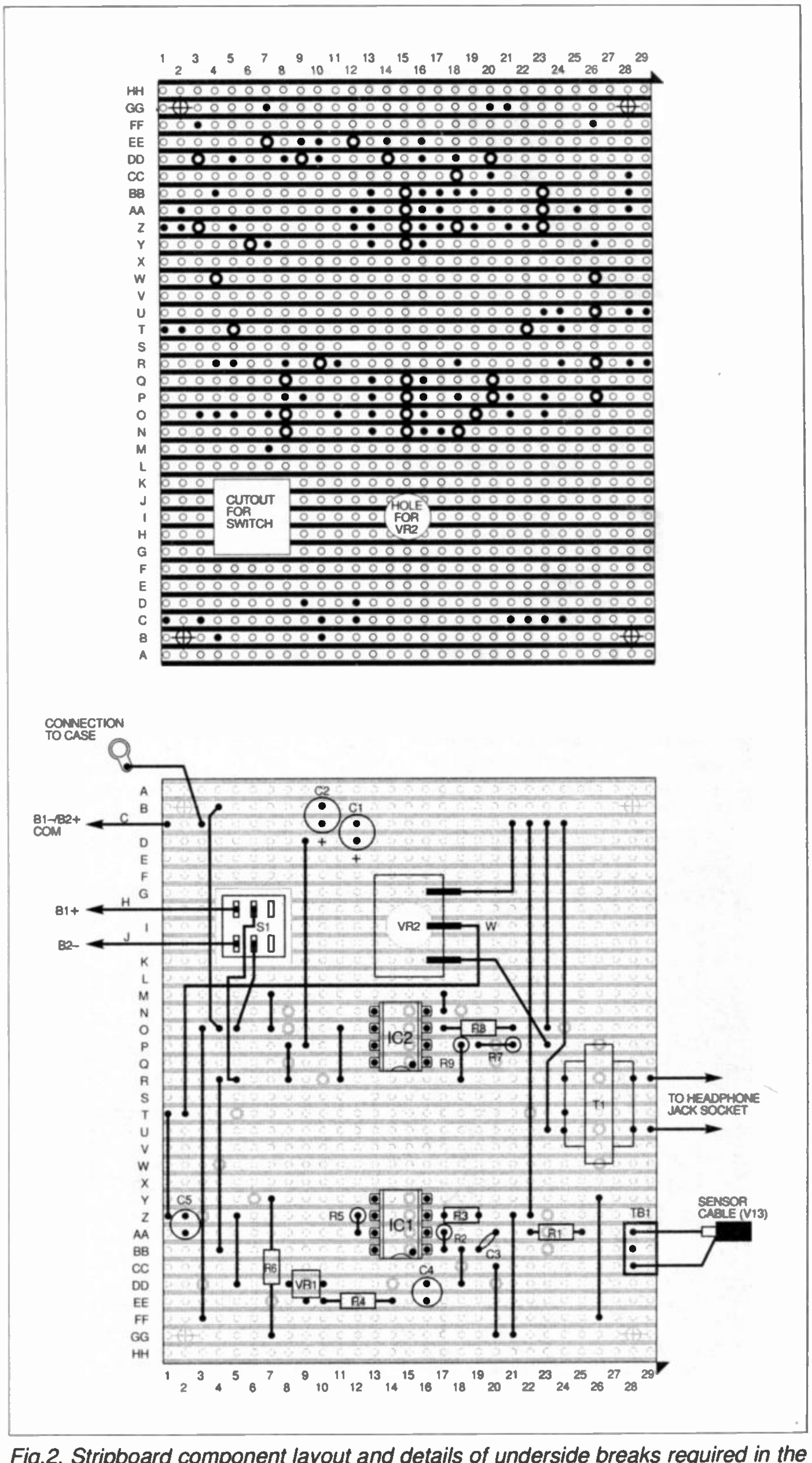


Fig.2. Stripboard component layout and details of underside breaks required in the copper tracks for the Distributed Microphone.

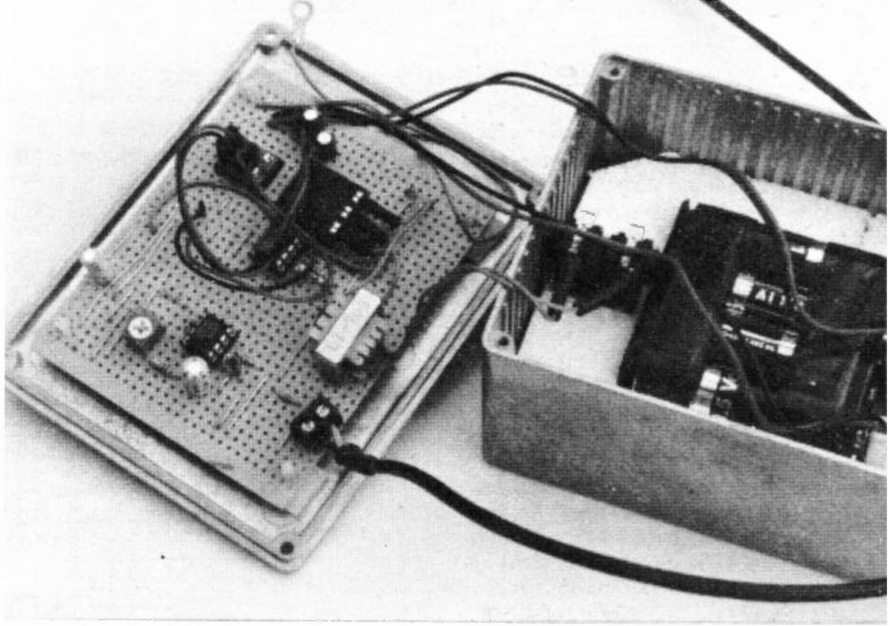
the cable, as at temperatures above 70°C the PVDF starts to lose its piezoelectric properties.

FIELD TRIALS

Having carried out the bench tests successfully, the system is ready to be tested in the field. Attaching the sensor cable to the inside of a window pane with adhesive tape will produce a microphone that will enable speech on the other side of the window to be monitored (this only works well on single glazed windows). When tested with a car windscreen, speech could be clearly heard up to about 10 metres away.

The cable can also be used as a musical instrument pick-up. For example, if the cable is attached to a piano soundboard using sticky tape, with careful adjustment to the gain to avoid overloading, the output from the amplifier can be connected to a tape recorder.

The advantage of using the sensor cable as a contact microphone is that it tends to eliminate extraneous noise from the surroundings. The cable has also been used with a keyboard amplifier, should you want to play your grand piano through a public address system.

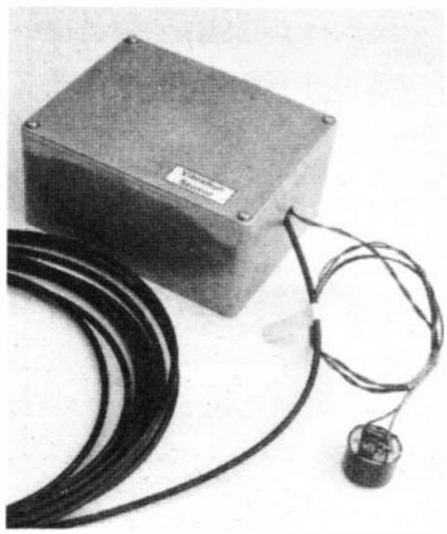


Circuit board mounted on lid the of case and jack socket on one end panel.

To function efficiently as a distributed microphone, the cable needs to be placed in contact with a vibrating diaphragm, such as a pane of glass, a sheet of wood or even corrugated cardboard, where it can be inserted through the corrugations. Trial and error will indicate the best way to attach the cable for a specific application.

Constructional Project

VIBRATION ALARM



Turn a fence into an alarm transducer or sense vehicle movement etc.

ONE of the major applications for Vibetek cable is in vibration sensing, particularly in perimeter security applications. A simple vibration sensing alarm circuit diagram, which may be used with either Vibetek 3 or 13 cables, is shown in Fig.3. This Vibration Alarm may be used in a variety of applications, ranging from security systems to an aid for reversing the car into the garage.

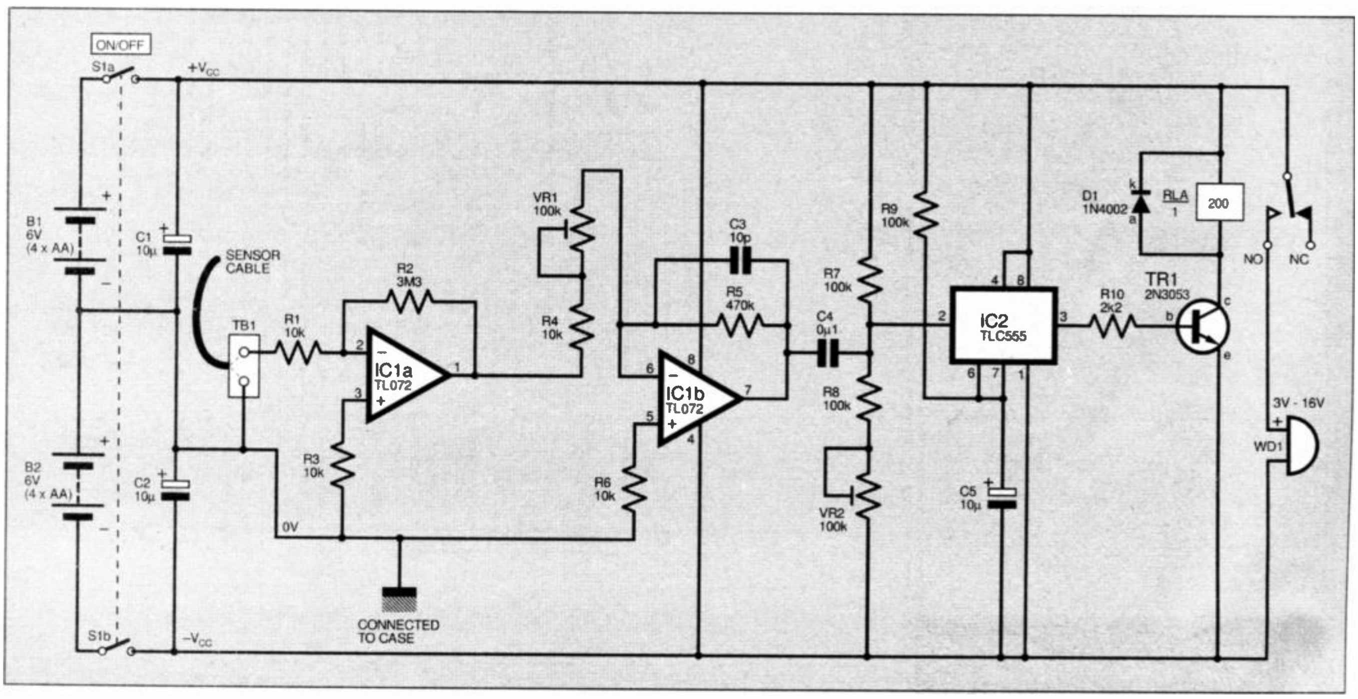


Fig.3. Full circuit diagram for the Vibration Alarm. This circuit uses Vibetek 3 or 13 cable.

CIRCUIT DETAILS

The circuit diagram of Fig.3 comprises two distinct stages: namely, an analogue voltage amplifier; plus threshold, timer and relay driver circuits.

Voltage amplification is provided by IC1, a TL072 i.c. consisting of two op.amp stages (IC1a, IC1b) in cascade. The input resistance (R1) to the first op.amp is ten kilohms and the feedback resistance (R2) was selected to provide a closed loop gain of approximately 330.

The input resistance to the second op.amp IC1b is provided by preset VR1 and resistor R4 (a 100k cermet trimmer in series with a 10k resistor), which in conjunction with the 470k feedback resistor (R5) can be adjusted to give a closed loop gain in the range 4·2 to 47. The employment of a preset trimmer at this point provides sensitivity adjustment.

An overall closed loop gain for the stage therefore ranges from approximately 1,386 to 15,510. Capacitor C3 is included across R5, to set a cut-off frequency of 5kHz.

The threshold and timing circuitry is provided by IC2, which is a CMOS 555 i.c. configured as a monostable multivibrator. The output of the timer is normally low and goes high when the trigger voltage on pin 2 falls below one-third of the supply line voltage. Once triggered, the output remains high, independent of the trigger, for about one second.

The positive pulse produced by the timer operates a relay, via transistor TR1, which switches the alarm (WD1) on.

Note that if a bipolar 555 timer is used, a 47µF tantalum capacitor should be mounted close to the device supply pins to eliminate noise retriggering.

CONSTRUCTION

Construction of the Vibration Alarm is also carried out on the same lines as that adopted for the Distributed Microphone project, including the use of a diecast metal box. Assembly of the circuit board should follow the normal procedure of

COMPONENTS

VIBRATION ALARM

Resistors

R1, R3, R4, R6	10k (4 off)
R2	3M3
R5	470k
R7, R8, R9	100k (3 off)
R10	2k2

All 0·25W 5% metal film

Potentiometers

VR1, VR2	100k cermet preset, lin. (2 off)

Capacitors

C1, C2, C5	10µ radial elect. 35V (3 off)
C3	10p disc ceramic, 50V
C4	0µ1 ceramic, 63V

Semiconductors

D1	1N4002 rec. diode
TR1	2N3053 *npn* med. power transistor
IC1	TL072 dual low-noise op.amp
IC2	TLC555 CMOS timer (or similar)

Miscellaneous

RLA	9V 200 ohm coil d.i.l. relay
S1	miniature 2-pole 2-way slide switch
B1, B2	6V battery pack (4 x AA cells in holder) (2 off)
WD1	12V d.c. piezoelectric buzzer

Stripboard, 0·1in. matrix 29 holes x 34 copper strips; 5 metre V3 or 1 metre V13 Vibetek piezoelectric cable (see text); 8-pin d.i.l. socket (2 off); diecast metal box, size 120mm x 95mm x 60mm; 2-way screw-terminal block, 5mm pin spacing; solid-core link wire; multistrand connecting wire; self-adhesive p.c.b. stand-off pillars; solder, etc.

Approx Cost Guidance Only £29 excluding batts.

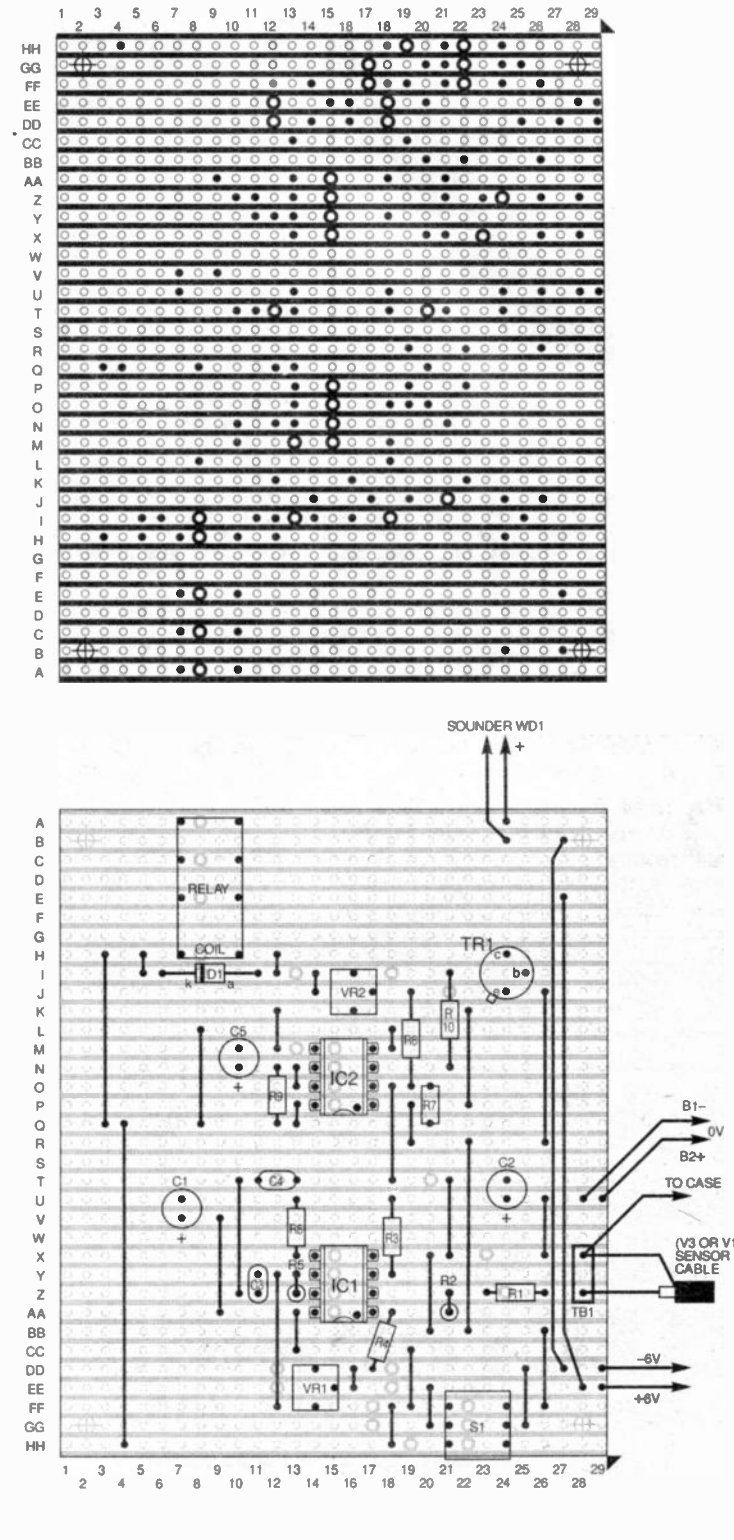


Fig.4. Vibration Alarm stripboard component layout and details of breaks required in the underside copper tracks.

starting with the lowest profile components working up to the largest.

Once again, the Alarm is built on a piece of 0·1in. matrix stripboard having 29 holes and 34 copper strips. The component layout, wiring and breaks required in the underside copper tracks are given in Fig.4. All components except the battery holders, sensor cable and the warning device WD1 are mounted directly on the circuit board.

APPLICATION

According to application, the sensor cable is linked to the board by using an additional length of coaxial cable. The warning transducer can be sited remotely from the unit, and linked to the board by two connecting leads, or it can be mounted on the outside of the case.

Having selected a possible application, the following simple setting-up and testing procedures should be carried out.

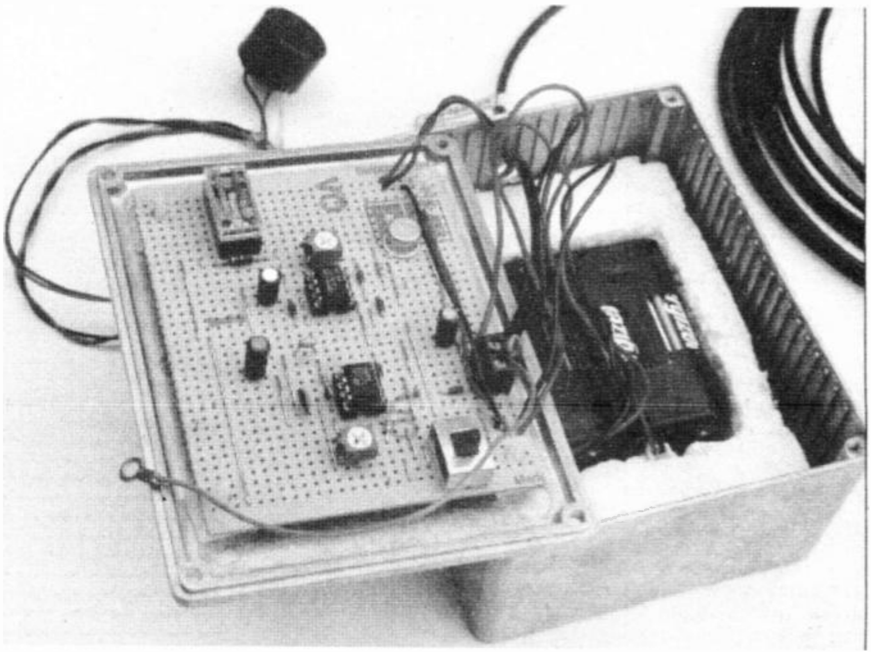
Fence Alarm

To operate as a Fence Alarm the sensor cable (V3) is securely attached to the metal fence using a plastic cable tie every 20cm. Using the preset cermet trimmers VR1 and VR2 the sensitivity of the system can then be set, by trial and error, to trigger at disturbances ranging from a sharp rattle of the fence to a more subtle contact. It should be noted that a gradual application of pressure or contact to the fence/cable will not be detected.

The minimum setting of sensitivity of the device is sufficiently low not to produce "false alarms" due to the effects of wind or small animals coming into contact with the fence. This simple circuit should only be used on short fences, of no more than about 10 metres in length. For longer fences, a far more sophisticated electronic analyser is required.

Parking Aid

As a Parking Aid, a length of sensor cable (V3) is inserted into a piece of garden hose, which is then securely fastened to the floor of the garage at a suitable distance from the rear wall. When a car is reversed into the garage and the wheels come into contact with the hose, the buzzer will sound.



Completed Vibration Alarm circuit board mounted on the lid of the diecast box. Note the case "earthing" solder tag and battery holders secured in the base of the box.

To ensure that the buzzer will be heard, it should be placed level with the driver's side window. The hose is used purely to provide some protection for the cable.

Pressure Pad

To produce a Pressure Pad, a heavy object, for example a garden ornament (a stately gnome?), is placed on a small coil of piezo-cable (V3 or V13). The gain and threshold can be adjusted so that when the object is disturbed the alarm sounds.

When the cable is placed under a doormat, similar results are obtained. However, the more sensitive cable (V13) may be required for optimum performance in this application, depending on the thickness of the mat.

Window Security

For Window Security the sensor cable (V3 or V13) is securely fastened to the window frame using adhesive tape. Breaking the glass, or an attempt to force open the window, will cause the alarm to trigger.

Once again the more sensitive cable (V13) may be required, depending on the type of windows and frames.

Door Security

To function as a Door Security alarm the sensor cable (V3 or V13) is securely fastened to the door using adhesive tape. Any disturbance to the door, e.g. a knock or thump, will trigger the alarm.

The more sensitive Vibetek 13 cable may be required depending on the type and thickness of the door.

CONCLUSION

These two projects were designed to be simple and cheap to build, and provide a basis for further experimentation by the electronics enthusiast. It must be stressed that the commercially available security systems, designed to use long lengths of Vibetek cable, are a great deal more complex, in order to provide a high probability of detecting an intruder coupled with a low false alarm rate. □

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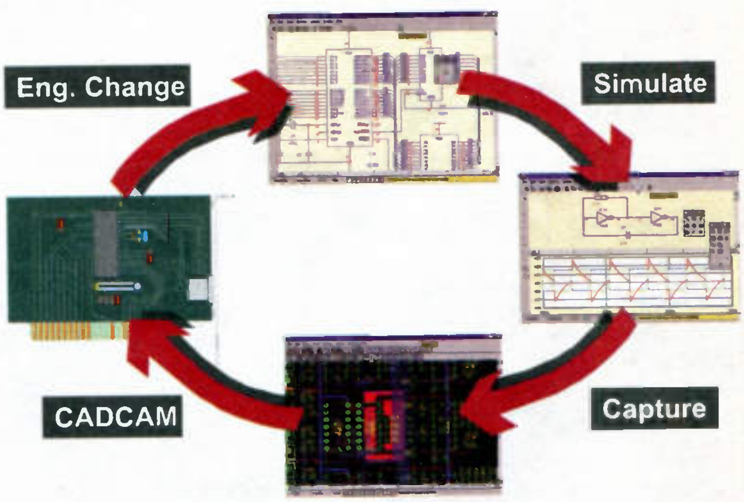

Use the multi layer autorouter, and/or manual routing to complete your PCB together with copper fill, etc as required. Finally print your design, or create CADCAM files suitable for manufacture (we even include a Gerber viewer for checking).

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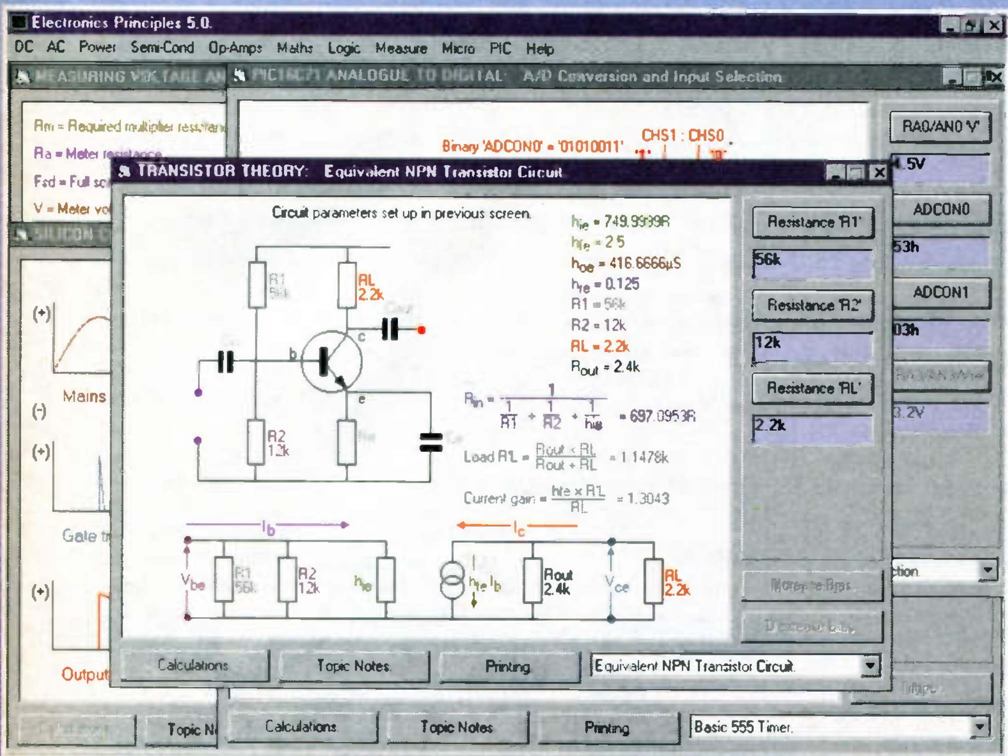
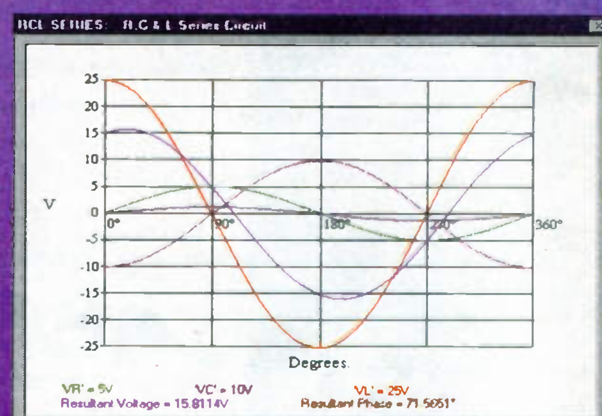


Electronics Principles 5.0 is a significant upgrade of our popular electronics educational software. Now containing even more analogue, digital and microcomputer theory. PLUS over a hundred new mathematics topics to further your understanding of formulae and calculations. Telephone for a comprehensive list or upgrade details.

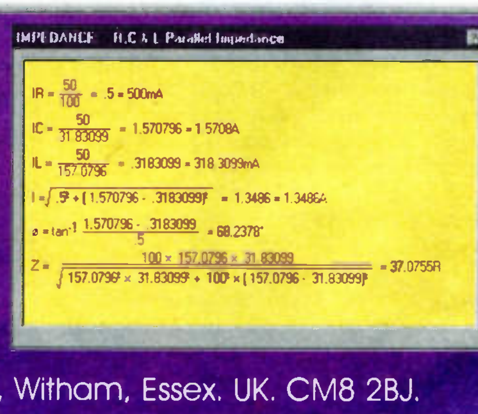
This software has been developed to teach electronics and is suited to both the complete novice and the more advanced student or hobbyist wanting a quick revision and access to hundreds of electronics formulae. It is extremely easy to use. Just select a topic, which is always presented as a default diagram (no blank screens!) and input your own values. Alternatively, use those from any standard electronics text book to see the results as frequency response curves, calculations, logic states, voltages and currents etc.

Graphics presentation has been enhanced and speeded-up with new menus and indexing which enables a quicker access and more informative description of the extended range of five hundred and sixty electronics and mathematics topics.



The PIC16C84 microcontroller hardware and instruction set has been introduced and brought to life through colourful interactive graphics where you can study the architecture of this device by changing the data values to simulate all of the registers, direct/indirect addressing, program/data memory and input/output port configuration. Along with those analogue to digital functions of the PIC16C71. If you would like to learn more about the principles of these popular microcontrollers then it could not be made easier.

Electronics Principles software is currently used in hundreds of UK and overseas schools and colleges to support City & Guilds, GCSE, A-Level, BTEC and university foundation courses. Also NVQ's and GNVQ's where students are required to have an understanding of electronics principles.



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Innovations

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

SELF-DESTRUCTING VIDEOS

Inspired by James Bond's "M", perhaps, video rental companies may soon issue movies that self-destruct after viewing. Barry Fox investigates.

AN AMERICAN company has developed a music CD or DVD movie disk which self-destructs after a few plays. The same technology ties a ROM disk to a PC, so that once it has been used on one computer it cannot be used on another, or copied.

The new system, developed by Hide and Seek Technologies of Nederland, Colorado, relies on a polymer coating applied to the disk surface which darkens progressively when exposed to light. So the disk initially plays perfectly but later refuses to play. The original intention was to control the use of ROM disks but when US company Divx recently announced its plans to launch a restricted play DVD movie disk that needs a special player, HST broadened its strategy.

The polymer system will now be used to restrict the playback of entertainment disks on conventional players. Video stores can sell disks which work only for the weekend, instead of renting out tapes which customers must rewind and return but often damage. HST predicts that disposable disks will be sold from vending machines and delivered with pizzas.

Photosensitive Polymers

Two years ago inventor Jerry Smith found a range of polymers which are initially transparent, but darken when exposed to the intense beam of red light which is emitted by the laser in a CD or DVD player. A similar polymer darkens when exposed to the ultra-violet rays in daylight. Chemical details remain secret until the patents are published.

The clear surface of a CD, DVD or ROM disk is covered with a thin layer of polymer by spin-coating after normal pressing, using a technique similar to that already used to apply protective lacquer. Varying the mix controls either the number of times which a disk can pass through the laser beam in a player, or the length of time the disk can survive after removal from light-tight packaging.

The computer industry can use HST to lock a ROM disk to a particular PC, and stop anyone copying it. When the program is installed from a virgin disk, software on the ROM makes the drive read a small section of the disk over and over again. Reading follows a pattern which is set by unique characteristics of the PC, such as the exact time of installation. The disk, or a copy that is made, now carries a uniquely coded pattern of darkened areas, and cannot be used on another PC because the installation patterns do not match.

If the coating is spun onto a conventional music CD or DVD movie disk, it plays perfectly for a few times, but then gets too dark for the laser to read it. Or the disk reacts to daylight and starts to darken as soon as it is unwrapped, to limit useful life. HST claims that the polymers can be "tuned" to allow anything from a few hours to a few days working life, or anything from a single to several plays.

Consumer Backlash

HST's proposal capitalises on a mounting backlash against Divx. Consumers who have bought conventional DVD players are furious to find that they will need new players next year to play Divx disks from major studios such as Disney. Dealers worry that their stock of DVD players now looks obsolete. The DVD Forum is split over the split standard.

Says Forum Chairman, Toshiba's Koji Hase "Divx is not a DVD format. In many respects that's the end of the story. One standard makes an industry, but two standards is chaos".

Says HST's CEO, James Weldon "We talked to Divx, but they were married to the idea of a modified player with encryption and a modem. If we throw a few rocks the whole Divx thing may just tumble down. We are now telling the movie studios that they can limit the number of times people play a disk on existing players. And it is only a question of time before hackers break the Divx security codes".

MEASUREMENT *ANTIDOTE*

LASCAR Electronics, a leading manufacturer of digital panel meters and data loggers, have introduced a new family of snap-in micro-miniature panel meters.

Punning intentionally on the illustrative photo, Lascar describe the meters as being the ANTidote to your measurement problem! The display digit heights range from 5·5mm to 11mm (so perhaps the ants are not as big as first seems the case ...)

The modules (coded DPM1, DPM2 and DPM3) operate from a 9V supply and feature auto-polarity, auto-zero, 150µA current consumption and 200mV full scale reading. A p.c.b. socket strip is provided to facilitate final assembly within the target design.

For more details contact Lascar Electronics Ltd., Dept. EPE, Module House, Whiteparish, Salisbury, Wilts SP5 2SJ. Tel: 01794 884 567. Fax: 01794 884616.

SNAILING NEWS

ADVERTISERS, you are welcome (and invited) to offer us info on your new products for possible inclusion on these pages.

But please *don't* send the details via E-mail – we get so much rubbish via E-mail that it is easy to miss important items, and also easy to file and forget them. Send your info, with photos if possible, via normal snail mail!

HELP FOR Y2K

COMING to the assistance of those who do not yet know if their computer is *Millennium Compliant*, Eurosoft has introduced a "check and repair" system.

The company's Fix2000 checks the PC's system clock, revealing whether or not the date roll-over process is supported. If necessary, Fix2000 then goes on to perform the correction of the century value automatically.

The product is available on disk (rrp £29.95) or via a ROM-based add-on board (rrp £49.95), which carries the additional bonus of being virus immune. Both have user-friendly easy-install instructions and once installed are fully functioning within seconds.

We ran the assessment disk on several machines. The only one to pass the Y2K compliance test was a recent Pentium Dell. The other machines, though, were all capable of being successfully corrected by the full Fix2000 software, except for a 12-year old Amstrad 1640 which refused to load the software.

Millennium Bug

For those not familiar with the Year 2000 (Y2K) problem, the "Millennium Bug" issue concerns software that reports the year element of a date. In order to save memory in many early computers (even in some very recent ones), only two digits were allocated, and as such the year can only be reported as, for example, 98, 99 or 00. The former half of the century is static and remains at 19.

Herein lies the problem. When the clock strikes midnight on 31st December 1999, many computers around the world will leap back 100 years to 1900. Any program that is date-related will suffer accordingly, as will any business depending on computer date accuracy.

Eurosoft are the developers of PC-check diagnostic software and test accessories supplied worldwide to PC maintenance, manufacturing and training companies, with over 17 years in the UK and international computer market place.

For more information on Fix2000, contact Eurosoft (UK) Ltd, Dept EPE, Hanover House, 3 St Stephens Road, Bournemouth, Dorset BH2 6JI. Tel: 01202 297315. Fax: 01202 558280.

E-mail:sharon@eurosoft-uk.com. Web: www.eurosoft-uk.com.

For more general information on the Y2K problem, there are several organisations you can contact:

Action 2000. Hotline: 0845 601 2000. Tel: 0171 628 5751.
Web: www.open.gov.uk/bug2000.htm.

British Computer Society – publication *The Year 2000: A Practical Guide*. Tel: 01793 417417.

Computing Services and Software Association. Web: www.cssa.co.uk.

De Jager and Co. Web: www.year2000.com.

IBM. Web: www.ibm.com/year2000.

IEE. Web: www.iee.org.uk/2000risk.

Taskforce 2000, PO Box 12269, London EC3A 67A. Tel: 0171 562 7650.

UK Year 2000 Interest Group, 86 Bathurst Road, Winnersh, Wokingham, Berks RG41 5JF. Tel: 0118 977 6915. Fax: 0118 978 4083.
E-mail: jill@wordsec.demon.co.uk.

Incidentally, what is also looming on the horizon for companies involved in international currency exchange rates, is the nightmare of changing software to suit EMU transactions. This will not only affect financial houses, but also those involved with import/export. Is *your* company EMU compliant?!

Boosting Channel 5

Those "deprived" of Channel 5 should welcome suggestions for C5's increased transmission power – except the French, perhaps? Barry Fox reports.

CHANNEL 5 wants to boost its London transmitter, to match the power used by the BBC and commercial TV stations. The Independent Television Commission has "endorsed" the plan, on condition that C5 retune any VCRs and satellite receivers in the UK which use C5's frequency to connect to TV sets and have so far been unaffected by C5's weak signals.

The UK government's Radiocommunications Agency is worried on a different score. C5 was licensed to transmit only weak signals, because TV stations elsewhere in Europe, particularly France, already use the same frequencies for broadcasting. If C5's stronger signals leak across the Channel, they could spoil (foreign) viewers' pictures.

The RA has written to all governments in Europe, formally notifying them of the proposed change. As an extra precaution, the RA has notified the Radiocommunications Bureau of the International Telecommunication Union in Geneva. The Bureau's job it to prevent international interference and it is now contacting European broadcasters direct to be sure they understand the significance of C5's proposal.

Powerful Complaints?

C5 wanted to begin experiments during the first quarter of 1998. The power of the Croydon transmitter will be gradually increased from its current 250kW, to the full 1000kW (as used by the BBC and ITV), to see who complains.

No public announcement has been made by C5, but a spokeswoman says C5 hopes to reach over four million new viewers by mid 1998.

C5's obligation to retune videos ended three months after the station first switched on, and its army of retuners has been disbanded. "But the obligation kicks in again as soon as C5 increases the power" says the ITC. "If they cause interference they would have to recruit a new army".

PIC LIBRARY

Microchip have announced the availability, via their website, of a "plug-in" library of software routines for the PIC16C5X and PIC12C5XX microcontrollers (no mention of the '84 series, however). The library is intended to allow designers to emulate peripherals in software as well as making it easier for first-time PIC users to design with these two families.

The library can be downloaded free from www.microchip.com.

MAPLIN GRABS THE CROC

MAPLIN has introduced Crocodile Clips 3, the new easy-to-use electronics software simulation package. This innovative electro-mechanical simulator allows both professional and hobbyist designers to combine electronic and mechanical components into a wide range of designs.

Crocodile Clips 3 translates textbook theory into a fun and easy to use design simulator using animation to explain electronics concepts. The program includes useful on-line help for both beginners and experienced users.

The CD-ROM software includes a large range of components which can be installed by simply dragging them from the toolbar and dropping them into a design. The software runs on a 386 PC (486 recommended) with Windows 95, 4Mb RAM and CD-ROM drive. A soundcard is optional.

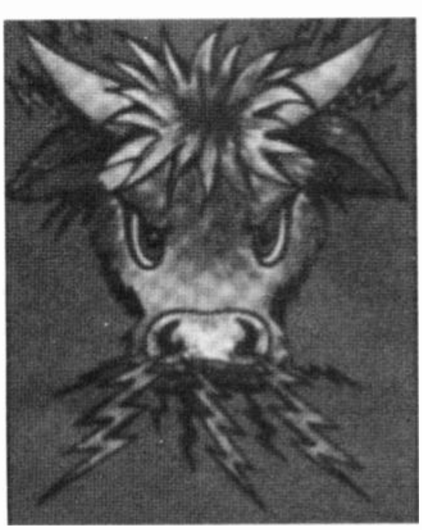
For ordering information and Maplin store locations, tel: 01792 554002, or write to Maplin Electronics PLC, Dept EPE, Maplin House, 274-288 London Road, Hadleigh, Benfleet, Essex SS7 2DE.

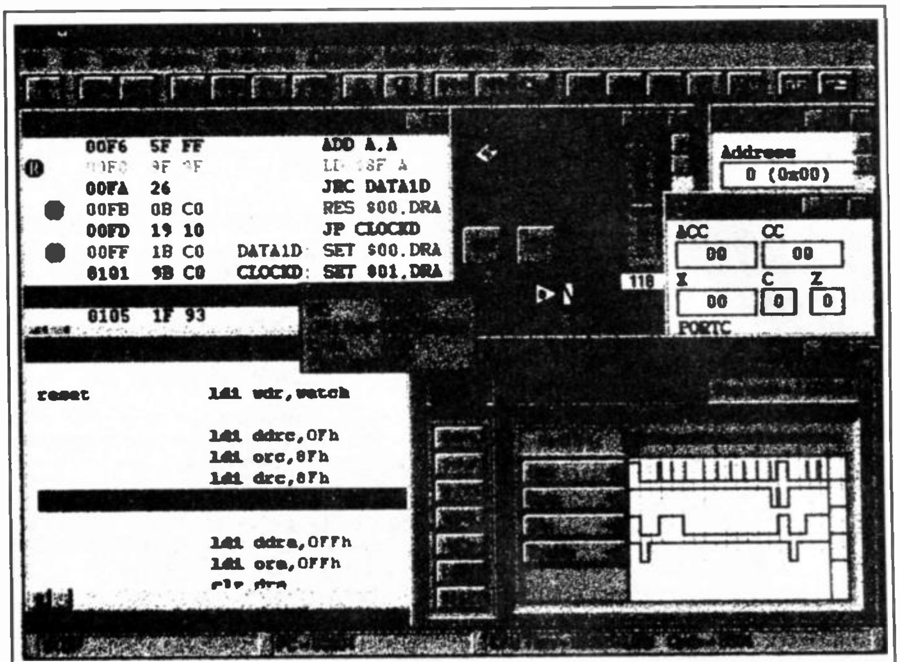
Hydroponic Bull

Long have we all been aware of the fascinating electronic products available from Bull Electrical (indeed we've just had in their latest catalogue detailing such goodies – we urge you to get your own copy and thoroughly browse it!).

We are fascinated, though, to learn that Bull has also entered a field that has nothing to do with electronics: hydroponics – the art of growing plants in a chemical solution without soil. Being of a scientific nature, the idea may well appeal to some of you enterprising experimenters, so we mention it! Bull have a separate catalogue of what they have available for the subject, which includes nutrients, systems, books and more.

For more details, contact Bull Electrical, 250 Portland Road, Hove, Sussex BN3 5QT. Tel: 01273 203500. Fax: 01273 323077.
E-mail: sales@bull-electrical.com.
Web: www.bull-electrical.com.





FRENCH UMPS

NEWS is in from France (but in excellent English) of an UMPS – a Universal Microprocessor Program Simulator. Virtual Micro Design, the originators of the product, state that it is the best and faster microcontroller simulator.

UMPS is an assembler/disassembler, logic analyser and serial link which simulates a range of popular microcontrollers and peripherals, including (amongst others) 8051 and derivatives, Motorola's 68HC7xx family, Thomson's ST62xx family, and what seems to be Microchip's full PIC range from PIC16C52 through PIC16C84 and upwards. VMD go on to say that UMPS can be extended to simulate any kind of microcontroller.

The system runs under Windows (3.1, 95 and NT4) and simulates a microcontroller and its external environment, drastically reducing the debugging phase of program development.

For full details (of which the above are just a few) contact Virtual Micro Design, Dept EPE, I.D.L.S., Technopole Izarbel, 64210 Bidart, France. Tel: +33 559 438 458. Fax: +33 559 438 401. E-mail: p.techer@idls.izarbel.tm.fr.

PICS IN PRINCIPLE

EPT Educational Software have released the latest version of their Electronic Principles software. Version 5.0 contains all the previous graphics windows of V3.0 and V4.0. In addition, there are many more advanced analogue and digital topics, i.e. active and passive filters, attenuators and Boolean algebra, plus a full microprocessor hardware, instruction set and addressing mode simulation. Mathematics principles are now included as well.

What is also most interesting to see is that EPT have devoted a new section entirely to PIC microcontroller principles and instruction set simulation.

Electronic Principles 5.0 is a complete PC-based electronics course and as such is fully self-contained, including graphics in full colour. Text calculations and frequency response curves appear in additional windows.

A number of the program screens are based on two *EPE* books, *Teach-In No 6* and *Teach-In No 7*, bringing them both to life in interesting formats. The former is sub-titled *Design Your Own Circuits* and was written by Mike Tooley. The latter is sub-titled *A Complete Electronics Course* and was written jointly by Alan Winstanley and Keith Dye.

EPT are well-experienced at producing mathematics and electronics software, having been doing so for around five years. We know that many readers have found tremendous benefit from EPT's products.

Electronic Principles 5.0 is supplied on three 3.5 inch disks containing compressed files for Windows 3.1, 95 and NT. The UK and EC price is £119.79 fully inclusive. Outside Europe the price is £99.95 plus £3.50 airmail postage. Site licences are available for schools etc.

For more information contact EPT Educational Software, Dept. EPE, Pump House, Lockram Lane, Witham, Essex CM8 2BJ. Tel/Fax: 01376 514008.
E-mail: sales@eptsoft.demon.co.uk.

New Technology Update

For switching power, f.e.t.s are becoming increasingly capable, especially those using the new DMOS and TrenchMOS processes – as Ian Poole reports

FIELD effect transistors are used in a wide variety of applications, from radio frequency amplifiers to high power switching applications. In all of these areas they are undergoing development to improve their performance.

In the area of switching, the performance of f.e.t.s is improving and as a result they are taking over more applications from relays. Traditionally relays have had several advantages. They offer a very low *on* resistance, which means that high currents can be switched, and they have a very high *off* resistance. Also, the input circuitry is isolated from the output enabling very high voltages to be switched.

However, their drawback is that they are mechanical devices. This means that they have a low switching speed and their reliability is not nearly as high as a solid state switch.

Now with increasing possibilities for the use of f.e.t. switches, developments are moving forwards with an increasing pace.

DMOS

One of the technologies which has become established in the f.e.t. switching arena is called DMOS (double diffused metal oxide semiconductor). There are two basic formats for this technology. In the first, which uses a horizontal topology as shown in Fig.1, an $n-$ substrate is taken (in this example).

P-type impurities are then diffused in to give a *p*-type area. *N*-type impurities are then diffused in to give an $n+$ area for the source. The *p*-type area is used as the channel and controlled by an insulated gate in the normal way for a MOS device.

The DMOS manufacturing process produces a very thin channel area and this provides very low levels of *on* resistance making it ideal for switching applications.

A further enhancement of the process is shown in Fig.2, which depicts a vertical version of the basic device. Here source contacts are placed either side of the gate, and the drain is located on the underside of the substrate. In this way a vertical structure with more channel area is obtained. This further improves the current handling performance of the DMOS device.

TrenchMOS

Although the basic DMOS process gives some significant advantages over previous forms of f.e.t., it still has some limitations. Accordingly, Philips are perfecting a process they call TrenchMOS (see Fig.3.).

The process receives its name from the fact that a continuous trench or groove is etched into the surface of the silicon and as a result it divides the devices into a large number of cells. The surface of the trench is covered with a thin layer of silicon oxide and then filled with polycrystalline silicon to give a thin conducting gate running between the small individual cells.

In view of the way in which the cells are formed, the current flow in the device is truly vertical, unlike the basic DMOS device where there is a significant amount of horizontal travel. As a result, the current path is shortened by up to 50 per cent and the *on* resistance is reduced.

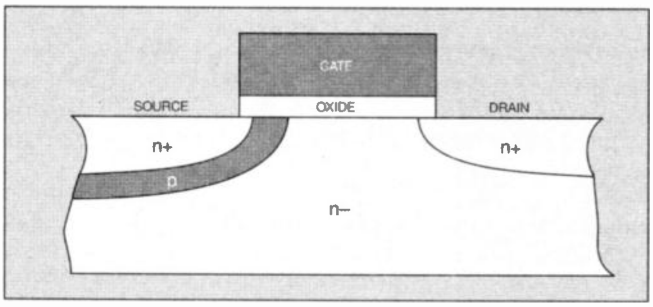


Fig.1 Lateral DMOS transistor

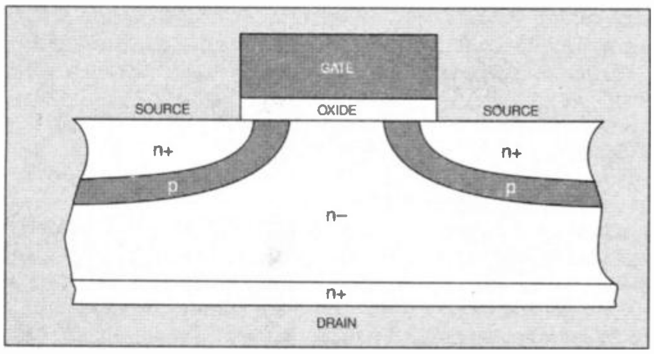


Fig.2 Vertical DMOS transistor

Although making the channel thinner will reduce the *on* resistance, it also reduces the maximum operating voltage. As these devices are aimed at electrical control applications, most of them need to withstand voltages of up to 60V for automobile applications and the channel cannot be made too thin otherwise breakdown will occur.

The shape of the cells is important and they have been made hexagonal. This reduces the unwanted field effects associated with sharp corners and allows better use to be made of the available active area.

A further improvement in performance is gained by the elimination of a side effect. This is akin to placing a j.f.e.t. in the device and it acts to reduce its current capability. Fortunately, the new TrenchMOS structure does not suffer from the effect and as a result its current carrying capability is improved still further.

The reduction in *on* resistance and increase in current capability are of particular importance for switching applications where even small improvements can give significant benefits.

There can also be significant cost reductions. By using a physically smaller device, small savings can be made. These savings can multiply significantly where very large quantities are used, as in the case of automobile manufacture.

Low Resistance

The improvements which can be obtained with the new process have been proved with practical results. Obviously the resistance is proportional to the area of the device and as a result figures are quoted in resistance for a given area. Using the conventional DMOS process an *on* resistance of 270 milliohms per mm^2 was achieved. However, for the TrenchMOS process a figure of only 125 milliohms per mm^2 was obtained.

By reducing the actual device resistance, other stray components need to be

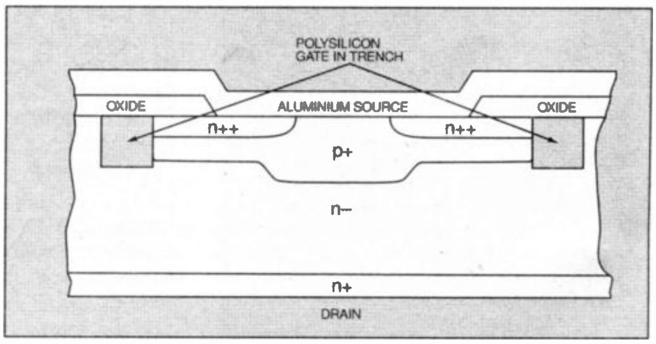


Fig.3 TrenchMOS cell structure

taken into consideration and addressed. The source metallisation and lead resistances now figure in the device performance. To prevent these from becoming significant, the final aluminium deposition onto the device has had its thickness increased. The bonding wire thickness has also been increased, as well as using three wires instead of two.

Finally, attention has been paid to the method used for the drain contact. In this way the performance of the whole device has been optimised to reduce the overall resistance.

The new methods used have enabled a far greater level of flexibility in device design. Smaller die sizes can be used. In addition to this, the lower *on* resistances have resulted in a reduction in power dissipation and both of these factors have enabled smaller packages to be used.

The devices are available in both standard leaded packages as well as surface mount, as might be expected from the fact that the sizes have been reduced.

More Protection

The reduction in the size of the die required opens a number of other opportunities. One is for the inclusion of ESD (electrostatic discharge) protection diodes.

It well known that static discharges can cause instant destruction to electronic devices. These instances, though, are only a small part of the problem – the greater problem lies in the long term reduction in reliability. It has been shown that a static discharge can cause latent damage that will only show up some time after the equipment has been in service, thereby reducing its long term reliability.

By including protection diodes, not only has the performance of the device been significantly improved over its predecessors, but so too has its reliability.

SHOP TALK

with David Barrington

Simple Metal Detector

The meter for the *Simple Metal Detector* project can be a normal 100µA panel type if preferred, but it was found that a "tuning meter" was quite adequate for this circuit and proved to be much cheaper. The meter used in the model came from **Maplin** and is their "signal strength" type (code LB80B), having a 250µA f.s.d. movement. Almost any meter having a full scale sensitivity of about 200µA to 250µA should work here. If you prefer to use a normal 100µA panel meter, you will need to increase the value of resistor R10 to 18 kilohms.

You need to obtain a *radial* 2·2mH inductor for the "search coil" L1. The unit has only been tested using a low current RS type and a Toko 8RB type. The 8RB inductor was purchased from **Cirkit** (☎ ***01992 448899***), code 34-2201 and the RS type can be ordered through **Electromail** (☎ ***01536 204555***), code 228-321.

The use of OA91 *germanium* diodes has been selected as they have a lower forward voltage drop than silicon types, giving slightly better results. Beware overheating these devices when soldering them in place. Also, space on the board is at a premium, so it is advisable to use p.c.b. mounting polyester capacitors with *5mm lead spacing*.

The Detector is built on the multi-project printed circuit board available from the *EPE PCB Service*, code 932 (see page 315).

Experimental Piezo-Cable Projects

Most of the components for the two *Experimental Piezo-Cable Projects* should be readily available items. The *non-polarised* electrolytic capacitors should be stocked by most of our component advertisers.

The Vibetek piezoelectric sensor cable is being made available to *EPE* readers by **Ormal Ltd** (☎ ***01793 484343***) at a special price of £15 inclusive for one metre of Vibetek 13 **or** five metres of Vibetek 3. To purchase both types will cost just £27.50.

If problems arise trying to locate the LT700 miniature transistor output matching transformer called for in the *Distribution Microphone*, it can be sourced from **Maplin**, code LB14Q. The volume control does not have to be a conductive polymer type, any miniature rotary carbon track "log." pot. will do.

A suitable 9V relay for the *Vibration Alarm* would be from the BT47 series stocked by **Farnell** (***0113 263 6311***), code 257-060. Another possible is the **Maplin** 12V BT47W6, code DC80B. The buzzer used in the model is an RS type from **Electromail** (☎ ***01536 204555***), code 249-794.

RC Meter

For those readers who are unable to program the PIC chip for the *RC Meter*, a ready-programmed PIC16C84 microcontroller is available from **Magenta Electronics** (☎ ***01283 565435***) for the sum of £10 inclusive.

The program is written using MPASM and the software is available from the Editorial Offices on a 3·5in. PC-compatible disk, order as PIC Disk 1. There is a nominal charge of £2.75 each (UK) to cover admin. costs, the actual software is free. For overseas readers, the charge is £3.35 surface mail and £4.35 airmail. Alternatively, it can be downloaded *free* from our Internet FTP site: **ftp://ftp.epemag.wimborne.co.uk/pub/PICS/RCMeter.**

The 2-line 16-character l.c.d. display module is an Hitachi LM016L type and can be purchased from Magenta. Any similar device should also be compatible for this circuit, but check pinout details first.

The printed circuit board is available from the *EPE PCB Service*, code 188 (see page 315).

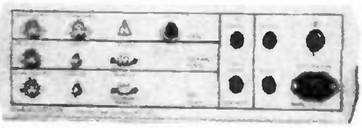
Single or Dual-Tracking Power Supply

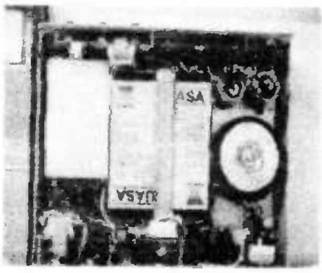
The main concern regarding parts for the *Single or Dual Tracking Power Supply* appears to be the "reverse-log" potentiometer. The choice of metal (***it must be metal***) case is left to individual preference, most of our component advertisers should be able to offer a good selection.

The reverse-log potentiometer took the designer some tracking down and was eventually purchased from **Electrovalue** (☎ ***01784 433604***), code J10KC, with switch. The small finned heatsink for the Darlington transistor came from **Electromail** (☎ ***01536 204555***), code 403-162. Other component suppliers should also stock identical types.

The miniature 4-pole 3-way rotary switch is a Lorlin type and came from **Maplin**, code FF76S. The 6VA 9V mains transformer was ordered from **Rapid Electronics** (***01206 751188***), code 88-0275. This is a 12VA type with two 6VA secondary windings.

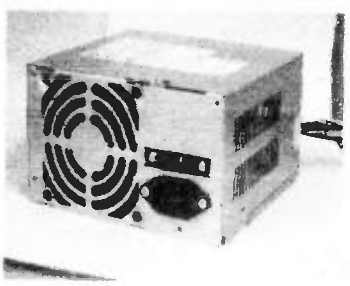
The printed circuit board is available from the *EPE PCB Service*, code 187 (see page 315).





SALE PRICE £9.95

VIDEO PROCESSOR UNITS?/6v 10AH BATTS/24V 8A TX Not too sure what the function of these units is but they certainly make good strippers! Measures 390X320X120mm, on the front are controls for scan speed, scan delay, scan mode, loads of connections on the rear. Inside 2 x 6v 10AH sealed lead acid batts, pcb's and a 8A? 24v torroidial transformer (mains in) sold as seen, may have one or two broken knobs etc due to poor storage £9.95 ref VP2X



Dell switched mode psu 12v 15amp £9.95

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UK made energy saving device that can give you a 15% saving on the running costs of fridges etc
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Pack of 10 is £69 ref LOT72
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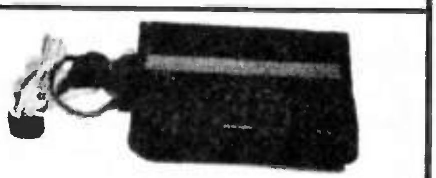

SALE PRICE £10

These units must be cleared at the absurd price of just £10!! you get loads of leads, an infra red remote keyboard and receiver, a standard uhf modulator, a standard bt approved modem 1200/75 and loads of chips, resistors, capacitors etc etc
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Switched mode psu special offer £2.99

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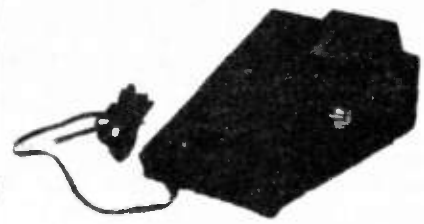

SALE PRICE £2.50

Customer returns, domestic telephone coin boxes, used to convert ordinary phones in to pay phones. ref CBT1X

The ultimate enclosure for your projects must be one of these!

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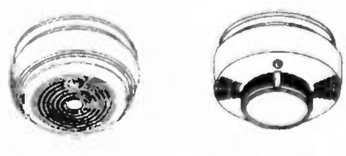
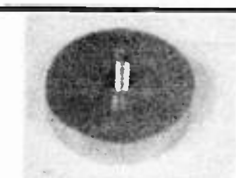


MAINS SMOKE ALARMS (GENT) NEW AND BOXED £4.99 ref SMKX

BBC selector videocrypt 's' tvtuner with smart card

sale price £9.95

Interesting new item in this week is this Selector. Originally made for the BBC to send encrypted video films to your VCR at night time. The project seems to have failed.
Very complex units consisting of a smart card slot in the front plus several switches and an IR receiver. Fully cased and measuring 230 x 430 x 90mm, new and boxed.
On the back of the unit is a scart socket plus a UHF input and output. A channel tuning control numbered 28 to 40 and an IR socket.
Inside is a comprehensive tuner section, smart card reader mechanism and control electronics plus a power supply section.
These units are sold as strippers but we imagine you could use one to convert a monitor into a TV or maybe use the videocrypt side of things for something else. Supplied complete with manual and mains lead.
Clearance price just £9.95 ref BBC1X



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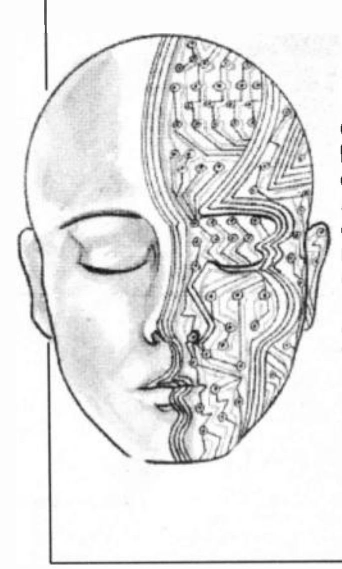
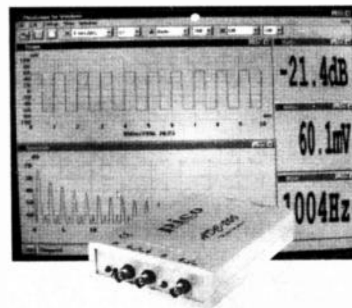
Just in this week are these incredible Neodymium magnets that will lift an incredible 33 kilo's! Each magnet has a threaded bolt protruding from the rear for easy fixing. 32mm diameter. £15 ref MAG33



INGENUITY UNLIMITED

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

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



WIN A PICO PC BASED OSCILLOSCOPE

- 50MSPS Dual Channel Storage Oscilloscope • 25MHz Spectrum Analyser
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- Signal Generator

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

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

Power-saving Solenoid Control – Hold It Low

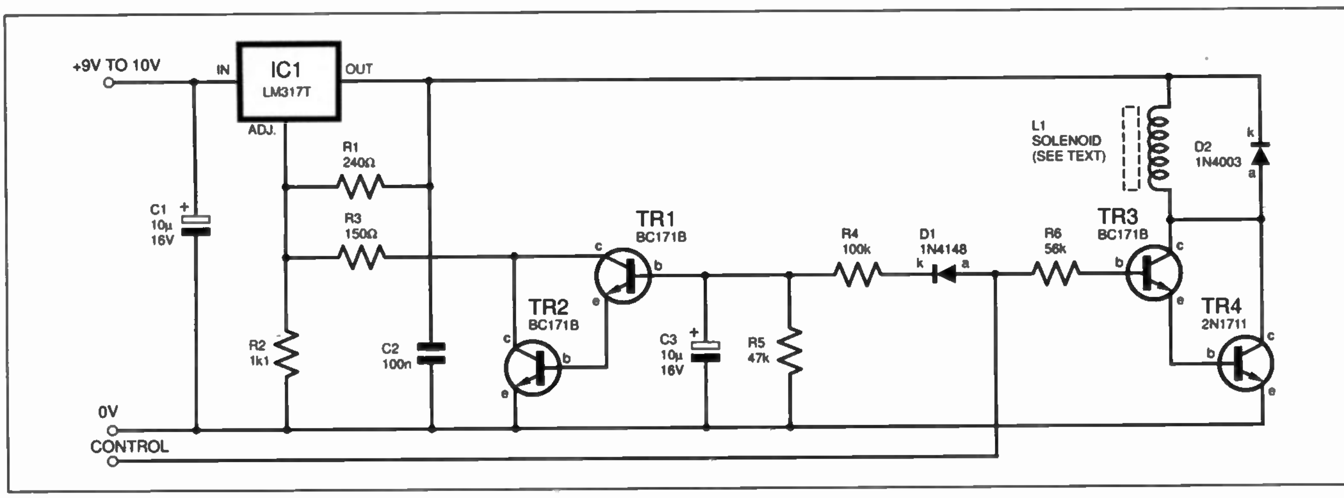

Fig. 1. Circuit of the Power-saving Solenoid Control.

A SALVAGED solenoid I was experimenting with was found to need a minimum of 6V to operate cleanly, but it was still holding in tenaciously at 1·75V. This had the benefit that the current needed dropped from 240mA to 70mA and, rather than getting very hot, the solenoid barely got warm. In terms of power, it held in at 29 per cent of the power it needed to initially operate.

The "power-saving" circuit of Fig.1 was designed to automatically lower the voltage after the solenoid operates. The solenoid, L1, is operated by a CMOS logic signal using an 8V supply.

An LM317T regulator (IC1) provides a regulated supply with resistor R2 chosen to give an initial 6V across the solenoid after allowing for the saturation voltage of Darlington pair TR3/TR4 driving it. When a logic high level is applied to the junction of diode D1 and resistor R6 the full 6V is switched across the solenoid by TR3/TR4.

Meanwhile capacitor C3 is charging via D1 and R4 and after approximately one second when the voltage has risen to 1·4 volts, Darlington pair transistor TR1/TR2 turn on. This places resistor R3 in parallel with R2 which reduces the output of IC1 to about 1·75V. When the logic level goes low C3 discharges completely via R5, and D1 prevents the possibility of C3 trying to momentarily turn on TR3/TR4.

A small heatsink is needed for IC1, but an additional benefit is that dissipation in the regulator is reduced to 60 per cent of that incurred by supplying the solenoid continuously with 6V. The circuit can be easily adapted to suit other solenoids or relays which have low "hold in" voltage ratings, by simply changing the values of resistors R2 and R3 and ensuring that the input to IC1 is 3V higher than the required coil operating voltage.

B.J. Taylor, Rickmansworth, Herts.

Alternative T-type Latch – An Alternative Type!

THE simple circuit of Fig. 2 shows how it is possible to create a "toggle" (T-type) latch using an ordinary 4017 CMOS decade counter i.c. This may prove useful if an alternative to a 4013 dual D-type flip-flop is required.

The counter's Q0 (pin 3) is used as the complementary output and Q1 is taken from pin 2 whilst the Reset signal from pin 15 is connected to Q2 at pin 4. With each clock pulse at pin 14, the outputs of the circuit mimic those of one half of a 4013 arranged as a toggle latch. The circuit can be easily assembled, taking care to use anti-static precautions as the 4000 range is static-sensitive.

Peter Gent, Sutton, Surrey.

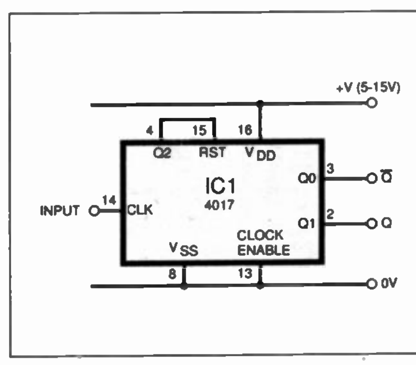

Fig.2. Circuit diagram of the 4017 Alternative T-type Latch.

Bi-colour L.E.D. Indicator – Nice and Easy

MULTI-COLOUR l.e.d.s are useful especially if panel space is restricted, as more than one state can be indicated by a single device. A simple drive circuit for a bi-colour light emitting diode (l.e.d.), of the variety which has a common cathode (k) and separate anodes (a) for each chip colour, is illustrated in Fig.3.

The indicator D1 will glow green when the input signal connected to TR1 base (b) is high, and red when the input is low. Thus two states of indication are possible from a single input signal.

When TR1 is switched *on*, its collector (c) goes low which also takes the base of TR2 low, turning off the latter transistor. This causes the red l.e.d. to be extinguished and D1 glows green. When TR1 is switched *off* (input low) then TR2 base is allowed to rise towards the positive rail via resistor R2, so TR2 switches on and illuminates the red l.e.d.; because TR1 is off, power to the green l.e.d. is removed.

Peter Gent, Sutton, Surrey.

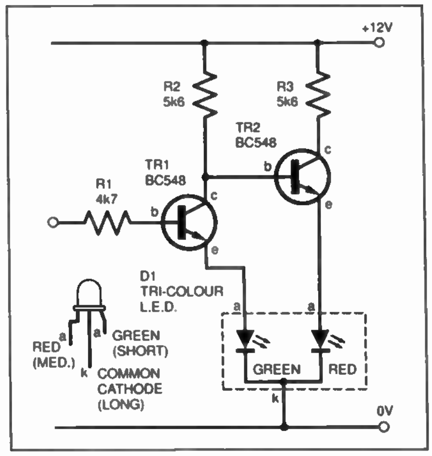

Fig.3 (right). Circuit diagram of the Bi-colour L.E.D. Indicator.

Traffic Light Simulator – Boole has the Answer

ONE standard exercise in logic systems is to convert a two-bit sequence into three outputs in order to simulate the sequence of British traffic lights, which go through *four* cycles (red, red and amber, green, amber, red). When recently tackling this problem, I only had a 4017 decade counter to hand rather than a binary counter, so the circuit of Fig. 4 was eventually devised to incorporate it.

It was realised that a clock pulse (*A*) could be used with a decade counter to give a divide-by-two function signal (*B*), which, together with the clock pulse, gives a sequence of four logic states:

Decade Counter Logic		Binary Counter Logic	
Clock pulse (*A*)	Divide-by-2 (*B*)	Most Significant Bit	Least Significant Bit
1	1	0	0
0	1	0	1
1	0	1	0
0	0	1	1
(Repeat)		(Repeat)	

This gives the correct numbers but in the wrong order. The next task was to equate this to the four stages of the traffic light sequence. By applying Boolean Algebra, it was possible to decode the *A* and *B* logic signals to give the logic behind the red, amber and green output states:

A	*B*	Red	Amber	Green
1	1	1	0	0
0	1	1	1	0
1	0	0	0	1
0	0	0	1	0

The Boolean reduction is very simply calculated as follows:

$$R = A.B + \bar{A}.B = (A + \bar{A}).B = B$$
$$Y = \bar{A}.B + \bar{A}\bar{B} = \bar{A}(B + \bar{B}) = \bar{A}$$
$$G = A.\bar{B}$$

Remember that the full-stop "." means Logic AND whilst the "+" symbol in Boolean algebra means Logic OR. *(Incidentally we emphasise the AND symbol by using a large blob ● symbol throughout our* Teach-In '98 *series. Sometimes, the full stop is omitted altogether. A.R.W.)* The three formulae were then translated into an electronic logic circuit as shown in Fig. 4, which divides into four distinct sections.

IC1 provides a clock pulse *A* based around a 555 astable multivibrator, with potentiometer VR1 controlling frequency. Resistor R1 is a low value to give a near 1:1 mark-space ratio. S1 when closed allows the traffic lights to be "frozen" by forcing the output of IC1 high, until either red or green displays continually.

IC2 is a 4017 configured as a divide-by-two, with Q2 (pin 4) hard wired to the reset pin (15). The decoded output Q0 (pin 3) is used as the *B* logic signal discussed earlier. A CMOS 4011 quad 2-input NAND gate is used for IC3, and the four NAND gates are used as inverters or gates as necessary to complete the logic design.

Each coloured l.e.d. is driven by a transistor switch, TR1 to TR3. Red is driven by *B*, the output from the 4017 at pin 3. Amber is driven by an inverted *A* clock pulse via IC3a, whilst Green requires three more NAND gates: IC3b inverts *B*, IC3c is used to NAND A with $\bar{B}$, and IC3d inverts this to produce an AND final result which drives the green signal.

Thomas (aged 10) and Nick Walton, Frodsham, Cheshire.

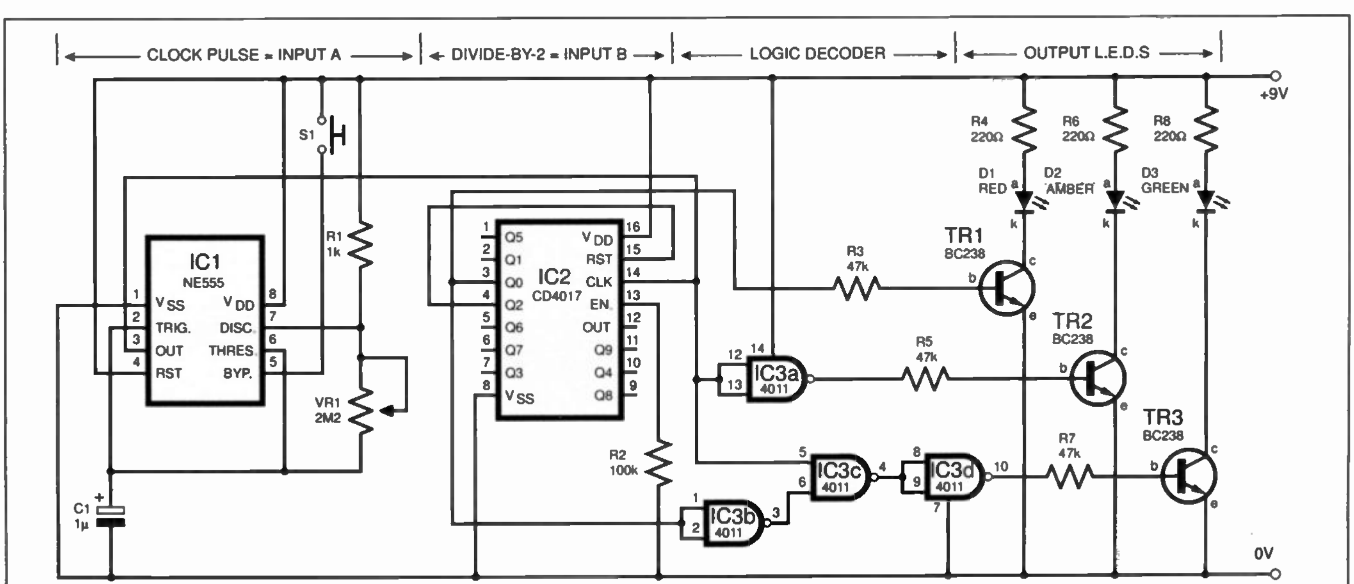

Fig.4. Circuit diagram of the Traffic Light Simulator driven by a decode counter.

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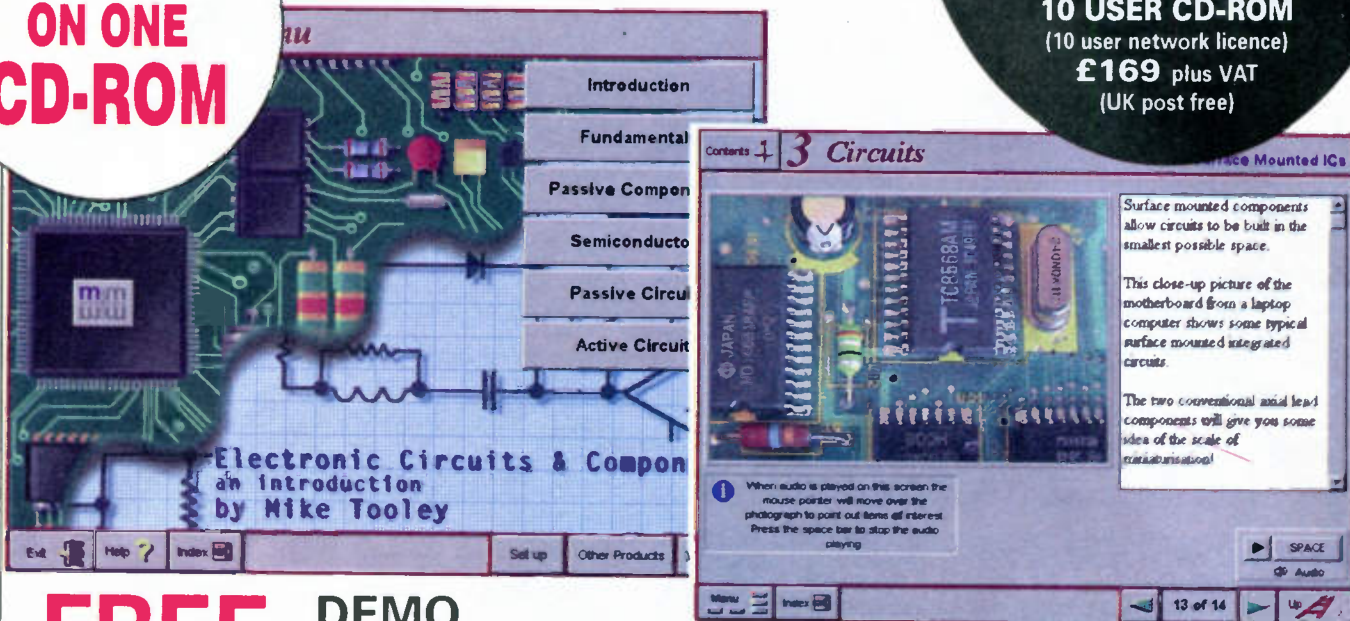

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EE11

READOUT

John Becker addresses some of the general points readers have raised. Have you anything interesting to say? Drop us a line!

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Every month Peak Electronic Design Ltd will be giving a DTA30 to the author of the best *Readout* letter published.

★ LETTER OF THE MONTH ★

BACKING THE FUTURE

Dear EPE,

I have been an electronics hobbyist for ten years now and it is a hobby which has also provided me with a successful career, as I am now a qualified electronics technician working at a major multinational company.

It has been with great sadness that I have read of the decline of electronics as a hobby. This decline seems to be a result of two separate factors. The first of these seems to be that many electronics hobbyists are switching off their soldering irons and switching on a PC instead.

The same is true of many of the electronics courses on offer today, with practical breadboard experiments being replaced by a PC-based circuit simulation. As a part-time lecturer in a local college, I have noticed this in many of the courses being run at present, This, in my mind, has led to an increase of college graduates who, although proficient in electrical and electronics theory, are generally lacking in the practical skills necessary in today's electronics industry. Some of them can have difficulty in making a good soldered joint.

The second factor relates to the view of many electronics hobbyists and would-be hobbyists, that commercial consumer electronic equipment can be purchased at a much lower cost than building home-made equipment. This view is in many ways correct, and it is with this point in mind that I believe your magazine, which I have bought every issue for the past ten years, has a vital role in keeping electronics alive as a hobby. It is only in publishing innovative projects each month which are not generally available commercially, due to the fact that they may not be commercially viable to manufacture, that you will keep hobbyists and students of electronics with their soldering irons in hand.

For example, some of the simple projects I have had published in *EPE* through *Ingenuity Unlimited*, such as the *Fuse Tester* (Apr '97) or *L.E.D. QuickTest* (Nov '96), are easy to construct, but are also difficult to obtain commercially. Projects like these keep hobbyists building and, when neatly enclosed in a suitable housing, become very presentable too.

So, the moral of this letter is more simple-to-construct, innovative projects please, like the series of "pocket-money" projects that you ran back in the '89/90 timeframe. These will be one sure thing to keep many constructors building.

Mark McGuinness,
Clondalkin, Co. Dublin,

It is unquestionably true that hobbyist involvement in electronics is less pronounced than it was at its peak during the 1970s. However, for the last few years, a degree of stability seems to have prevailed and not only do we have a hard-core of readership who remain loyal to their hobby, but also sufficient numbers of newcomers to reassure us that there continues to be a viable future for hobbyist electronics enthusiasts.

Whilst, since the mid '70s, computers have indeed displaced the role and opportunities for the "pure" electronics hobbyist, we regard them as an essential tool in the electronics workshop – as important a tool as the multimeter and oscilloscope. There is so much software available now that allows them to be used in all sorts of ways in which electronic designs can be created, tested, drafted, simulated and so on.

We know that in many electronics colleges computer simulation and instruction techniques are widely used to teach electronics, partly for tutorial convenience, but probably mainly for reason of financial restrictions. Quite simply, to put an oscilloscope, multimeter, signal generator, frequency counter, logic analyser, power supply and the rest on each student's workbench would cost many times more than providing them each with computer simulation facilities (and there are many excellent software packages readily and cheaply available). In an ideal world the hands-on approach is desirable, but inevitably those with the chequebooks usually have a more powerful say than those who teach the subject.

As we have highlighted in many previous Readout *pages, there is definitely a necessity for us to publish simple projects. There is, after all, a constant pool of beginners for whose needs we have to cater. Nonetheless, the needs of our more advanced readers must also be fulfilled through the publication of more complex designs. Naturally, since many of those readers have discovered the benefits of computers, microprocessors, microcontrollers and similar sophisticated digital products, we try to keep them happy too.*

The amazing reception that PIC-orientated projects produce confirms that our approach to electronics must include not only hardware discussions and examples, but also projects and features involving firmware and software. Reader interest in programming generally is well evidenced by the correspondence we receive.

Thank you for your interesting observations and comments.

UNPROCRASTINATED!

Dear EPE,

After years of passive interest (i.e. procrastination!) I have finally decided to take up electronics as a hobby and have subscribed to your magazine to follow the *Teach-In* series.

My previous interest was 30 years ago when as a 6th former I became a founder member of the school electronics club, and campaigned for electronics to be taught as a regular lesson. Ironically, the campaign was successful in the year I left school – too late for me to benefit.

I am amazed at the low cost of components today and the brilliance of the Protobloc breadboard. I placed a mixed component order with one of your advertisers (Greenweld) and within minutes of receipt had a working astable oscillator (using BC108s) – thrilled to bits or what!

I am looking forward to following the series and already have a few ideas for bespoke security and automotive circuits.

Incidentally, after reading *Readout* of Feb '98, I can confirm that the whole area where I live has lead water pipes and just a couple of months ago a Water Authority official assured me that there was no risk to health as I live in a hard water area and the pipes are all long since furred up!

Bob Hylands,
Coventry

Always good to hear of people willing to become addicted to electronics again (beware that there is still no known cure, though!). If you come up with any interesting circuit ideas you would like to share with other readers, drop us a line.

PDSL

Dear EPE,

Your *Virtual Scope* article of Jan '98 mentions that the machine code was prepared using the A86/D86 compiler from the Public Domain Shareware Library (PDSL). I would like a copy of this but am unable to find the PDSL on the Net to download it. Could you please help?

Nick Gribble,
via the Net

Ringing PDSL, I was told that they are not yet on the Net, but to "watch this space" – i.e. they have Plans Afoot!

In the meantime, anyone wanting more info about PDSL's enormous range of Shareware software can do so via:

PDSL, Dept EPE, *Winscombe House, Beacon Road, Crowborough, Sussex TN6 1UL. Tel: 01892 663298.*

Ask them for a catalogue – it's well worth having!

FULLER DESCALING

Dear EPE,

Having built the *PIC Pipe Descaler* (Oct '97) from a Magenta kit last September, I feel that some report is due from my own personal angle.

The unit has been running in two modes for 24 hours a day (except when we were on holiday). The obvious check over a total period of ten weeks operation was the kettle element casing (six boil-ups a day).

In August '97 it took over four and half minutes to boil two pints of water from cold, the scale thickness being then 2·5mm. By the middle of December, by softening and dispersing molecularly, the scale thickness had reduced to 0·7mm then, within a fortnight, to 0·5mm, which showed that two pints could be boiled in three minutes seven seconds!

This meant that the kettle usage over one day had reduced by nine minutes switch-on time. At the same time, assuming the *PIC Descaler* burns 2W per hour at 6·16p per unit, it costs 28p per 13 weeks. The saving of the kettle alone at 1·5kW for 13 weeks is 13·65 hours at 9·24p per kW hour.

Therefore, by my calculations, about £1 is saved every 13 weeks, or £4 per year, on the kettle alone, without assessing an even larger saving on the 3kW immersion heater used for household water heating – an extra £8 per year, perhaps.

Also, the shower head has not needed descaling, whereas normally before the advent of the *PIC Descaler* I cleared its holes every six weeks.

Our house is a standard three-bedroom semi with a half-inch bore mains water inlet and our water supply is drawn from a chalk down.

I am grateful to Mark Stuart for his article and have been, and remain, excited by the whole affair. I feel my efforts have been well worth while in building this descaler.

John D. Fuller,
Waterlooville, Hants

Thanks for confirmation that electronic water descaling can be effective. Any more of you with tales to relate on this subject?

DEVOTED IN OMAHA

Dear EPE,

I would like to say I find your magazine one of the best I have read in a long time. I have been picking up copies at the newsstand but they don't seem to be carrying them any longer. I will have to mail in my subscription.

Here in the USA we have a wide variety of magazines in the electronics world, but none that come close to yours in quality. I am sure if more people here were to see the magazine they would feel the same way.

Keep up the good work. I look forward to receiving the next issue soon.

Tom,
a devoted fan in Omaha, USA,
via the Net

Thanks for your kind comments. We are encouraging our US distributor to obtain better EPE *availability on your side of the pond.*

TUNING PIPES?

Dear EPE,

Exchange rates in Malaysia deter me from ordering parts for the *PIC Water Descaler* (Oct '97) from Britain at present.

Examining the software downloaded from the Web, however, it looks like Mark Stuart sweeps only in the audio frequencies. So, instead of using the *Descaler* controller as published, can I use an old transistor radio to drive the coil? And can you please give some advice as to whether rock, classical or talk radio would descale best?

Whilst on the subject, has there been any work done on clearing plaque from cardiac arteries? The world is waiting for some non-invasive technique, and this may be just what is needed!

K.C. Toh,
Petaling Jaya, Malaysia, via the Net.

In those immortal sporting words, "you can't be serious"! Or are you? We've been caught out before on leg pulls ...

However, seeing as how the whole subject of water descaling still has no satisfactory explanation, why not experiment with your Tranny? As to the audio subject matter, we suggest you try such fluid favourites as Handel's Water Music, La Mer, The Blue Danube, Bridge Over Troubled Waters, The Onedin Line, *or the* Dam Busters March.

Even if this music doesn't do much for the household pipes, at least you'll *feel better for it, and that must surely be good for your heart and its pipes!*

WELL TAYLORED!

Now for an extract from a very lengthy letter from our inveterate letter writer and IU contributor, BJT (you must love designing and writing as much as I do, Barry!).

Dear EPE,

First, many thanks to you, AW and Pico for selecting me as the first prize winner for my IU submission (award reported in IU Dec '97).

The background to the circuit started about 20 years ago when I noticed in the 1976 edition of the *RCA IC Data Book* that the CA758E and CA1310E stereo decoders had a buffered 3V positive-going square wave from their internal v.c.o.'s divide-by-4 output on pins 11 and 10 respectively. Having found that the tolerance of the pilot tone was ±2Hz, I used this to check the accuracy of a counter I had built.

Recently, I expanded the counter and needed a reference source to check it, but no longer have a tuner using one of the above decoders. As far as I can tell, present day decoders don't have a 19kHz output available.

After much consideration and the help of an excellent American college text book (*Experiencing Electricity and Electronics*, Mark Hazen), plus a calculator, it became clear that I had a suitable choke "in stock". Thirty minutes later I had a working prototype!

Barry J. Taylor,
Rickmansworth, Herts

And the rest is IU *history!*

MORE WRITING REWARDED

Dear EPE,

Great news, I have been reading *PE/EPE* since 1973 but very rarely write in. It is great to have contributed and to be selected as *Letter of the Month* (March '98). Very many thanks.

I am currently looking forward to the PIC programming series, having recently built a 16C/F84 programmer/in-circuit tester.

Bill Ellingham, Lydney, Glos

Could you be in-line for the Lottery as well, perhaps?

SCOPE .BAT

Dear EPE,

Thank you for your advice on installing my Virtual Scope files (*An "L" of a Problem, Readout* March '98) – bingo, I have success!

Readers might be interested to know that I have also written the following .BAT file for it, using the DOS EDIT screen editor:

```
CD\SCOPE
QBasic/RUN VSCOPE.BAS
CD\
```

This was saved as **SCP.BAT** and now just typing **SCP** when in the root directory of C: results in the *EPE Virtual Scope* program loading and running all ready to go.

Many thanks for your help in sorting out my problem.

Bob Bradley,
Scarborough, N.Yorks

Isn't the feeling great when you get something to work! Your use of EDIT to create a .BAT file is commended – knowledge of DOS as well as BASIC is a valuable asset.

BASIC SYSTEM

Dear EPE,

Referring to R.L.A. Latham's assumption (*Readout* Dec '97) that the SYSTEM call will work with QBasic is only true if QBasic is entered through use of the RUN option, e.g.:

C:\DOS\QBasic/RUN TEST

where TEST is the QBasic program name.

Jeya Bala Singam,
Malaysia, via the Net

You've taught me something as well! Having tried it now with QBasic and QuickBASIC, both from within a program and via the F6 real-time screen, I can confirm that it works – up to point.

I find that if a program is stopped, modified or saved and then run using F5 or shift-F5, the return to DOS does not occur. Instead, one is simply given the option to "Press any key to continue", doing which simply drops you back into Basic edit mode.

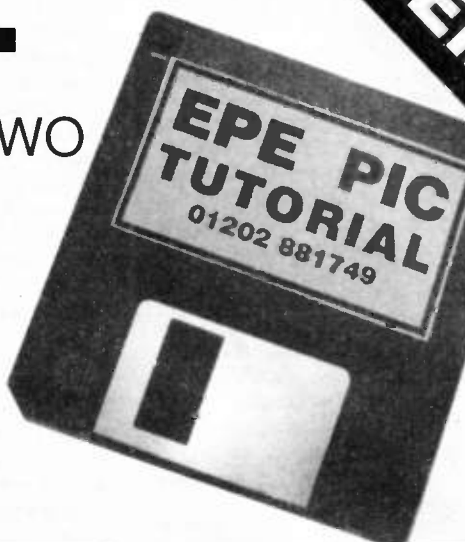
Nonetheless, if the program is not halted, the RUN/SYSTEM combination does return you to DOS (or the directory level from which the command was first given).

Another useful bit of knowledge acquired. Thanks!

FREE SUPPLEMENT

EPE PIC TUTORIAL

JOHN BECKER PART TWO



Quite simply the easiest way to learn about using PIC Microcontrollers

In this part we play with switches, make noises, count time, and generally have fun with some more PIC16C84 commands!

TUTORIAL 4

CONCEPTS EXAMINED

Double-naming numbers
Bit naming
Bit codes C, F, W
Bit testing
Conditional loop
Instructions PAGE0 and PAGE1
Instruction #DEFINE
Command MOVLW
Command MOVWF
Command RLF
Command RRF
Command BTFSS
Command BTFSC
Command PCL
Program counter
Register PORTB
Register TRISB

PROGRAM – TUT 4
SWITCH SETTINGS – see Fig.10 (shown in Part 1)

INSTRUCTIONS #DEFINE AND PAGE

One concept that you are likely to see in PIC-TASM software is that of defining a frequently used command format as a single name. Each time TASM encounters that name during assembly, the defined command will be substituted in the coding.

Two such definitions appear at the top of Listing 4:

#DEFINE PAGE0 BCF STATUS,5
#DEFINE PAGE1 BSF STATUS,5

The command PAGE0 is then used each time the programmer would otherwise key in BCF STATUS,5. Likewise with PAGE1.

It's not only shorter, but conveys another concept more clearly than would direct manipulation of STATUS bit 5, that of Pages, which were referred to in passing earlier.

We have seen that STATUS bit 5 switches between addresses $00 to $7F and $80 to $8C. In fact, the latter extends to $FF, but addresses greater than $8B are not available to the programmer. Writing to them simply wraps them back to an address $80 bytes earlier.

All of the Special Function registers, of which so far we have met five, are held between $00 to $0B and $80 to $8B (see Table 2 and Table 3 in Part 1). It makes for an easy shorthand way of defining which group is which if we refer to the lower group as being in PAGE0, and those of the second group as being in PAGE1. In fact, any other names could be used, as with named numerals, but page numbering

LISTING 4 - PROGRAM TUT4

```
; TUT4.ASM
; using aliases, bit names and conditional loops
#DEFINE PAGE0 BCF STATUS,5
#DEFINE PAGE1 BSF STATUS,5
            .AVSYM
STATUS:     .EQU $03            ; STATUS register
TRISB:      .EQU $06            ; Port B direction register
PORTB:      .EQU $06            ; Port B data register
C:          .EQU 0              ; Carry flag
W:          .EQU 0              ; Working register flag
F:          .EQU 1              ; File register flag

            .ORG 4              ; Interrupt vector address
            .ORG 5              ; Start of program memory

            CLRF PORTB          ; clear Port B data register
            PAGE1               ; PAGE1
            CLRF TRISB          ; set all Port B as output (clear direction reg)
            PAGE0               ; PAGE0

LOOP1:      MOVLW 1             ; load value of 1 into Working register
            MOVWF PORTB         ; load this value as data into Port B
            BCF STATUS,C        ; clear Carry flag

LOOP2:      RLF PORTB,F         ; rotate value of PORTB left by 1 logical place
            BTFSS STATUS,C      ; check if the Carry flag (bit 0) of the STATUS
            GOTO LOOP2          ; command is actioned only if PORTB is not
                                ; yet 0
                                ; the program jumping back to address LOOP2
            GOTO LOOP1          ; command is actioned only when PORTB
                                ; now = 0

            .END                ; final statement
```

EXTRA PROGRAM!

Since publishing Part One, an extra program has been added to the disk – TUT.BAT
It allows quick assembly of all the TUTxx.ASM files, just type TUT

LISTING 4A - THE .SYM SYMBOL FILE FOR LISTING 4

AS C	N:0000
AS F	N:0001
AS LOOP1	N:0009
AS PORTB	N:0006
AS LOOP2	N:000c
AS STATUS	N:0003
AS TRISB	N:0006
AS W	N:0000

from zero is a common situation in computing generally.

This, then, is why the terms PAGE0 and PAGE1 have been defined as above: it's simply an easy to remember convenience.

In Listing 4, following the two definitions we see STATUS and PORTB being nominated (equated) as in Listing 3 (Part 1), representing $03 and $06 respectively. The name TRISB has crept in, though, and it also relates to $06. Why two names for the same number?

It is done for the convenient reason that we know address $06 relates to registers which appear in PAGE0 and PAGE1, but which have different functions, Port B's data and direction registers, respectively. It saves confusion, therefore, to have a different name for each, even though their address numeral is the same.

The name TRISB is given to Port B's direction register since this is the name given to that address in the PIC16C84 data book. The name PORTB now simply refers to Port B's data register.

Exactly the same convention can be applied to Port A, using PORTA and TRISA as the names.

(Incidentally, as we mentioned earlier, there is a command TRIS available as part of the PIC16C84's command set, as shown in the *PIC Data Book*. Microchip recommend that it should not be used since it has been deleted from chips later than the PIC16C84. The same applies to the command OPTION. None of these commands will be discussed here. You will see the use of TRISA, TRISB and OPTION in this tutorial, but the terms are used as *file* names, not as commands.)

Where Special Function registers have had their functions equated to a name that is similar, henceforth the new name will be used. For example, Port B will be referred to as PORTB, Port A as PORTA and Status as STATUS.

Additionally, in order to avoid repetition of comments made in earlier listings, from now on listing comments will not always be shown here for situations that have previously been discussed. The listings on the disk, however, show the appropriate comments where appropriate.

You will have noticed that the use of hexadecimal notation is gradually being introduced for some numbers.

BIT NAMES

All the numerals to which names have been allocated so far have been related to file byte addresses. It is equally possible to allocate names to particular bits in a file byte. This is especially useful when individual bits of particular files perform specific functions.

We could, for example, call STATUS bit 5, PAGE or bit P, equating it to 5 at the head of the listing, as with other names:

P: .EQU 5

In this instance, however, it is of no benefit to do so because an equivalent shorthand now exists through the PAGE definition. It is beneficial, though, to several other file bit uses, three of which are shown in Listing 4:

C: .EQU 0
W: .EQU 0
F: .EQU 1

BIT NAMES F AND W

We have already said that data can be routed either to files or retained in the Working register. A single bit code, either 0 or 1, determines which destination. This bit value statement is required following the comma used with some commands.

For example, take the two similar commands RLF PORTB,0 and RLF PORTB,1, the command RLF (which is discussed in a moment) tells the PIC that the value within the file then stated (in this case the file is PORTB) is to be rotated left (multiplied by two).

The result of this rotation can either be put back into PORTB, using the 1 suffix, or held in the Working register for further use, using the 0 suffix. If the Working register is chosen, the value in PORTB remains as it was.

Again for easy human understanding, it is more convenient to give a name to the different conditions than having to remember numbers. So the file destination 1 is called F for File, and the Working destination 0 is called W for Working. All very logical and clear!

The two example commands thus become RLF PORTB,W and RLF PORTB,F.

CARRY FLAG BIT C

One bit of STATUS, bit 0, is the bit which indicates whether a Carry or a Borrow has occurred during some commands. (It is, incidentally, common to refer to such bits as being "flags": the flag is then said to be set or cleared by any action which affects it.)

The Carry flag is frequently required to be read in most programs and it is convenient to also give it a name, in this case C, hence the setting-up statement:

C: .EQU 0

The bit can be manipulated or tested by commands such as BCF STATUS,C or BTFSS STATUS,C (discussion of BTFSS comes in a jiffy or two!).

Before going any further with the contents of Listing 4, load its code into your PIC and run it (TUT4.OBJ).

What you will see is that individual l.e.d.s on PORTB are being turned on at the same time that the preceding one is turned off. The movement will appear to be going from right to left, from bit 0 to bit 7 (LB0 to LB7), and restarting at bit 0.

There are several ways of doing this (and many reasons why you should need to). Two programming techniques are discussed here, the one in Listing 4, and then a much shorter one in Listing 5.

The one in Listing 4 demonstrates the use of the commands MOVLW, MOVWF, RLF, BTFSS, and how two loops can be "nested" and made dependent upon each another.

COMMANDS RLF AND RRF

Many of you will be familiar with the electronic concept of shift register chips. Data can be loaded into the register either serially (bit entry) or in parallel (byte entry). The data can be shifted to the "left" or "right" in the chip, in response to a clock signal. The shifted data can then be made available either serially as bits, or in parallel as a byte.

When data is shifted left and read as a byte (parallel output), each shift has the effect of multiplying the data by two. Shifting to the right divides it by two.

Take the 8-bit binary code 00000100 (decimal 4), for example. If this is shifted left by one place, the result is 00001000 (decimal 8). If the code had been shifted right by one place, the result would be 00000010 (decimal 2).

Most files within the PIC16C84 are capable of having their data shifted (rotated) to the left or to the right (although doing so on the special registers may sometimes produce unpredictable results). The two commands are RLF and RRF (Rotate Left File and Rotate Right File). Both commands have to be followed by the file which is to have its data rotated, then a comma and then the destination, either F or W. For example: RLF PORTB,F or RLF PORTB,W.

If the W destination is chosen, the original contents of the file remain intact (the result going into W); they are only changed if the F suffix is used.

There are two problems associated with rotating a file's contents left or right.

For the first, consider the situation when a file (for the sake of example, call it PORTB) contains a value such as 11010111 (decimal 215) – there are many numbers that could illustrate the point about to be made.

Suppose the rotate left command RLF PORTB,F is given, all bits are rotated left by one place. The value retained in PORTB becomes 10101110 (decimal 174) which is definitely not 2 × 215; the original lefthand bit has vanished from this 8-bit byte – a 9-bit byte would be needed to show the correct answer.

RIGHT AND CARRY

Alternatively, suppose the rotate right command RRF PORTB,F is given, all bits are rotated right by one place. The value retained in PORTB becomes 01101011 (decimal 107), which is definitely not 215/2; the original right-hand bit has vanished from this 8-bit byte.

In some cases, of course, the intention of rotating left or right may have nothing to do with multiplying a value by 2. It may be that we simply want to change the position of the bits for another purpose, such as changing the commands sent to the outside world to turn equipment on or off. In this case, the arithmetic accuracy of the rotate result would be immaterial.

The other problem (although it can be used beneficially) is that bits rotated out from either end of the byte are rotated into the Carry bit of STATUS. Simultaneously, the previous bit held in the Carry bit is rotated into the byte at the other end.

Supposing that the Carry bit is initially zero, in the first RLF example above, the original value of 11010111 would be rotated left and the result would be correct as shown (10101110) because the 0 has come in to the right from the Carry bit. However, the last left-hand bit of the original value (which is a 1) would now be in the Carry bit.

Suppose then that another rotate left is made. The bits within PORTB would be rotated left but, at the same time, the Carry bit from the previous rotation would now be rotated into PORTB from the right.

The value held in PORTB thus becomes 01011101 (decimal 93), and again the Carry bit now holds the 1 from PORTB bit 7. Therefore, the next rotation will result in a answer of 10111011 (decimal 187).

To avoid a set Carry bit (which retains the status last acquired anywhere in the program) being rotated automatically into a file byte from the other end, the Carry bit can be cleared by the command BCF STATUS,C prior to each rotate command, unless, of course you want a set Carry bit rotated into a byte.

Referring again to the display you see on the l.e.d.s at the moment, controlled by TUT4, the Carry bit clearing technique is being used immediately prior to the RLF command. We shall see what happens if the Carry is not cleared when we view TUT5 later.

COMMAND MOVLW

In Listing 4 is the command MOVLW 1. The MOVLW command (MOVe Literal value into W) is the command which allows literal values (numbers) contained within the program itself to be moved (copied) into the Working register for further manipulation. The range of values is from 0 to 255, i.e. an 8-bit byte. Command MOVLW 1 instructs that the value of 1 is to be moved into W.

Literal values may be expressed in decimal, hexadecimal or binary. The following statements are equivalent in their result:

MOVLW 73 (decimal)
MOVLW $49 (hexadecimal)
MOVLW %01001001 (binary)

Literals may also be the address values of other files whose names have been specified at the head of the program, or they may be the values assigned to be represented by other words or letters. The following are all legal commands:

MOVLW STATUS, MOVLW PORTB, MOVLW W, MOVLW LOOP1

Respectively, the commands would move into W the address value of STATUS (which we have specified as $03), the address value of PORTB ($06), the value assigned to be represented by W (0), the address within the program at which the command line prefaced by LOOP1 resides (a value known only to the program – unless you examine the .LST file).

An important point about any of the Move commands, such as MOVLW, MOVWF and MOVF is that the original value (source value) itself remains where it is and is unchanged. The value is simply *copied* into the destination specified.

Having moved a literal value into W it can then be immediately moved into a specified file destination, or it can be used as part of a further manipulation.

COMMAND MOVWF

Following the MOVLW 1 command in Listing 4 is the command MOVWF PORTB. Command MOVWF (MOVe W into File) simply copies the contents of the W register into the file specified, in this case PORTB. Apart from the destination statement, no commas or other statements are needed (or allowed) with this command.

The MOVWF command is the only way in which full bytes of data can be copied from W into other destinations. As used in Listing 4, it is the value of 1 which is copied.

COMMAND BTFSS

Another command we are introducing in Listing 4 is BTFSS, Bit Test File Skip if Set. What BTFSS does is to examine the status of the file bit specified in the remainder of the command (bit C of STATUS in this case: BTFSS STATUS,C). The word Set now becomes the important one. The PIC is being asked to test if the bit specified is Set (i.e. is it logic 1?).

There can only be one of two answers, either *yes* or *no*. In programming (and digital electronics too) if the answer is *yes*, then the answer is said to be *true*. If the answer is *no*, then the answer is said to be *false* (not true).

Now we come to a situation which some find difficult to grasp until they understand *what* happens when the validity of the question has been established. It's simple, though, once the facts are known!

The convention is that if a situation is *true* then it can be represented by logic 1. Conversely, if the situation is *false* it can be represented by logic 0. Logic 1 and logic 0 are, of course, the two states in which a binary bit can be. Hold this idea in your mind for a moment and consider the next fact.

We have seen that programs are stored as instructions in consecutive bytes. It has been shown that these bytes are numbered from zero upwards (Listing 3A – TUT3.LST). Microcontrollers such as the PIC16C84 keep track of which program byte number is currently being processed, and there is a counter which holds this information – the Program Counter (PCL, as it is named for the PIC – Program Counter Literal).

Unless told otherwise, when one instruction has been performed, the program counter is simply incremented (a value of 1 added to it) and the next consecutive command is performed.

CHANGE OF ADDRESS

The program address number held by the PCL can be changed, either when the instruction is one such as GOTO or CALL, or by the user telling it to add another literal value to itself. The next instruction performed is that at the address pointed to by the new value.

It will be seen, then, that if the value of 0 is added to the PCL, the next instruction is simply the next one on. If, however, the value of 1 is added to the PCL, then the next consecutive instruction is bypassed (skipped) and the one beyond it is performed instead.

For example, if the program counter is at 12, then normally it will automatically add one to itself and the next instruction will be that at 13, and the one after that will be at 14, etc. If, somehow, we intervene and add 1 to the counter while it's still 12, the counter will become 13 but will still add its own value of 1 to itself, making 14. The program will thus jump straight from 12 to 14, omitting the instruction at 13. Should the value of 0 be added, then, of course, the program will go straight from 12 to 13.

Coming back to BTFSS, we know that the answer will be either 0 or 1. When the PIC performs the BTFSS command, the answer is automatically added to the PCL. Therefore, still assuming a PCL starting value of 12, if the answer is true (1), the PCL has 1 added to it and so the next instruction performed is that at 14, as above. If the answer is false (0), then zero is added to PCL and so the instruction at 13 is performed, again as above.

Look again at Listing 4: we see the command BTFSS STATUS,C, i.e. we are checking if bit C of STATUS is set (true). If if is true that the bit is set, then the 1 of the truth answer is added to PCL and so the command GOTO LOOP2 is bypassed and that which says GOTO LOOP1 is performed.

If STATUS bit C is not set (false) then the program simply takes GOTO LOOP2 as the next command because the 0 of the false answer is added to PCL. OK so far?

COMMAND BTFSC

While we still have this concept in our minds, let's look at the command which is the opposite of BTFSS, namely BTFSC (Bit Test File Skip if Clear).

What this command does is to check if it is true that the bit being tested is clear (0). If it is true that the bit is clear, then the answer is 1. If it is false that the bit is clear (that the bit is not 0, but 1), then the answer is 0.

Let's see what happens in Listing 4 if we replace BTFSS by BTFSC. BTFSC STATUS,C tests the C bit to find out if it is true that it is clear. If it is true, 1 is added to PCL and command GOTO LOOP1 is performed. If it is false that bit C is clear, then 0 is added to PCL and so GOTO LOOP2 is performed.

We have, perhaps, somewhat laboured this explanation, but the concept of bit testing and the resulting action is one which causes some people problems, especially when testing for a bit being clear. Why, they ask, is it that the answer is 1 if the tested bit is zero? Why does 1 equal 0? It doesn't, what you are looking for is the truthful answer to the question posed. Think about the question, think about the answer to it.

It is an important concept to grasp, and there are other situations where it occurs: when testing the digit carry and zero flags of the STATUS register (bits 1 and 2, respectively). We shall encounter those situations in Tutorials 5 and 7.

LISTING 4 AGAIN

What you see the program of Listing 4 doing is the simple action of repeatedly "moving" an l.e.d. from right to left. There are only seven commands involved, yet, as witnessed by the length of discussion so far, there are several important commands and their concepts to be fully understood.

Let's relate those commands in simple terms to what is happening in the program.

First, at label LOOP1 the value of 1 is moved into W, this is then moved into PORTB, setting its bit 0 to 1 and clearing bits 1 to 7. As a result, the first l.e.d. at the right is turned on (LB0) and the others (LB1 to LB7) are turned off. In binary, PORTB's value is now 00000001.

Next, the Carry bit of STATUS is cleared to prevent it from interfering with the results of the rotate-left command that follows at label LOOP2 (as discussed earlier).

You will see that this command is RLF PORTB,F. The F suffix means that the result of the rotation is retained in PORTB, and the contents of PORTB will have shifted so that the second l.e.d. (LB1) has come on because the 1 previously set by the MOVWF command has shifted from PORTB's bit 0 to its bit 1. Since the Carry bit was previously cleared, 0 is moved into PORTB bit 0, turning off l.e.d. LB0. The binary value has become 00000010.

Now the value of the Carry bit in STATUS is checked to see if a 1 has been shifted out from PORTB bit 7. In fact, it cannot have occurred yet since it takes eight shifts to bring the 1 from the right and into Carry. However, the PIC is not aware of that fact, so the Carry bit has to be checked following each shift left.

If the Carry bit is not yet set, the command GOTO LOOP2 is performed, the program jumps back to that position and the RLF command is again actioned. As a result the third l.e.d. (LB2) will come on and the second l.e.d. (LB1) will go out, binary 00000100.

Eventually, after eight shifts, the 1 will have shifted through all eight bits of PORTB and into the Carry bit. At this point, there will be no bits set in PORTB, and so no l.e.d.s will be on. Now, on the test for the Carry bit being set, the answer will be true, command GOTO LOOP2 will be bypassed and the command GOTO LOOP1 will be performed, the program jumping to that label.

The whole sequence then recommences by a 1 again being loaded into PORTB bit 0. As written, the program will repeat until the PIC is switched off or the Reset switch is switched on.

EXERCISE 4

4.1. What do you think will be the l.e.d. display sequence if another value is loaded into PORTB via the MOVLW command? Try any multiple of 2; then try any value that has more than one bit set, using the binary format, e.g. %01001100.

4.2. Also see what happens if the command RRF PORTB,F is used instead of RLF PORTB,F. What do think will happen if you replace PORTB,F by PORTB,W? Then see what happens if BTFSC is used instead of BTFSS? (It is a common mistake to use the wrong command in this sort of situation.) Now swap the two commands GOTO LOOP2 and GOTO LOOP1.

4.3. Just out of interest, also try deleting the command BCF STATUS,C (just put a semicolon in front of it).

A SIMPLER ROTATION

PROGRAM – TUT 5
SWITCH SETTINGS – as in Fig.10

Load TUT5.OBJ and run it. It will be seen to be shifting the l.e.d. display to the left, as occurred when TUT4.ASM was first run as TUT4.OBJ (before you started changing it – though, hopefully, you saved each variant under a different name).

You should notice that TUT5 is running a bit faster than TUT4 did. This is because there are now fewer commands to process for the same result. Simplicity of code usually makes for faster processing speeds (or, rather, the fewer commands that need to be processed to perform a particular function, will result in a faster processing speed).

LISTING 5 - PROGRAM TUT5

```
; TUT5.ASM
; Showing how Carry bit rotates into
; register

#DEFINE PAGE0 BCF STATUS,5
#DEFINE PAGE1 BSF STATUS,5

STATUS:  .EQU $03
TRISB:   .EQU $06
PORTB:   .EQU $06
W:       .EQU 0
F:       .EQU 1
C:       .EQU 0
         .ORG 4
         .ORG 5

         CLRF PORTB
         PAGE1
         CLRF TRISB
         PAGE0

         BSF STATUS,C
LOOP:    RLF PORTB,F
         GOTO LOOP
         .END
```

Look at Listing 5 and you will see how few commands there are in the loop, just two. Let's examine the program flow.

Everything up to the statement PAGE0 is the same as in TUT4. Then advantage is taken of the fact that a set Carry bit will be shifted into a file when it is rotated left or right; the command BSF STATUS,C is given before the loop, so setting the Carry bit.

Now when PORTB is rotated left with the command RLF PORTB,F, the Carry bit comes straight into PORTB bit 0, turning on l.e.d. LB0. Simultaneously, the Carry bit is cleared (remember why?). The next command is GOTO LOOP, which the program does, again to rotate PORTB, causing LB1 to come on and LB0 to go out.

For eight rotations left, the Carry bit remains clear, then on the ninth rotation the original 1 that has traversed PORTB will drop into the Carry bit, to be rotated back into PORTB on the next rotation. And so it goes on, indefinitely.

There numerous situations in which rotation occurs and when the setting of the Carry bit is desirable. In this way, several files can be coupled as a very long shift register, e.g.:

```
BSF STATUS,C
RLF FILE1,F
RLF FILE2,F
RLF FILE15,F
```

This technique was powerfully used with the *EPE PIC Time Machine* of November '97, for recording serial data from the Rugby transmitter (eight registers in the chain).

EXERCISE 4 CONTINUED

4.4. What happens if you add another RLF PORTB,F after the first? And if you add a third RLF PORTB,F?

4.5. What happens if you substitute a W for the F in one of the statements?

4.6. What happens if you put the command RLF PORTA,F after the RLF PORTB,F command? Note that because pin RA4 is open collector, LB4 will only come on if switch SA4 is pressed when PORTA bit 4 is set. Why does the sequence not repeat with PORTA rotating back into PORTB?

TUTORIAL 5

CONCEPTS EXAMINED

STATUS bit 2
Zero flag
Command MOVF

PROGRAM – TUT 6
SWITCH SETTINGS – as in Fig.10

It is appropriate at this moment to introduce a command allied to the Carry bit tests, testing the Zero flag bit of the STATUS register. This is bit 2 and in the heading of program TUT6, shown in Listing 6, the letter Z has been equated to it:

Z: .EQU 2

The two opposite commands for zero testing are BTFSS STATUS,Z and BTFSC STATUS,Z, identical to the Carry checking commands except for the change of final letter.

We also take the opportunity to formally demonstrate command RRF (Rotate Right File). It was described in Tutorial 4, but not shown. You probably used it, though, when experimenting with Exercise 4.

Thirdly, the command MOVF is introduced and demonstrated.

Run TUT6.OBJ and refer to Listing 6.

The l.e.d. display controlled under TUT6 should be seen to be rotating right, but otherwise the display repetition should be as seen in TUT4 and TUT5.

LISTING 6 - PROGRAM TUT6

```
; TUT6.ASM
; Using RRF and Z
; Status bit 2
; Zero flag use
; Command MOVF

#DEFINE PAGE0 BCF STATUS,5
#DEFINE PAGE1 BSF STATUS,5

STATUS:  .EQU $03
TRISB:   .EQU $06
PORTB:   .EQU $06
W:       .EQU 0
F:       .EQU 1
C:       .EQU 0
Z:       .EQU 2
         .ORG 4
         .ORG 5

         CLRF PORTB
         PAGE1
         CLRF TRISB
         PAGE0

LOOP1:   MOVLW 128
         MOVWF PORTB
         BCF STATUS,C

LOOP2:   RRF PORTB,F
         MOVF PORTB,F
         BTFSS STATUS,Z
         GOTO LOOP2
         GOTO LOOP1

         .END
```

The program opens up with the necessary initialisation commands. The command at LOOP1 is then seen to be MOVLW 128 instead of the previous MOVLW 1. Decimal value 128 is 10000000 in binary and thus the 1 is at the left of the byte. This is moved into PORTB and the Carry bit is cleared, both commands as in Listing 4.

At LOOP2, command RRF PORTB,F now replaces RLF PORTB,F, instructing the program to rotate to the right, the 1 moving progressively from bit 7 to bit 0 and then into the Carry bit.

Next comes MOVF PORTB,F. Let's examine it.

COMMAND MOVF

Whereas MOVLW meant moving a literal value into W, MOVF means MOVe File value. The file (PORTB in this case) is named following the command, but the command itself does not say where the value is to be moved (unlike MOVLW, where W as the destination is included in the command). The destination is stated by adding a comma after the file name and then adding either W or F, e.g.:

MOVF PORTB,W or **MOVF PORTB,F**

Normally, the command would be used with W, so that the contents of the file are brought into W for presumed further use. At first, then, the concept of using F as the destination seems strange. Why move the file value back into the file without the value having undergone some sort of manipulation?

The reason is that many commands automatically affect various flags in the STATUS register (see Table 1 in Part 1), setting or clearing them as appropriate. We have already seen the Carry flag being affected by RLF and RRF, but the Zero flag is not affected by these two commands (regrettably), so a different technique has to be used to check for zero.

When command MOVF is performed, irrespective of the W or F destination, the Zero flag is affected. It is set if the file value is zero, cleared if the file value is greater than zero.

So, if we wish to know whether or not the file value is zero, we can use the MOVF command to affect the zero flag, and do so without changing the file value.

That is what is happening in Listing 6, moving F back into F to affect the Z flag, which is about to be tested in the next command, BTFSS STATUS,Z. What is being looked for is PORTB's value becoming zero after the 1 has exited from the right of the file (from bit 0).

The logic of BTFSS STATUS,Z is the same as that for the Carry flag. We are looking for the truthful answer to a question, in this case is it true (1) that the Zero flag is set (1)? The answer will only be true if the file value is zero (0) – another of those concepts which some people may find difficult to comprehend, a 1 being used to mean the presence of 0.

If the file value is greater than zero, i.e. does not equal 0, then the answer is false (0) and so the Zero flag is cleared (0).

As with Carry testing, the result of the Zero test (1 or 0) is added to the program counter (PCL) and, depending on the result, either GOTO LOOP2 (Z = 0) or GOTO LOOP1 (Z = 1) is the command actioned.

Consequently, LOOP2 commands will be cycled through eight times before a jump is again made to LOOP1.

EXERCISE 5

5.1. Prove that the Zero flag is affected by the command MOVF PORTB,W as well as MOVF PORTB,F (the proof is that the rotation is the same as before).

5.2. What happens if the 128 of command MOVLW 128 is replaced by another number? Experiment with different values.

TUTORIAL 6

CONCEPTS EXAMINED

Command INCF
Command DECF
Command INCFSZ
Command DECFSZ
Counting upwards (incrementing)
Counting downwards (decrementing)
Use of a file as a counter

PROGRAM – TUT 7
SWITCH SETTINGS – as in Fig.10

To conserve page space, from hereon we shall usually omit the program initialisation commands that have up to now been shown at the top of each listing. Some will be included where they help to clarify the program. Otherwise, assume that any name used in the listing extracts shown will have been defined or equated in the headings. The commands are included in full on the disk file program listings.

Load TUT7.OBJ and run it, then refer to Listing 7.

There are now two new commands illustrated in TUT7, INCFSZ (INCrement File Skip if Zero) and DECFSZ (DECrement File Skip if Zero). Two allied commands, INCF (INCrement File) and DECF (DECrement File), will also be examined.

The ability to increment (add one to) a value, or decrement it (subtract one from) has wide benefits in programming. Two such instances are keeping track of events through the use of counters, and of changing the values of flag bits (when in bit 0).

COMMANDS INCF AND DECF

The concept of commands INCF and DECF are extremely easy to follow. The first simply adds 1 to a file value, the other simply deducts 1 from a file value. If the file value is 255 (11111111 binary) when INCF is called, the value rolls over to zero. If the file value is zero when DECF is called, the value rolls over to 255.

Whenever the result of INCF or DECF is zero, the Zero flag is set, otherwise it is cleared. Testing of the Zero flag can be performed using BTFSS or BTFSC as discussed in Tutorial 5.

Taking PORTB again as the example file, the command formats are INCF PORTB,W or INCF PORTB,F, and DECF PORTB,W or DECF PORTB,F.

As previously discussed, the result of either command with a W suffix is that the new value is held in W, the file itself remaining unchanged. Conversely, the F suffix returns the new value to the file stated. Both F and W suffixes affect the Zero flag response.

LISTING 7 - PROGRAM TUT7

```
BEGIN:    CLRF COUNT
LOOP1:    MOVF COUNT,W
          MOVWF PORTB
          INCFSZ COUNT,F
          GOTO LOOP1
LOOP2:    MOVF COUNT,W
          MOVWF PORTB
          DECFSZ COUNT,F
          GOTO LOOP2
          GOTO LOOP1
```

COMMANDS INCFSZ AND DECFSZ

There are two commands which, respectively, can replace the INCF and DECF commands and which automatically test the Zero flag and take the appropriate route depending on the truth of the answer. These commands are INCFSZ and DECFSZ, as defined at the start of this section.

Using PORTB as the example file, the command formats are INCFSZ PORTB,W or INCFSZ PORTB,F and DECFSZ PORTB,W or DECFSZ PORTB,F.

If the result of any of these commands is zero, the Zero flag is automatically set, otherwise the Zero flag is cleared. The status of the flag determines the program routing in the same way as if the flag had been tested using BTFSS STATUS,Z or BTFSC STATUS,Z.

COUNTING UP AND DOWN

Listing 7 illustrates two loops, one counting up, the other down, alternating between the two after each 256 steps. INCFSZ is used in the first, DECFSZ in the second.

Before entering the loops, at the label BEGIN the counter (COUNT) is cleared. Then at LOOP1 the command MOVF COUNT,W is given, followed by MOVWF PORTB. You should now recognise what the actions do: they cause the value of COUNT to be output to PORTB.

Next, the command INCFSZ COUNT,F is given, adding 1 to the value of COUNT, simultaneously checking if it has reached zero. An answer of not-zero (Z = 0) causes command GOTO LOOP1 to be performed.

Eventually, when COUNT has rolled over to zero, after 256 increments, GOTO LOOP1 is skipped (bypassed) and LOOP2 is entered where the command MOVF COUNT,W is performed, followed by MOVWF PORTB.

These two lines are repeats of those at the start of LOOP1. We shall see later how duplicated lines of code can be avoided by using the code once in a sub-routine, calling it from any other routine that we wish.

Next, DECFSZ COUNT,F is performed, decrementing COUNT from the entry value of zero. COUNT thus rolls back to 255. Simultaneously, the command checks if COUNT has reached zero. If it has not, GOTO LOOP2 is performed.

When COUNT has decremented to zero, command GOTO LOOP1 is performed and the cycle restarts, and so on.

It will be spotted that the use of a separate counter is not actually required in this example. We could increment or decrement the value of PORTB directly, but we are using COUNT instead to illustrate the use of a separate file to store data. We might, for example, want to increment COUNT, and then go off and do some other processing using COUNT's value, outputting that answer to PORTB instead.

EXERCISE 6

6.1. If you were to use INCF and DECF instead of INCFSZ and DECFSZ, what would be the necessary changes to the program?

6.2. What extra commands would be needed to start each loop with a non-zero value, while still counting until zero occurs?

6.3. What would happen if you had erroneously used W instead of F in one or other of the INC/DEC statements?

TUTORIAL 7

CONCEPTS EXAMINED

Switch monitoring
Command ANDLW
Command ANDWF
Command ADDWF
Command ADDLW
Nibbles
STATUS bit 1
Digit Carry flag

PROGRAM – TUT 8
SWITCH SETTINGS – as in Fig.11

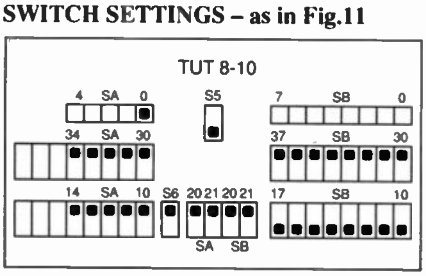


Fig.11. Switch settings for programs TUT8 to TUT10.

We now turn to looking at how data is input via switches and shall continue to show the results on individual l.e.d.s. In Tutorials 21 and 22 we shall look at 7-segment l.e.d.s and intelligent l.c.d.s as the output displays.

Load TUT8.OBJ and run it. Pushing switch SA0 on and off, PORTB's l.e.d.s will be seen to go on and off in a binary sequence when the switch is on (pressed), but will remain in the last condition when the switch is off (released).

In this example, the program tests whether the status of switch SA0, which is connected to PORTA RA0 (bit 0), is on or off. If it is on then the counter variable, COUNT, is repeatedly added to (by 1 in this example). A value of zero is added to the count if the switch is off. The count value is output to PORTB.

First let's look at two of the commands introduced here, ANDLW and ADDWF. Their counterparts ANDWF and ADDLW will also be examined.

COMMANDS ANDLW AND ANDWF

As no doubt most of you are aware, if one binary number is ANDed with another, then only if the same bits of both numbers are set (1) will the answer also have a 1 in that position. Any zeros on either or both sides for any bit will automatically produce a result of 0, e.g.:

First number: 01110010
Second number: 01011001
ANDed answer: 01010000

This technique is widely used in electronics and computing, the final answer determining the subsequent action to be taken by a circuit or software routine.

There are two ANDing commands available with the PIC16C84, ANDLW (AND Literal to W), and ANDWF (AND W with File value).

Suppose that the first number above (01110010) is already contained within W, we then wish to AND it with a fixed number as stated in a program command. Assuming that the fixed number is the second number above, the command is:

ANDLW %01011001

The PIC ANDs the second (literal) number with that already held in W. The answer (01010000) is retained by W and is available to be further manipulated or copied into any file as specified by the command which follows ANDLW. You could, for example, use the command MOVWF PORTB which will turn on l.e.d.s LB6 and LB4 (01010000).

Any of the three numerical formats may be used with ANDLW, e.g. %00011111 (binary), $1F (hexadecimal), 31 (decimal), are all legitimate and equal. It is also legitimate to use a name that has been equated with a value, e.g. ANDLW PORTB (which would AND 6 with W since we have previously specified that the name PORTB represents the value 6).

The command ANDWF is used to AND an existing value within W to a value within a named file, either retaining the answer in W (ANDWF FILENAME,W) or back in the named file (ANDWF FILENAME,F).

It is not possible to directly AND the contents of two files together, the value of one or other file must have already been moved into W before the ANDing can take place.

With both commands ANDLW and ANDWF, if the answer is zero, the Zero flag of STATUS is set. If the answer is greater than zero, the Zero flag is cleared. Zero is the only flag affected by an AND command.

LISTING 8 - PROGRAM TUT8

```
BEGIN:  CLRF COUNT
LOOP:   MOVF PORTA,W
        ANDLW %00000001
        ADDWF COUNT,F
        MOVF COUNT,W
        MOVWF PORTB
        GOTO LOOP
```

COMMANDS ADDLW AND ADDWF

There are two ADDing commands available with the PIC16C84, ADDLW (ADD Literal to W), and ADDWF (ADD W to a File value).

Command ADDLW is used where a fixed number (literal) within a program is to be added to an existing value within W and which has been obtained by a previous operation.

Suppose that W holds the answer produced in the previous ANDing example, 01010000 (decimal 80), and you wish to add a fixed value to it, 53 decimal (00110101), for instance. The command would be:

ADDLW 53 (or ADDLW $35 – hexadecimal, or ADDLW %00110101 – binary). The answer in this instance is 10000101 (decimal 133) and is retained in W for further use or copying into a file, e.g. MOVWF PORTB.

Command ADDWF adds the contents of W to the value within a stated file. The answer can be held in W (ADDWF PORTB,W) or put back into the named file (ADDWF PORTB,F).

Three flags within STATUS are affected by any ADD command, Carry, Zero and Digit Carry.

If the answer to an addition is greater than 255, the Carry flag is set, otherwise it is cleared. If the answer equals zero, the Zero flag is set, otherwise it is cleared.

The third flag, Digit Carry, we have not encountered yet. Although the concept is not illustrated until later (Tutorial 19), it is appropriate to describe it now.

If you imagine that an 8-bit binary number (e.g. 10110110) is split into two halves (known as *nibbles*), 1011 and 0110, the right-hand nibble is monitored by the PIC as a separate digit and it is served by its own flag, the Digit Carry flag. If an addition takes place which produces a result greater than 15 (1111) for that nibble, the Digit Carry flag is set, otherwise it is cleared.

LISTING 8 FLOW

Having described the new terms, we shall now see what happens in Listing 8. Note that PORTA push-switches are biassed so that PORTA pins are normally at 0V (low) but go high when pressed.

In this example program, at the label LOOP the contents of PORTA are copied into W (MOVF PORTA,W), which then holds the status of all five usable bits of that port.

We are only interested, though, in the status of the switch on PORTA bit 0, switch SA0. Therefore, in the next command (ANDLW %00000001) bit 0 is ANDed with 1 to isolate its value, the other seven bits in W being cleared by the respective zeros of the ANDed value.

The answer in W is then added to the contents of the counter (ADDWF COUNT,F). Next, the contents of the counter are brought back into W (MOVF COUNT,W) and then copied into PORTB (MOVWF PORTB), whose l.e.d.s are turned on or off depending on the binary count value.

With the command GOTO LOOP, the sequence is repeated. It will be seen that there is only an increase in the count value if PORTA bit 0 holds a 1, therefore the count will only change if the switch is on (pressed). Pressing any other PORTA switch has no effect.

When the counter passes 255, its value rolls over to zero and starts counting upwards again.

EXERCISE 7

7.1. Can you see another way of writing the first two lines using MOVLW and ANDWF?

7.2. Can you see how the BTFSS or BTFSC commands might be used to achieve the same output result; the use of MOVLW 1 or ADDLW 1 could be useful here.

7.3. There is also the opportunity to use INCF in this type of situation. Try rewriting to include this command.

7.4. What happens if you bias PORTA pins and switches to the opposite polarity by setting SA20 and SA21 to the down position? (Return them upwards when you have finished examining this situation.)

TUTORIAL 8

CONCEPT EXAMINED

Increasing processing speed of TUT8
Bit testing for switch status

PROGRAM – TUT 9
SWITCH SETTINGS – as in Fig.11

In TUT8 we saw that the count adding commands etc. were performed even if the count value was zero. This is a waste of processing speed, why bother to add zero to a count?

The program in Listing 9 shows a faster alternative. Load TUT9.OBJ and run it.

LISTING 9 - PROGRAM TUT9

```
LOOP:     BTFSS PORTA,0
          GOTO LOOP
          INCF COUNT,F
          MOVF COUNT,W
          MOVWF PORTB
          GOTO LOOP
```

By using the command BTFSS to check the status of a switch (in this case still SA0 on PORTA bit *0), if* the switch is not pressed we can avoid the count incrementing procedure, jumping immediately to a further switch status test. Alternatively, in another program, by substituting another destination instead of LOOP, we could jump to a totally different routine and perform some other procedure.

Another choice is to use the command RETURN instead of GOTO LOOP to return to another routine which had called this one. Commands CALL and RETURN will be covered in Tutorial 13.

It is expected that you will recognise from Listing 9 what the program does and how it does it. If you don't, re-read Tutorial 4 and the section on BTFSS.

EXERCISE 8

8.1. What happens if you use BTFSC instead of BTFSS?

8.2. Could one of the Zero flag testing commands be used instead of BTFSS? If so, how, and would an AND command be useful? (Remember that PORTA has more bits than just bit 0).

TUTORIAL 9

CONCEPT EXAMINED

Responding to a switch press only at the moment of pressing

PROGRAM – TUT 10
SWITCH SETTINGS – as in Fig.11

LISTING 10 - PROGRAM TUT10

```
BEGIN:    CLRF COUNT
          CLRF SWITCH
TESTIT:   BTFSC PORTA,0
          GOTO TSTPRV
          BCF SWITCH,0
          GOTO TESTIT
TSTPRV:   BTFSC SWITCH,0
          GOTO TESTIT
          INCF COUNT,F
          MOVF COUNT,W
          MOVWF PORTB
          BSF SWITCH,0
          GOTO TESTIT
```

In the switch press examples of Listings 8 and 9, we saw that the counter was incremented for the entire duration of the switch being on. Often, only a single response to a change of switch status might be required. This entails testing the switch status and comparing it with a previous test. Only if the switch is on and if that on condition has not yet been responded to will the next action be performed.

Load TUT10.OBJ and run it. We are still monitoring PORTA bit 0 for the switch press (SA0), responding to it via the l.e.d.s on PORTB. Observe the l.e.d.s while pressing SA0 on and off. For each pressing, only one change of the l.e.d. count will occur.

Study Listing 10: the entry to the routine is at BEGIN where two variables, COUNT and SWITCH are cleared. At the label TESTIT, the command is BTFSC PORTA,0, testing the status of PORTA bit 0 (is it clear?). Remember that we are only interested in the bit being set.

If it is false that bit 0 is clear (i.e. that it is set – the switch is pressed) the command GOTO TSTPRV is performed and then the status of SWITCH bit 0 is tested, BTFSC SWITCH,0. This bit serves as the flag to keep track of the previous status of the switch.

At this moment, the bit will be clear because the whole byte was cleared on entry to the routine. Consequently, the GOTO TESTIT command is skipped, the count is incremented and its value output to PORTB.

Now SWITCH bit 0 is set (BSF SWITCH,0) to indicate that the count has been incremented for this switch press (i.e. the flag is set), and the program jumps back to TESTIT.

If the switch is still pressed, then at TSTPRV the BTFSC SWITCH,0 command will produce a false answer and the command GOTO TESTIT will be performed, thus preventing the counter from being further incremented at this time.

What is now needed is for the switch to be released so that the two commands BCF SWITCH,0 (clear the flag) and GOTO TESTIT can occur.

The stage is then once again set for the next switch press to be responded to by the counter.

EXERCISE 9

9.1. In Listing 10, AND and MOV commands could have been used instead of BTFSC and BCF. How, and with what other command?

9.2. Would using BTFSS instead of BTFSC involve more commands and labels having to be used as well?

TUTORIAL 10

CONCEPTS EXAMINED

Performing different functions dependent upon which of two switches is pressed
The use of a common sub-routine serving two other routines

PROGRAM – TUT 11
SWITCH SETTINGS – as in Fig.12

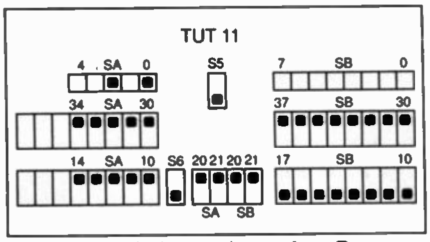


Fig.12. Switch settings for Program TUT11.

The response of the programs will by now seem to be getting a bit slow, so switch S6 has been switched down to disconnect capacitor C3 and so increase the clock rate. Adjust preset VR1 to suit yourself.

Load TUT11.OBJ, run it and experiment with the switches on PORTA bits 0 and 2 (SA0 and SA2).

You will discover that switch SA0 causes the count displayed on the l.e.d.s to be increased, and that switch SA2 decreases the count.

The basic logic flow is the same as that in Listing 10, except that two switches are used and each switch is responsible for a different routine. Note that whilst each switch could have had its own routine to output to PORTB, the two routines would be the same. Consequently, each switch routine is routed into a common output sub-routine (OUTPUT).

At the end of SA0's routine, the command GOTO OUTPUT needs to be given, but at the end of SA2's routine, no GOTO OUTPUT command is needed because OUTPUT follows immediately after it.

LISTING 11 - PROGRAM TUT11

```
BEGIN:    CLRF COUNT
          CLRF SWITCH
TEST1:    BTFSC PORTA,0
          GOTO TSTPR1
          BCF SWITCH,0
          GOTO TEST2
TSTPR1:   BTFSC SWITCH,0
          GOTO TEST2
          BSF SWITCH,0
          INCF COUNT,F
          GOTO OUTPUT
TEST2:    BTFSC PORTA,2
          GOTO TSTPR2
          BCF SWITCH,2
          GOTO TEST1
TSTPR2:   BTFSC SWITCH,2
          GOTO TEST1
          BSF SWITCH,2
          DECF COUNT,F
OUTPUT:   MOVF COUNT,W
          MOVWF PORTB
          GOTO TEST1
```

EXERCISE 10

10.1. How do you think a single test for *neither* of the switches being pressed could be introduced, shortening the testing time? Could an AND be used with a STATUS check, or can a STATUS check be used on its own without an AND? (Think carefully about the latter.)

10.2. How would you increase the count by more than one, say two, at each press of switch SA0? With the knowledge you've gained so far, three ways should come to mind, one of them including the use of a new named variable.

10.3. If you want to add 255 each time a switch SA0 press occurs, do you need an ADD command, or is there another command which will do the same job?

TUTORIAL 11

CONCEPTS EXAMINED

The ease of reflecting PORTA's switches on PORTB's l.e.d.s!
Command COMF
Command SWAPF
Inverting a byte's bit logic
Swapping a byte's nibbles

PROGRAM – TUT 12
SWITCH SETTINGS – as in Fig.13

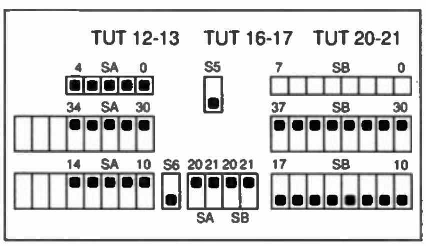


Fig.13. Switch settings for Programs TUT12, 13, 16, 17, 20, 21.

Load and run TUT12.OBJ; experiment with pressing any combination of the switches on PORTA (SA0 to SA4) while observing the l.e.d.s on PORTB.

This routine should need no further comment. Another way of expressing the first two commands is:

```
LOOP:     MOVLW %00011111
          ANDWF PORTA,W
```

Now load TUT13.OBJ and run it, again experimenting with pressing any combination of the switches on PORTA (SA0 to SA4) and observing the l.e.d.s. on PORTB.

PROGRAM – TUT 13
SWITCH SETTINGS – as in Fig.13

You will see while you press PORTA's switches, that its four right-hand switches (SA0 to SA3) are having their status displayed on PORTB's four left hand l.e.d.s. (LB7 to LB4). The fifth switch (SA4) will be affecting the first l.e.d. on the right (LB0).

What is happening is that the software has been told to swap and move into W (SWAPF PORTA,W) the left and right-hand four bits of PORTA (its nibbles, as introduced in Tutorial 7). The answer is then ANDed with bits that reflect the swapped status in order to remove any possibility of influence by the original three unused bits of PORTA.

The SWAPF command is especially useful if the values of the two nibbles are required separately as values of up to 15

LISTING 12 - PROGRAM TUT12

```
LOOP:     MOVF PORTA,W
          ANDLW %00011111
          MOVWF PORTB
          GOTO LOOP
```

LISTING 13 - PROGRAM TUT13

```
LOOP:     SWAPF PORTA,W
          ANDLW %11110001
          MOVWF PORTB
          GOTO LOOP
```

LISTING 14 - PROGRAM TUT14

```
LOOP:     COMF PORTA,W
          ANDLW %00011111
          MOVWF PORTB
          GOTO LOOP
```

(00001111). A good example of its use will be seen in Tutorial 21. It is illustrated now because of its programming similarity to TUT12 and TUT14.

The F suffix can be used with SWAPF instead of W, as with other files discussed. There is no command which allows nibbles to be swapped once the byte is in W. If a byte within W needs swapping, it must be put out to a file, and then the SWAPF FILE,W command given to bring it back into W.

Let's look now at another command which uses a similar demonstration routine to TUT12 and TUT13. Load and run TUT14.OBJ. Once more, experiment with pressing any combination of switches SA0 to SA4 while watching PORTB's l.e.d.s.

PROGRAM – TUT 14
SWITCH SETTINGS – as in Fig.14

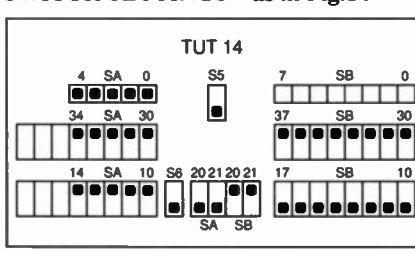


Fig.14. Switch settings for Program TUT14.

You will now discover that instead of l.e.d.s being turned on when a switch is pressed, they are turned off, and vice versa. This is due to the command COMF, which automatically inverts each bit of a byte, 1s becoming 0s, 0s becoming 1s, i.e. it performs a task known as 2's complement, hence COMF – COMplement File.

There are several uses for this command, one of which is the situation when all the switches are biased to the 0V line instead of the positive. In that instance, and using the switch testing techniques shown earlier, pressing the switches would produce the wrong bit levels for the commands shown: switches would need to be held pressed for off, releasing them for on. Not an easy thing to do with push-switches!

Switch down PORTA switches SA20 and SA21 so that PORTA pins RA0 to RA4 are biassed to +VE, going low when switches SA0 to SA4 are pressed (as in Fig.14 and as you did in Exercise 7.4).

Run the program again. Now you will find that the l.e.d.s respond as they did for TUT12. Now run TUT12 again and confirm that the l.e.d. results are the inverse of that previously seen with it.

Another use for COMF is in subtraction. This is a concept for experienced programmers and will not be illustrated here. However, in a nutshell, the use of COMF allows *addition* to be used instead of subtraction while still achieving the desired objective. This technique can be easier in some instances than using the available subtraction commands.

The F suffix can be used with COMF instead of W, as with other files discussed. There is no command which allows the inversion of a byte once it is in W. If a byte within W needs inversion, it must be put out to a file, and then the COMF (FILENAME),W command given to bring it back into W.

EXERCISE 11

With these exercises, switches SA20 and SA21 should be restored to their previous settings, i.e. up, as in Fig.13.

11.1 If SWAPF was not available as a command, how would you write a routine which produced the same result (would RLF or RRF be suitable commands)?

11.2 Rewrite TUT13 and TUT14, putting the contents of W out to a file of any name (which you must equate at the beginning of the program), performing another COMF or SWAPF action, and then bringing it back into W for output to PORTB. Can PORTB be used as the temporary file store in these rewrites?

11.3. Write a routine that allows the nibbles of a byte to be put into separate files and each having a value no greater than $0F (decimal 15); there are several ways of doing it.

TUTORIAL 12

CONCEPTS EXAMINED

Generating an output frequency in response to a switch press
The use of two port bits set to different input/output modes
Command NOP

PROGRAM – TUT 15
SWITCH SETTINGS – as in Fig.15

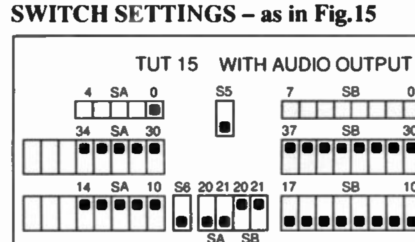


Fig.15. Switch settings for Program TUT15.

So far we have been outputting data to l.e.d.s, and at a comparatively slow rate. We have also been using one port as a switch input and the other port as the output.

Here we examine how the same port can be used simultaneously for input and output via different bits. In doing so, we use sound as the medium by which we indicate the status of a switch, generating an audible frequency when it is pressed.

Change the switch settings as shown in Fig.15. Also, via jack socket SK1, connect

LISTING 15 - PROGRAM TUT15

```
SOUND:   MOVLW 80
         MOVWF NOTE
         MOVWF FREQ

GETKEY:  BTFSC PORTA,0
         GOTO GETKEY
         DECFSZ NOTE,F
         GOTO GETKEY
         MOVF FREQ,W
         MOVWF NOTE
         MOVLW 16
         ADDWF PORTA,F
         GOTO GETKEY
```

a pair of high impedance headphones or plug the circuit into the input of an amplifier system. Do not connect a loudspeaker directly to this circuit; there is insufficient power to drive it.

Note that switches SA20 and SA21 are set down in order to bias pin RA4 (open-collector) so that an output can be generated on it.

Load TUT15.OBJ and run it, pressing switch SA0 on and off – a frequency tone will be heard.

In the initialising statements at the head of the full TUT15.ASM program, PORTA has been set with bits 0 to 3 as inputs and bit 4 as an output (MOVLW %00001111, MOVWF TRISA).

You should now recognise all the commands given in the heart of the program shown. Only a general commentary on what happens is given.

On entry into the routine headed SOUND, a value of 80 is loaded into the files named NOTE and FREQ. The value is arbitrary as far as this demonstration is concerned. You may choose any other from 1 up to 255; the lower the value, the higher the frequency generated.

PORTA's status is monitored at GETKEY and the clearance (logic 0) of PORTA bit 0 by switch SA0 is being looked for. Switch testing is repeated until SA0 is pressed. When that occurs, file NOTE is decremented and its zero status tested.

If it is not yet zero, the routine jumps back to the switch test. When the switch has been pressed for long enough (mere thousandths of a second), NOTE will eventually reach zero, at which point the command MOVF FREQ,W is reached, followed by the fixed value of FREQ being reset into NOTE.

Next, the value in PORTA has 16 added to it to increment the count at bit 4 (alternating between 0 and 1), and then there is a jump back to further switch testing.

For as long as switch SA0 is pressed, PORTA bit 4 will be periodically incremented. The speed at which the routine runs causes this bit to change at the audio frequency rate to which you are listening. If you adjust the rate setting preset (VR1) on the p.c.b. you will hear the change in the resulting frequency.

In a real-life situation, of course, the operating frequency of the system would normally be fixed. The only frequency correction choice then is to change the value of FREQ.

There is, though, another factor that will affect the resulting audio frequency: the number of commands within the controlling loops. To illustrate the point, let's change the number of commands involved.

You may think that to add more commands would be difficult, what would they do which would not interfere in the completion of the loop? Well, there are several options, such as repeating some of the existing commands, MOVF FREQ,W for example, or MOVWF NOTE. None of these commands would actually change anything, except for the rate of operation.

However, a tailor-made command is already available in the PIC's vocabulary which is intended for use where delay tactics are needed, command NOP.

COMMAND NOP

Command NOP simply stands for No OPeration. Responding to this command takes the PIC just as long as responding to any other but its response is to just do nothing!

This command, then, can be used here to slow down the resulting note frequency. Insert it immediately before DECFSZ NOTE,F. When running the amended program you will notice that a change in the output frequency has occurred.

EXERCISE 12

12.1. Experiment with different values for FREQ. What happens if you set FREQ to zero – does it stop a note being generated? Explain the result.

12.2. Experiment with more than one NOP command in the loop.

12.3. At which other places can you alternatively insert NOP, and is the frequency change still noticeable?

12.4. Are there any places where you *cannot* use NOP?

TUTORIAL 13

CONCEPTS EXAMINED

Command CALL
Command RETURN
Command RETLW

PROGRAM – TUT 16
SWITCH SETTINGS – as in Fig.13

Before looking further into sound generation, there are several commands that we should examine. Three of those are associated with calling sub-routines: CALL, RETURN and RETLW.

Remove your audio connection for the moment, and set the switches as in Fig.13. Load TUT16.OBJ, run it and experiment with pressing different combinations of switches SA4 to SA0 while observing PORTB's l.e.d.s.

COMMANDS CALL, RETURN AND RETLW

Programs can be written as a series of sub-routines which can be reached in one of three ways, directly by default, via a GOTO command, or by a CALL command. (Routing following automatic detection of an interrupt event is another matter and is discussed later.)

We have seen several examples of the first two. Program TUT4 (Tutorial 4) uses them both: the sub-routine LOOP1 is entered directly following the initialisation routine. LOOP2 is also entered directly from the end of LOOP1. Both LOOP1 and LOOP2 are then further accessed by GOTO commands.

However, a CALL command can be used if one routine needs to make use of another and then once that has been completed, for the program to jump back to where it was before the other routine was *called*.

The use of sub-routines allows the same routine to be accessed from many other areas within the overall program, so saving on program space.

A second command always has to be used before the program returns to the calling origin. That command takes one of two forms, RETURN (which is an obvious command – RETURN to where you came from) or RETLW (RETurn to where you came from with a Literal value held in W). There is a third return command, RETFIE, which we shall meet later in connection with interrupts.

A GOTO command can never be used to end a sub-routine call – the PIC will continue to expect a return command and, if repeated calls to a sub-routine are made without a RETURN or RETLW command, it will become confused and unpredictable results could occur.

For example, the following is "illegal":

```
PROG1:   CALL PROG2
         GOTO PROG1
PROG2:   GOTO PROG1
```

This is "legal", though:

```
PROG1:   CALL PROG2
         GOTO PROG1
PROG2:   RETURN
```

When the program returns from a call following a RETURN command, the contents of W are those which were put there by the last command which used W. Consequently, you can perform a complex sub-routine, end up with an answer in W and, using the RETURN command, return to the main program with that result still retained in W.

Command RETLW, though, returns to the main program with W holding the value which RETLW has acquired as part of that command. A literal value is always specified as part of the RETLW command, e.g. RETLW 127 or RETLW 0. That value replaces any other value within W and is the one which is held in W on the return to the calling point. The value may be expressed in decimal, hexadecimal, binary or as a "named" value equated during program initialisation.

LISTING 16 - PROGRAM TUT16

```
LOOP:    CALL PROG1
         MOVWF PORTB
         GOTO LOOP

PROG1:   MOVF PORTA,W
         RETURN
```

To explain Listing 16, then, at LOOP the sub-routine at PROG1 is called from where the value held in PORTA is moved into W. A return is made to the loop where the next command to be performed is MOVWF PORTB, after which the GOTO LOOP command again takes us back to CALL PROG1 again.

EXERCISE 13

13.1. Rearrange TUT16 so that reading PORTA is in the main loop and outputting data to PORTB is in the called routine.

13.2. Try adding other commands in the subroutine, such as AND or ADD.

13.3. Use RETLW as the final statement in the subroutine, using any literal value of your choice, verifying its operation!

TUTORIAL 14

CONCEPTS EXAMINED

Tables
Register PCL
Register PCLATH

PROGRAM – TUT17
SWITCH SETTINGS – as in Fig.13

The use of look-up tables, whose tabulated commands or values are determined by a value set elsewhere in a program, is of enormous benefit. Tables depend on the use of the Program Counter (PCL – discussed in Tutorial 4) and the commands CALL, RETLW, RETURN and GOTO. They *can* be used with other calls within them, but this usually requires making additional commands prior to accessing the table.

When a table is accessed, the value already held in W is added to PCL and causes the program to jump forward by the same number program commands as are in W. The command at the jump address is then performed.

Load TUT17.OBJ, run it and experiment by pushing switches SA0 to SA4 in any combination while observing the l.e.d.s. on PORTB. The l.e.d.s should come on according to the binary value shown in the comments column of Listing 17, i.e. all l.e.d.s will be on if no switch is pressed.

LISTING 17 - PROGRAM TUT17

```
PAGE0
GOTO LOOP
TABLE:
  ANDLW 15          ; AND W with 15
  ADDWF PCL,F       ; ADD to PCL
  RETLW 255         ;0  11111111
  RETLW 1           ;1  00000001
  RETLW '5'         ;2  00110101
  RETLW 0           ;3  00000000
  RETLW 31          ;4  00011111
  RETLW 193         ;5  11000001
  GOTO OTHER        ;6  00011111
  RETURN            ;7  00000111
  RETLW %10101010   ;8  10101010
  RETLW $C7         ;9  11000111
  RETLW 'A'         ;10 01000001
  RETLW 65          ;11 01000001
  RETLW 'B'         ;12 01000010
  RETLW 'x'         ;13 01111000
  GOTO OTHER1       ;14 10001110
                    ;  or 10011110
  MOVF STORE,W      ;15 00000000
  RETURN
LOOP:
  MOVF PORTA,W
  CALL TABLE
  MOVWF PORTB
  GOTO LOOP
OTHER:
  RETLW STORE
OTHER1:
  MOVLW 128
  ADDWF PORTA,W
  RETURN
```

In TUT17, the instruction PAGE0, although individually stated in the extract shown here, follows the initialisation in the normal way. After initialisation, and before any tables are encountered, the command GOTO LOOP bypasses the table commands. Failure to bypass them would cause confusion to the PIC.

At the first command of LOOP, switch data from PORTA is brought into W. The CALL TABLE command then routes the program to the first command within the table, ANDLW 15.

The AND command is essential here to limit the possible value which can be added to the Program Counter (PCL). Because all five switches SA0 to SA4 are in use, we know that the binary value at PORTA could be greater than 15 (all five switches on = 11111 binary = 31 decimal) and we also know that the number of "routing" commands within the table is 16 (0 to 15).

If the table were to be given a value greater than 15, the additive PCL address jump would cause the program to jump beyond the boundary permitted, with unpredictable results.

The ANDing could, alternatively, have been done immediately prior to CALL TABLE.

OMITTING THE AND COMMAND

There are circumstances when the AND statement is not needed. For example, if it is known that the value present in W on the call can never be greater than five, AND would not be needed and the table could be limited to six jump options only (remember that 0 counts as a jump value).

However, if in doubt about the maximum value that could be in W, always use a value limiter of some sort (techniques other than AND can be used). This limiting is especially necessary when a program is being developed since errors in other regions of the program could result in an excessive W value, resulting in a system "crash". When consequential crashes of this type occur, it can be difficult sometimes to establish the primary cause of the problem which is elsewhere.

At the command ADDWF PCL,F the ANDed value remaining in W is added to the Program Counter and the command within the table which corresponds to the new address is performed. For clarity, W's entry value is shown alongside each of the 16 table jumps.

If the W value is 0, then the command performed within the table is the first one (0), RETLW 255. As instructed, the program now returns to the calling point with 255 in W. If the value added to PCL is 5, the command performed is RETLW 193.

In all instances of the RETLW command within the table, the stated literal value is copied into W and the return is made. You will see that, as with other xxxLW commands, the literal value can be expressed in decimal, hexadecimal, binary or equated name values.

What you have not encountered yet is the use of characters in single quotes. Any standard ASCII character from the full 0 to 255 set can be entered in this way, numbers, upper or lower case letters, symbols, etc. During assembly by TASM, any character within the quotes is translated into its ASCII value and it is that value which is returned in W. (In reality, a lot of the ASCII codes will not be available on your keyboard.)

Note that only the "apostrophe" type of quote is permitted ('), that normally residing on your keyboard between the semicolon (;) and the hash symbol (#). The double-quote symbol (") is not permitted, nor is the "left-hand" single quote (‘) found on many keyboards (to the left of numeral 1 and the exclamation mark).

Four examples of "quoted" characters are shown in the table. Quoted '5' will be translated as ASCII 53 (not as the value 5); 'A' and 'B' will become ASCII 65 and 66 respectively; lower case 'x' will be returned as ASCII 120.

You will find this conversion technique invaluable when compiling tables of messages for output to an intelligent l.c.d. (see Tutorial 22 in Part 3).

The simple command RETURN at jump 7 will cause the current value already within W to be returned; i.e. the value on the switches after it has been ANDed with 15. It may not be immediately clear what this action would achieve, but an example is given in Tutorial 15.

TABLED GOTO

There are two examples of a tabled GOTO command in Listing 17, at jumps 6 and 14. These cause the program to jump to the sub-routines named, OTHER and OTHER1. At OTHER, the command MOVLW STORE is executed, after which the program returns to the calling program (not back into the table) with the equated address value of STORE.

The routine at OTHER1 shows how a table jump can go to a routine in which more than one action can be performed, in this case adding 128 to the value at PORTA, then returning as usual. Any action can be performed here, on any file, for any purpose, and there is no limit to the number of commands performed before the final RETURN (within the program space available, of course).

The command at table jump 15 is interesting. It looks as though a command other than GOTO, RETURN or RETLW is being performed. However, this jump is the last in the table and so it is perfectly legitimate to perform any other action(s) here since the program will automatically follow them through without interfering with the normal table action. Here the simple action of getting the value held in STORE is performed, immediately followed by a RETURN.

What would cause table difficulties is if the command at a mid-table jump did not allow an immediate exit from the table. For example, consider the following mid-table jump commands:

```
RETLW 0         ;3
MOVF STORE,W    ;4
RETLW 193       ;5
```

Jump 3 would be OK, so would jump 5. Jump 4, though, would perform MOVF STORE,W (bringing the value within STORE into W), but the exit route for that command is via the address of jump 5, which is RETLW 193, immediately replacing the value acquired in jump 4 with the value 193. Not very helpful!

Mind you, the commands GOTO or RETURN could be at jump 5, which would be fine for jump 4, but what of the result of actually jumping to jump 5, would you necessarily want to just RETURN or GOTO?

One could, perhaps, envisage a table consisting only of INCF STORE,F commands, for example, in which the number of increments generated would be the equivalent of the entry point value of W. But the use of a loop or an addition would, though, probably be more appropriate to that requirement.

It is legitimate to GOTO a table, or arrive at it from the end of another routine, but in this case it may be necessary to only exit the table by GOTO commands. Unless you are already in the middle of a call, "return" commands will cause a program crash.

TABLE SPAN

There is a significant restriction on tables which must not be overlooked. Because of the way in which the Program Counter handles the calls to and from tables, all of the tabulated data must be contained within the first 256 bytes of the program (0 to 255, theoretically, but limited to 6 to 255 because of the restrictions of the Send program as discussed earlier). Not a single jump address must fall outside this block.

Normally, this will be of no great hardship, other than to those who have a whimsical preference to keep the tables near to their calling routines.

When writing software, it can sometimes be difficult, depending on program structure, to ascertain from the code editing program (word-processing software) whether or not the tables overlap beyond the block.

If this is the case, come out of the WP package and assemble the code through TASM. Don't send it to the PIC, but come back into the WP and examine the .LST file that has been generated by TASM for the program as it now stands (for this to work, the program must be free from errors to which TASM will object).

Look at the address numbers (in the second column as you saw earlier in Listing 3A) and see if any part of the table(s) occurs beyond the $00FF hex address (decimal 255). Any overlap beyond (even $0100 – 256) is unacceptable.

PCLATH

Advanced programmers do have a way round the table block limit should they need to find one. It is through the use of the PCLATH register which allows the 256 byte block restriction to be moved into another area of the program.

This command will, of course, be useful if the total number of tabulated items is greater than 256. The author has not yet had occasion to use PCLATH, but did come close to needing more than a 256 block table area for his *EPE Time Machine* (Nov '97).

Being an advanced programmer's command, we shall not illustrate PCLATH here. Interested readers are referred to application note AN556 in the *Microchip Embedded Control Handbook*.

With both the "normal" and PCLATH modified table areas there is no limit on the number of tables within them, and the calling routines can be anywhere within the program, start, middle or end.

It is perfectly legitimate to have subroutines placed between different tables, but remember that their length also consumes part of the 256 byte block.

EXERCISE 14

14.1. Write a routine that calls a table which multiplies a binary number by seven. Use the switches as the source of that number and restrict it to between 0 and 7, showing the results on PORTB's l.e.d.s.

14.2. Using the first four switches of PORTA, create a table to convert the binary numbers generated by them to a BCD (binary code decimal) format; tens of units in the left four l.e.d.s, units in right four l.e.d.s. (If you are not familiar with BCD, think about what it might mean and how it might be shown on l.e.d.s. The use of BCD formats is discussed in Tutorial 19.)

TUTORIAL 15

CONCEPTS EXAMINED

Using four switches to create four different notes

Use of a table to selectively route program flow

PROGRAM – TUT18
SWITCH SETTINGS – as in Fig.16

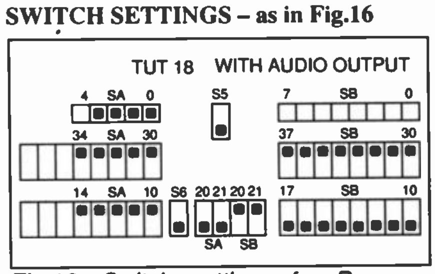


Fig.16. Switch settings for Program TUT18.

The program in Listing 18 allows any one of four notes to played by the switches on PORTA RA0 to RA3 (SA0 to SA3). As with Tutorial 12, the audio output is on RA4. Reconnect your audio monitor, load TUT18.OBJ, run it and press some switches.

You will immediately notice that the "note" frequencies belong to no musical scale known to man. There is nothing we propose to do about that, we are interested in more mundane matters!

The object of this program is to show the use of a table and several sub-routines which allow four notes to be played (singly) depending on the switch presses. Multiple pressing of switches is ignored.

To conserve page space only one note routine is shown. The others are identical except that they process different notes and PLAY4 omits the GOTO OUTPUT command since OUTPUT immediately follows its final command.

You will see the now-familiar commands in the GETKEY and PLAY1 routines. The table should seem recognisable as well.

As in Listing 17, when the program first starts, the table is bypassed and the first main command is at PRESET. Here the frequency values for the four notes are set up as NOTE and FREQ variables.

Switches are monitored as before and calls made to the table. There, routing to different notes occurs only if individual switches are pressed (jumps 1, 2, 4, 8). Any other switch setting, including none, results in a return to the calling point.

When the selected note routine has been processed, a jump to OUTPUT occurs from where the output pin RA4 is toggled, causing a note to be heard.

A RETURN command follows, returning the program to the calling point.

Even from this cut-down version of the program, it is apparent that a lot of commands are involved and that many of them are similar (PRESET) or even identical (PLAY by four).

You will also see that only five calls to the table achieve useful results. The others are wasted but have to be included because four switches can generate 16 permutations of settings. You can't just say to the musician "never press more than one key at once", you have to allow for human fallibility.

If an error can be made by the program user, it will at some time *be* made – Murphy's Law. Programmers must always think about what *might* happen and write the software accordingly (making it "user-friendly" is another way of putting it!).

LISTING 18 - PROGRAM TUT18

```
TABLE:      ANDLW 15
            ADDWF PCL,F
            RETURN       ;0
            GOTO PLAY1   ;1
            GOTO PLAY2   ;2
            RETURN       ;3
            GOTO PLAY3   ;4
            RETURN       ;5
            RETURN       ;6
            RETURN       ;7
            GOTO PLAY4   ;8
            RETURN       ;9
            RETURN       ;10
            RETURN       ;11
            RETURN       ;12
            RETURN       ;13
            RETURN       ;14
            RETURN       ;15
PRESET:     MOVLW 80
            MOVWF NOTE1
            MOVWF FREQ1
            MOVLW 110
            MOVWF NOTE2
            MOVWF FREQ2
            MOVLW 140
            MOVWF NOTE3
            MOVWF FREQ3
            MOVLW 160
            MOVWF NOTE4
            MOVWF FREQ4
GETKEY:     COMF PORTA,W
            CALL TABLE
            GOTO GETKEY
PLAY1:      DECFSZ NOTE1,F
            RETURN
            MOVF FREQ1,W
            MOVWF NOTE1
            GOTO OUTPUT
(PLAY2 to PLAY4 are similar to PLAY1)
OUTPUT:     MOVLW 16
            ADDWF PORTA,F
            RETURN
```

The programmer must usually also think about program speed and program compactness. Sometimes they can both achieve the same result, but not always. More comments on this are made in the author's *PIC-olo Music Maker* project of *EPE* August '97. In that application, program compactness would have unacceptably changed the design's frequency response.

However, for the sake of discussing program options available, in a moment we'll look at how TUT18.ASM could be written in another way. First an exercise for you:

EXERCISE 15

15.1. Change the frequency values in TUT18.ASM to produce notes that are somewhat more harmonically related! What problems do you come up against?

TUTORIAL 16

CONCEPTS EXAMINED

Indirect addressing
Using unnamed file locations
Port B internal pull-ups
Command FSR
Command INDF
Register OPTION

PROGRAM – TUT19
SWITCH SETTINGS – as in Fig.17

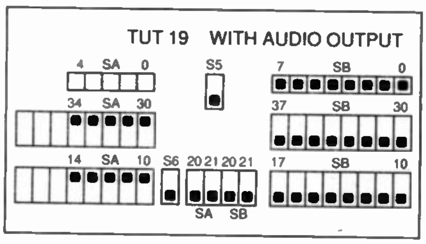


Fig.17. Switch settings for Program TUT19.

Time now to examine a concept that allows us to access generalised routines which can manipulate file values without actually specifying the file names within them. This concept is called *Indirect Addressing*. It also has profound implications for the ability to minimise the number of sub-routines required by a program.

Program TUT19, which uses the technique, will then be discussed and demonstrated.

Indirect Addressing allows the use of generalised routines which do not apply to any specific files. The file(s) which the routine accesses are specified prior to entry into the routine and can be changed at will to suit different aspects of the program.

COMMANDS FSR AND INDF

The two key commands (or, rather, *file registers*) in Indirect Addressing are FSR (File Special Register) and INDF (INDirect File).

The idea of Indirect Addressing is that you place the address of the file that you wish to access in file FSR. Commands to access the specified file address are then made via file INDF.

Not only does this facility allow the same routine to be applied to different calling routines, it also allows a loop to access a sequence of files without having to specify their individual addresses other than that for one of them in the sequence.

In the following example, assume that we have a sequence of files between address $10 and $1F (eight files). Let's call the first file NOTE0. Its address will have been equated at the head of the program in the usual way.

However, provided we assume the next seven addresses to be reserved for seven files which are consecutive to NOTE0, we do not have to give them names unless we actually need to use the names in the body of the program. Even then the names could be anything we like; they do not have to called NOTE1, NOTE2 etc., unless we wish to.

Suppose, for example, we wished to clear all eight of these files prior to another routine and that we shall do it in ascending order using a loop.

Prior to entering the loop we get the address of the first file, in this case NOTE0, copy it into FSR and reset the loop counter, let's call it LOOPA:

```
        MOVLW NOTE0
        MOVWF FSR
        CLRF LOOPA
```

Now all we need to do is use the following simple routine:

```
RESET:  CLRF INDF,F
        INCF FSR,F
        INCF LOOPA,F
        BTFSS LOOPA,3
        GOTO RESET
```

Command CLRF INDF,F clears the file whose address is held in FSR. Next, INCF FSR,F increments the value held by FSR, in other words FSR is incremented to point to the next file we wish to clear (NOTE0 in the first instance of the loop, NOTE1 in the next).

Next, we increment the loop counter, INCF LOOPA,F, and test its bit 3 (BTFSS LOOPA,3) to see if a count value of 8 (00001000) has been reached (remember we started at 0). If the count is not yet 8, the loop is repeated, GOTO RESET. If the count equals 8, the next command after GOTO RESET is performed, whatever that might be in a full program.

Another way of doing it (and there are several ways) is:

```
        MOVLW NOTE0
        MOVWF FSR
        MOVLW 8
        MOVWF LOOPA

RESET:  CLRF INDF,F
        INCF FSR,F
        DECFSZ LOOPA,F
        GOTO RESET
```

You can also use similar constructions to access a sequence of table values (from anywhere within that table) and add them to the values within a sequence of indirectly addressed files, keeping the maximum resulting addition to less than 32.

In the following example (nothing directly to do with TUT19), the first address required in the table is at jump 3. We want to start adding the acquired table value to the file starting six bytes beyond NOTE0 (note how the value of 6 is added to the known address of NOTE0) and that we want to perform the action five times (once for each note).

```
        MOVLW 3
        MOVWF COUNT
        MOVLW 6
        ADDLW NOTE0
        MOVWF FSR
        MOVLW 5
        MOVWF LOOPA

GETVAL: MOVF COUNT,W
        CALL TABLE
        ADDWF INDF,W
        ANDLW 31
        MOVWF INDF
        INCF FSR,F
        INCF COUNT,F
        DECFSZ LOOPA,F
        GOTO GETVAL
```

LISTING 19 - PROGRAM TUT19

```
TABLE:   ANDLW 7
         ADDWF PCL,F
         RETLW 80
         RETLW 110
         RETLW 140
         RETLW 160
         RETLW 180
         RETLW 200
         RETLW 220
         RETLW 240
PRESET:  CLRF PORTB
         PAGE1
         BCF TRISA,4
         MOVLW 255
         MOVWF TRISB
         BCF OPTION,7
         PAGE0
SETUP:   MOVLW 8
         MOVWF LOOPA
         CLRF COUNT
         MOVLW NOTE1
         MOVWF FSR
SETUP1:  MOVF COUNT,W
         CALL TABLE
         MOVWF INDF
         INCF FSR,F
         INCF COUNT,F
         DECFSZ LOOPA,F
         GOTO SETUP1
GETKEY:  MOVF PORTB,W
         MOVWF STORE
         MOVLW 8
         MOVWF LOOPA
ROTATE:  BTFSS STORE,7
         GOTO PLAY
         BSF STATUS,C
         RLF STORE,F
         DECFSZ LOOPA,F
         GOTO ROTATE
         GOTO GETKEY
PLAY:    DECF LOOPA,W
         ADDLW NOTE1
         MOVWF FSR
         DECFSZ INDF,F
         GOTO GETKEY
         DECF LOOPA,W
         CALL TABLE
         MOVWF INDF
OUTPUT:  MOVLW 16
         ADDWF PORTA,F
         GOTO GETKEY
```

INDIRECT ADDRESSING DEMONSTRATED

In the following worked example, part of whose program is shown in Listing 19, we demonstrate how Indirect Addressing allows generalised file accessing routines to be used, how a table can help in that process, and how it helps code to be compacted to achieve more actions within the space available.

With your audio monitor still connected, load TUT19.OBJ and run it, playing with the eight push-switches on PORTB (SB0 to SB7).

You will find that all eight switches produce "notes", but not musically tuned, though! They are also much lower in pitch because of the extra number of commands being processed.

The technique used is, in effect, the same as that demonstrated in TUT18. There are, though, some notable (no pun!) differences:

First, if you look at the full listing on your disk, you will see that in the initialisation, we have only equated NOTE1 (NOTE0 is not used this time) there is no mention of FREQ1 etc. Yet, we are actually using *eight* files to behave as NOTE1 to NOTE8 and we use a table instead of FREQ1 to FREQ8.

What we have done (as discussed a moment ago) is to consider a block of consecutive file addresses to be allocated to NOTE1/NOTE8, starting at $10. To remind us at some future time, there is a comment alongside NOTE1 to this effect in the full disk listing. The next address which we specify cannot, therefore, occur until eight bytes later, at $18, where LOOPA is equated. Any consecutive block of eight bytes could have been used.

As seen in the full program and the extract listed here, a table has eight values in it and an AND command limits the jump span from zero to seven. The values shown are the tuning values which will be accessed periodically throughout the program while it is running.

OPTION BIT 7

In the PRESET routine, note the command BCF OPTION,7. This statement activates PORTB's internal "light pull-ups". This facility allow switches to be used without biassing resistors (assume as a rule-of-thumb that they have an equivalent resistance of about 100kΩ). Note that the default value for each bit in OPTION at power-up and reset is 1 (i.e. 11111111).

Making use of the light pull-ups, however, means that PORTB's input pins are active low, rather than active high as in the previous switch monitoring examples. This means that the port pins to which the switches are connected are normally held high, a switch press then taking them low. Consequently, it is the low condition for which we shall be looking.

Routines SETUP and SETUP1 make use of the indirect addressing facility to set the initial (FREQ) values into the eight notes.

Next comes routine GETKEY in which the status of the eight switches is obtained in the usual way. Now, though, we have to get round a table problem. There are 256 possible combinations of the switches and we only want eight of them, those for any single switches being pressed.

To use a 256 jump table would be extravagant with program space, besides which the jump addresses alone would occupy the entire table block allowable (without compensatory action through PCLATH).

We could, of course, not use a table but simply test each bit of PORTB in turn, and use GOTO statements to obtain data about which note should be played and which note reset value is needed.

Instead, though, for the sake of demonstration, a different technique is used, converting the 8-bit PORTB value to a 3-bit value, covering eight possible combinations rather than 256.

PORTB's value is copied into STORE and a loop set for a maximum of eight operations. Up to eight rotate left (RLF) actions can then be called in routine ROTATE, and the value of STORE bit 7 tested. Each bit of STORE corresponds to a separate switch, so the rotation allows all eight switches to be tested.

The switches have been set to be active-low, i.e. when "on" a zero occurs on its PORTB bit. If a zero is found during the rotation, the value of the loop corresponds to the switch in question and a jump is made to the play routine. If no zero is found, then no switches are pressed and no note play action occurs.

In the PLAY routine, the loop value (LOOPA) is decremented while being moved into W (the loop value will be between 8 and 1 but for program ease we need a value between 7 and 0).

The value of W is added to the address of NOTE1 and the answer is put into the indirect address register FSR.

The note now pointed to by FSR is decremented via INDF and if the result is not zero, a return to GETKEY is made. A zero result causes the value of LOOPA to again be decremented into W and then the table is called, returning with the reset value for the note in use, which is put into it via INDF.

As we have seen before, the output value at PORTA RA4 is then incremented and a jump back to GETKEY occurs.

Had this whole operation been programmed as separate routines for each note, its length would have been considerably greater; indirect addressing, bit rotation and a table have changed that.

We shall use indirect addressing again later.

EXERCISE 16

16.1. In Program TUT19, priority has been given to switches in descending order (test bit 7). How would you rewrite to give priority in ascending order?

16.2. If you wanted one of the switches to be ignored, what extra command(s) would be needed, and where? When considering where, think of the number of times the situation has to be checked for between each input of PORTB's value, remembering that each command processed unnecessarily wastes valuable time.

16.3. In this program, is the AND command at the head the table actually necessary?

16.4. As the program stands, there is one extra file name used than needs to be; which file could be used in two situations?

16.5. Also, with careful thought, parts of the program could be slightly rewritten to save at least seven commands. Can you spot how this could be done? Question all aspects, from initialisation downwards (see also the full listing).

(Whilst the SETUP routine could be heavily rewritten to save four of these commands, in a real programming situation, unless you are extremely short of program space, it is better to concentrate on saving commands in routines that are being called frequently, so significantly increasing the speed of operation. SETUP is only used once, and so has no affect on the loop speed.)

TUTORIAL 17

CONCEPTS EXAMINED

Command XOR
Command IOR
Tone modulation

In a moment, we shall come down to a somewhat simpler audio program, in which we illustrate how two tones can be created, one modulated, the other fixed. Both tones could find use in, for example, a simple intruder alarm.

Also to be illustrated, is how the combined status of two or more switches on a port can be tested using the XOR (Exclusive-OR) command. This allows us to take one action only if all the specified switches are on simultaneously, otherwise taking another action. First, let's examine the XOR command on its own.

COMMAND XOR

PROGRAM – TUT20
SWITCH SETTINGS – as in Fig.13

The command XOR checks for *equality* between two numbers. There are two commands, XORLW (XOR Literal with W) and XORWF (XOR W with value in specified File). The latter is followed by the file name, a comma, and the destination (W or F), e.g. XORWF STORE,W and XORWF STORE,F.

Probably you know that in electronics there are XOR gates included in the digital logic chip families, and you will no doubt have read descriptions of truth tables relating to just two inputs of an XOR gate (two bits):

0 XOR 0 = 0
0 XOR 1 = 1
1 XOR 0 = 1
1 XOR 1 = 0

As far as the PIC16C84 XOR function is concerned, the result of XORing two bytes of eight bits is the condition being checked. It is easier here to show the principle by means of switches and l.e.d.s rather than by truth tables.

To do this we should really use eight switches on one port and eight l.e.d.s on the other. However, since PORTA has only five I/O pins, we shall just use a 5-bit number to illustrate the principle, with five switches on PORTA and five l.e.d.s on PORTB.

The basic program we shall use is shown in Listing 20. Disconnect the audio output, load program TUT20.OBJ, run it and play with PORTA's push-switches. You will find that when no switches are pressed, PORTB l.e.d.s LB0, LB2 and

LISTING 20 - PROGRAM TUT20

```
GETKEY:  MOVF PORTA,W
         ANDLW %00011111
         XORLW %11110010
         MOVWF PORTB
         GOTO GETKEY
```

LB3 are off, and LB1 and LB4 are on. When switches SA1 and SA4 are pressed, they turn off their respective l.e.d.s (LB1 and LB4). Switches SA0, SA2 and SA3 turn on their l.e.d.s (LB0, LB2 and LB3) when pressed. You will also see that the left-hand three l.e.d.s. (LB5 to LB7) are always on.

In this listing, the value on PORTA is input as usual. The next command (ANDLW %00011111) is necessary to this demonstration since we can only use the first five bits of PORTA. If all eight bits could be used, the AND command would be omitted.

The status of each switch is being XORed with the respective bit in the statement XORLW %11110010; switch 0 with bit 0, switch 1 with bit 1, etc.

If any bit of PORTA is equal to that of the same bit in the XOR command, the same bit in the W register will be cleared. Thus two zeros will produce a 0, and two 1s will produce a 0. If the bits are dissimilar (1 and 0) the W bit is set (1).

The reason that the three left-hand l.e.d.s are on is that bits 5 to 7 from the AND command and bits 5 to 7 from the XOR command have resulted in three non-equalities.

Suppose that the switches produce binary number 00111, the ANDed result in W is 00000111, the sequence of events is:

```
MOVF PORTA,W      answer = xxx00111
ANDLW %00011111   answer = 00000111
XORLW                      11110010
                  answer = 11110101
```

Bits that are equal to their counterparts have their corresponding l.e.d.s turned off, those that are *not* equal have their l.e.d.s. turned on. Take another example:

```
MOVF PORTA,W      answer = xxx10010
ANDLW %00011111   answer = 00010010
XORLW                      00010010
                  answer = 00000000
```

Here each bit is equal to its counterpart, therefore all l.e.d.s are turned off, i.e. a zero result has occurred and, importantly, the Zero flag will have been set accordingly.

Therefore, we can check for equality by checking the Zero flag following an XOR command. Non-equality clears the flag, equality sets it. Consequently, following an XOR command you simply check STATUS,Z and route accordingly.

PROGRAM – TUT21
SWITCH SETTINGS – as in Fig.13

Let's use l.e.d. LB7 to illustrate this, turning it on if equality exists, turning it off if it doesn't. Any bit between 0 and 4 which is equal to the same XOR bit will have its corresponding l.e.d. turned off, otherwise its l.e.d. will be on. Load and run TUT21.OBJ, pressing PORTA switches SA0 to SA4 to observe this in action. Pressing SA4 and SA1 together causes LB7 to come on. The commands are shown in Listing 21.

LISTING 21 - PROGRAM TUT21

```
GETKEY:  MOVF PORTA,W
         ANDLW %00011111
         XORLW %00010010
         MOVWF PORTB
         BTFSC STATUS,Z
         BSF PORTB,7
         GOTO GETKEY
```

LISTING 22 - PROGRAM TUT22

```
ENTRY:   MOVLW 80
         MOVWF NOTE
         MOVWF FREQ
         MOVLW 16
         MOVWF MODLAT

GETKEY:  MOVF PORTA,W
         ANDLW %00000011
         XORLW %00000011
         BTFSC STATUS,Z
         GOTO GETKEY
         DECFSZ NOTE,F
         GOTO GETKEY
         MOVF FREQ,W
         BTFSC PORTA,1
         GOTO OUTPUT
         DECFSZ MODLAT,F
         GOTO GK2
         MOVLW 16
         MOVWF MODLAT
GK2:     ADDWF MODLAT,W

OUTPUT:  MOVWF NOTE
         MOVLW 16
         ADDWF PORTA,F
         GOTO GETKEY
```

COMMAND IOR

Although we shall not meet it until later (Tutorial 21), it is opportune to mention now that there is an "ordinary" OR command available. It is more correctly termed "Inclusive-OR" (as opposed to Exclusive-OR). It has two versions, IORLW (Inclusive OR Literal with W) and IORWF (IOR W with value in specified File). The latter is followed by the file name, a comma, and the destination (W or F), e.g. IORWF STORE,W and IORWF STORE,F.

MODULATION

PROGRAM – TUT22
SWITCH SETTINGS – as in Fig.18

The use of XOR in a practical situation is illustrated in Listing 22. Reconnect the audio output.

Load and run TUT22.OBJ, pressing any switches SA0 to SA4, but principally use switches SA0 and SA1 since these are the ones coded to be active.

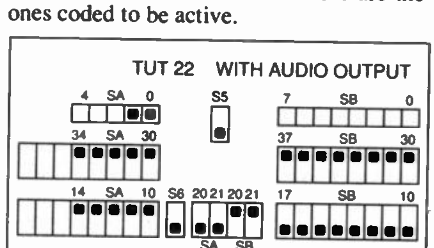


Fig.18. Switch settings for Program TUT22.

Listening to the output from PORTA, you will find that switch SA0 controls a static tone and SA1 controls a modulated (ramped) tone. As you will have heard, the tone starts at a high pitch, descends and then jumps back high again, repeatedly (adjust VR1 until this fact is more obvious). All other switches are ignored. Look at the program's listing.

As with earlier tone generation examples, a starting value is loaded in NOTE and FREQ, then a modulation starting value is loaded into MODLAT, after which the GETKEY loop is entered.

Here the switch settings on PORTA are read (normally both RA0 and RA1 are biassed high), and ANDed with 00000011 to isolate switches SA0 and SA1. The answer is XORed with the same value to check for equality. If neither switch is pressed, no further action is required and the routine jumps back to GETKEY.

We are looking for the situation in which either of the two switches is pressed. We could do it simply by bit testing (indeed, it would be easier!), but part of the aim of this demo is to show a use of XOR.

When either switch is pressed, NOTE is decremented and checked for zero and reset as appropriate, as before. When zero is encountered, if switch SA1 is pressed, the value of MODLAT is added to the NOTE reset value and the value of MODLAT itself is then decremented. When MODLAT reaches zero, it is reset to 16.

The OUTPUT routine is common to both switch routings.

EXERCISE 17

17.1. Experiment with different settings for FREQ and MODLAT

17.2. How would you change the coding to respond to two other switches instead, e.g. SA2 and SA4?

17.3. How would you reverse the ramp to create a rising tone rather than a falling one?

17.4. The addition of a third switch would allow tones to be switched for rising, falling or fixed. Can you write the program for it?

17.5. Can you add another routine which would create a triangular modulation pattern (rising tone, followed by falling, followed by rising, and so on)?

TUTORIAL 18

CONCEPTS EXAMINED

Command INTCON
Command OPTION
Command TMR0
Use of internal timer

PROGRAM – TUT23
SWITCH SETTINGS – as in Fig.19

The PIC16C84 has one special register reserved for use as an 8-bit timer, TMR0

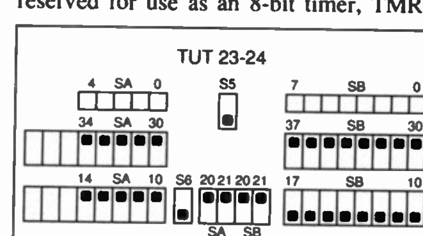


Fig.19. Switch settings for Program TUT23 and TUT24.

(Timer 0). It divides its input frequency by 256 and can be both written to and read from. In most situations, though, it is unlikely that you will need to use the read/write facility, but note that if TMR0 is written to, the timer is inhibited from counting for two clock cycles.

Probably more useful than writing to TMR0 is to use its output as it occurs naturally at the 1:256 division rate, and then to use the prescaler to subdivide that rate as required. The prescaler divides its input pulses by presettable powers of two. There are eight possible division ratios which are set via bits 0, 1 and 2 of the OPTION register.

When used with TMR0, the prescaler division ratios are 1:2, 1:4, 1:8, 1:16, 1:32, 1:64, 1:128 and 1:256. The prescaler can alternatively be allocated for use with the Watchdog Timer (WDT), in which mode each of these ratios is halved (minimum is thus 1:1 and maximum is 1:128) – more on this later.

We noted earlier that the PIC effectively runs at one quarter of the input clock frequency at pin 16 (OSC1/CLKIN). When TMR0 is used as an internal timer, the pulses it counts also occur at one quarter of the clock frequency. So, if the clock frequency (set by a crystal oscillator, perhaps) is running at 3.2768MHz, TMR0 will count at 819200Hz and its 1:256 roll-over rate will be 3200Hz. This rate is then divided by the ratio set into the prescaler. If we divide by 32, for example, we obtain the convenient rate of 100Hz.

In TMR0 mode, when the prescaler rolls-over to zero, a flag is set in the INTCON register, at bit 2. The setting of this bit can be used as an interrupt which automatically routes the program to another specified routine, irrespective of which routine is currently being processed, returning to the same point after the interrupt procedure has been finished. The interrupt can also be turned off and INTCON bit 2 read by the program to establish its status, taking action accordingly.

TIMER SUB-DIVISION

Using the timer and the prescaler, you can specify that some actions will only be performed at specified sub-divided values of the clock frequency. Amongst other things, this allows the PIC16C84 to be used as a real-time clock, a function towards which we now progress.

First, let's illustrate the effect of setting different prescaler ratios and, using the l.e.d.s. on PORTB, see what happens. Load TUT23.OBJ and run it. Set VR1 to full anticlockwise rotation (slowest rate). In this program we read the status of INTCON bit 2 rather than using the interrupt facility (interrupts are discussed in Part 3).

Initially, you will see a fairly fast binary count occurring on PORTB's l.e.d.s, LB3 to LB7. It is created with the timer "in-circuit" with the prescaler set for a minimum division ratio of 1:2. This is because OPTION bits 0 to 2 are set to 000, a value which is shown on LB0, LB1 and LB2 – all off at the moment.

This rate of counting continues for eight cycles of 32 increments (incrementing PORTB's count in steps of eight). The ratio is then set at 1:4 (prescaler value 001), and again another eight cycles occur. Similarly, the other ratios are set. The difference in the resulting l.e.d. count rates will be obvious. Adjust the setting of preset VR1 if the slowness becomes tedious in later ratios. After the eight ratios, the whole cycle restarts from 1:2.

LISTING 23 - PROGRAM TUT23

```
        CLRF PORTB
        PAGE1
        CLRF TRISB
        MOVLW %00000000
        MOVWF OPTION
        PAGE0
        CLRF RATE
        MOVLW 8
        MOVWF COUNT
        BCF INTCON,2
INTRPT: BTFSS INTCON,2
        GOTO INTRPT
        BCF INTCON,2
        MOVLW %00001000
        ADDWF PORTB,F
        BTFSS STATUS,C
        GOTO INTRPT
        DECFSZ COUNT,F
        GOTO INTRPT
        BSF COUNT,3
        INCF RATE,W
        ANDLW 7
        MOVWF RATE
        MOVWF PORTB
        PAGE1
        MOVWF OPTION
        PAGE0
        GOTO INTRPT
```

Looking at Listing 23, you will see that the TMR0 rate is set into the OPTION register while in PAGE1 mode, along with the port direction registers. The initial value of zero is put into OPTION, shown here as a binary number.

Although, in this instance, CLRF OPTION could have been used instead, you should be aware that OPTION bits 2 to 7 have other functions and in some programs it will be necessary to set these at the same time, so CLRF OPTION would not always be an appropriate command. More on other functions later. It is best to stick with the binary format in such listings so that the settings of all the bits are immediately obvious.

EXERCISE 18

18.1. Study TUT23.ASM, note the comments and see if you understand what is happening at each stage. Note the detection and resetting of the INTCON,2 flag and the need to go via PAGE1 when changing the prescaler rate.

TUTORIAL 19

CONCEPT EXAMINED

BCD (Binary Coded Decimal) counting

PROGRAM – TUT24
SWITCH SETTINGS – as in Fig.19

Having established the use of the timer, we now work towards its use as the pulse source for a real-time clock. There are a few bridges to be crossed yet, though. The first is counting in decimal rather than binary, facilitating the eventual output to a 7-segment l.e.d. or a liquid crystal display.

We could keep the counted units in one byte, tens in another, hundreds in another, and so on, but, to conserve precious byte space, it is equally possible to use each byte as two 4-bit nibbles, keeping units in bits 0 to 3, and tens in bits 4 to 7. Hundreds units and tens would be treated similarly in a second byte.

For simplicity now, we concentrate on counting up to 99, first considering the use of two bytes.

In 8-bit binary, a value of decimal 9 is expressed as 00001001, decimal 10 is 00001010, decimal 16 is 00010000.

It is obvious that with decimal values we have no single symbol for a number greater than nine. When a value one greater than nine occurs, what we do is reset the units digit to 0 and add one to the next digit, i.e. ten is written as 10.

While counting in binary coded decimal (BCD), we can do a similar thing. When the byte holding the units reaches ten, we reset that byte to zero and add one to the next byte. In 8-bit BCD and at a count of nine, the two bytes would read 00000000 (tens) and 00001001 (units). At the count of ten, the bytes become 00000001 (tens) and 00000000 (units).

When using two nibbles of an 8-bit byte (instead of the above two bytes), a BCD value of nine reads as 00001010, but a BCD value of ten reads as 00010000. And, for example, a BCD value of 37 reads as 00110111, i.e. the left-hand nibble (MSN – Most Significant Nibble) holds a value of 3 and the right-hand nibble (LSN – Least Significant Nibble) holds 7.

A value of 99 is expressed as 10011001. For a value of 100, both nibbles are reset to zero (00000000) and if there is a byte for hundreds and tens of hundreds, its right-hand nibble (LSN) would be incremented, and so on.

Thus, when counting in BCD, we have to check the four bits of the LSN on their own and see if their value is greater than nine. If it is, that nibble is reset and the MSN incremented. The MSN is then taken on its own as a 4-bit value and checked if it is greater than nine. If so, this nibble is reset and the LSN of the next byte incremented accordingly.

CHECKING FOR EXCESS VALUES

There are (as in many programming matters) several ways of checking the nibbles for excess values, of which we shall describe one: an additive checking routine.

We discovered earlier (Tutorial 7) that there is a Digit Carry (DC) flag which signals if the binary value of the LSN has become greater than 15 following an addition. We can use this fact by adding a number to the LSN which will make the answer greater than 15 if the basic value of the LSN is greater than 9. The number to be added is 6, e.g. 10 + 6 = 16 with DC flag set; 9 + 6 = 15 with DC flag clear.

Therefore, to check if an LSN value is greater than 9, we temporarily add 6 to it and check the DC flag. If the flag is clear, the LSN is left as it is. If the flag is set, we increment the MSN and clear the LSN.

There is a short cut to doing this, taking advantage of the fact that 10 + 6 = 16, being 00010000 in binary. If you look at this answer, the LSN is now zero, while the MSN has been incremented automatically, thus representing decimal 10 in BCD.

Thus, when we add 6 to the byte as a whole, if the DC flag is clear, no further action on that byte is needed (or on any subsequent bytes for that matter). If, though, the DC flag is set, we simply replace the existing value in the byte with the value now stored temporarily. These commands do the job:

```
MOVLW 1             ; move value to be
                    ; added into W
ADDWF COUNT,F       ; add it to file value
MOVLW 6             ; move 6 into W
ADDWF COUNT,W       ; add it to new file
                    ; value but keep
                    ; answer in W
BTFSC STATUS,DC     ; is the Digit Carry
                    ; flag clear?
MOVWF COUNT         ; no, so move W
                    ; into file, replacing
                    ; previous value
(next command)
```

Whilst any value can be *added* to COUNT in the first instance and set the DC flag accordingly, the DC flag is unaffected by an INCF or INCFSZ command (neither is the Carry flag). Consequently, in the above example, the opening two commands cannot be replaced by INCF COUNT,F.

When the DC flag is set, the resulting action changes the value of the MSN, which then has to be checked to see if it (as a 4-bit nibble) is greater than 9, i.e. is the BCD value of the whole byte now equal to or greater than decimal 100?

Again there is an easy additive technique. If we translate BCD 100 (10100000) into a binary value the answer is 160. If we temporarily add 96 (256 – 160) to the whole byte, we can then check the Carry flag (C) to see if it has been set, which it will be if the binary answer has rolled over beyond 255.

As before, if the flag is clear, the byte can remain as is; if the flag is set, we replace the value with the temporary one.

Here's the extended routine. Note the inverted logic for checking Digit Carry, BTFSS STATUS,DC in the first instance, BTFSC STATUS,DC in the second.

```
        MOVLW 1
        ADDWF COUNT,F
        MOVLW 6
        ADDWF COUNT,W
        BTFSS STATUS,DC
        GOTO ENDADD
        MOVWF COUNT
        MOVLW 96
        ADDWF COUNT,W
        BTFSC STATUS,C
        MOVWF COUNT
ENDADD:
```

Let's look at the BCD additive technique in practice, triggering it from the timer routine. In Listing 24, note the use of CLRF COUNT before OUTPUT at the end. This can be used here since we know that adding 1 to the count is occurring, rather than adding values of 2 or greater. In the latter instance, the resulting temporary answer must be MOVed into COUNT, as in the above examples.

Load TUT24.OBJ, run it and observe the count incrementing on the l.e.d.s. The

LISTING 24 - PROGRAM TUT24

```
INTRPT:  BTFSS INTCON,2
         GOTO INTRPT
         BCF INTCON,2
         INCF COUNT,F
         MOVF COUNT,W
         ADDLW 6
         BTFSS STATUS,DC
         GOTO OUTPUT
         MOVWF COUNT
         ADDLW 96
         BTFSC STATUS,C
         CLRF COUNT
OUTPUT:  MOVF COUNT,W
         MOVWF PORTB
         GOTO INTRPT
```

prescaler is now run at a fixed ratio of 1:128. Try adjusting VR1 so that an l.e.d. count rate of one per second (1Hz) occurs.

EXERCISE 19

19.1. Suppose our counting system was not decimal but quinary, i.e. no digit greater than 5, rather than no digit greater than 9. How would you change the additive values in the above examples (you can use decimal, binary or hexadecimal for those!).

19.2. Checking for excess BCD values can be done using an XOR technique which is valid if the count is being incremented rather than added to. Adding to the BCD value cannot be used with XOR since the answer could be to either side of the equality being checked for. Can you write an XORed BCD incrementing program?

TUTORIAL 20

CONCEPTS EXAMINED

Precision timing at 1/25th second
Counting seconds 0 to 60

PROGRAM – TUT25
SWITCH SETTINGS – as in Fig.20.

Moving on from decade counting between 0 and 99, it is an easy step to count in BCD from 0 to 59, accurately simulating the seconds count of a real-time clock. In doing so, though, it can be useful to actually increase the count rate available via the prescaler from 1Hz to 25Hz, 50Hz or even 100Hz.

Indeed, if a crystal oscillator running at the convenient rate of 3.2768MHz is used, it is actually easier to work with one of these three rates. This is due to the subdivision values available from a crystal of this frequency which can used in conjunction with the TMR0. Prescaler division ratios of 1:128, 1:64 or 1:32 respectively produce these rates.

So let's change the PIC16C84's operational mode from RC to XT, allowing a 3.2768MHz crystal to be the clock generator. All of the programs you have used so far, with the exception of TUT1 and TUT2, can be run under crystal control. Consequently, if you want to go back and look at some of them again, you do not need to reset the PIC for RC mode.

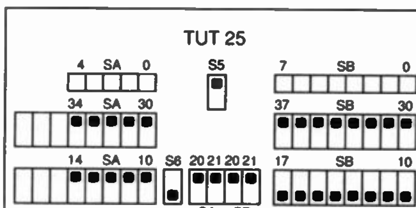


Fig.20. Switch settings for Program TUT25.

To use the crystal, run the TASM SEND program, select Option 1 and then select the settings for XT, WDT off and POR off. Switch S5 must be up, as shown in Fig.20.

Load TUT25.OBJ, run it and observe PORTB's l.e.d.s. You will see them incrementing at a rate of one per second, and the twin-nibble BCD count will be seen to progressively step from zero to 59, then restart again at zero, just as would an ordinary seconds clock and, indeed, it should take one minute for the full cycle to occur.

There are two differences between this program (see Listing 25) and the previous one (apart from the precise clock frequency that is being generated):

First, the prescaler rate has been set for 1:128, providing an INTCON,2 pulse rate of 1/25th of second. A counter, CLKCNT, counts down from 25 in response to the pulses. When it reaches zero, it is reset to 25 and a seconds counter, CLKSEC is incremented in BCD.

Checking for the BCD count becoming ten is performed by the additive (+ 6) technique we have already seen. However, checking for the count being at BCD 60 is done using the XOR equality testing method (XOR 01100000 = BCD 60). If equality exists, the CLKSEC counter is reset to zero.

There are no exercises for Tutorial 20.

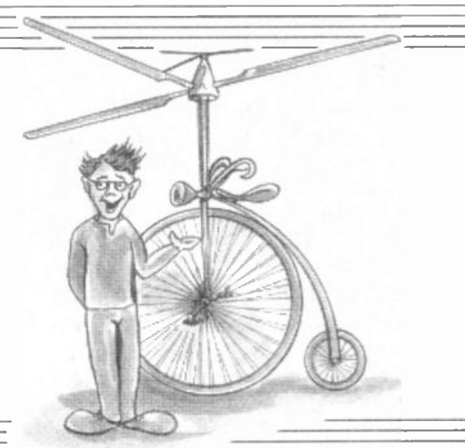
PART THREE

In the final part we move on to display systems – and upwards!

LISTING 25 - PROGRAM TUT25

```
         CLRF PORTB
         PAGE1
         CLRF TRISB
         MOVLW %00000110
         MOVWF OPTION
         PAGE0
         MOVLW 25
         MOVWF CLKCNT
         CLRF CLKSEC
         BCF INTCON,2
INTRPT:  BTFSS INTCON,2
         GOTO INTRPT
         BCF INTCON,2
         DECFSZ CLKCNT,F
         GOTO INTRPT
         MOVLW 25
         MOVWF CLKCNT
         INCF CLKSEC,F
         MOVF CLKSEC,W
         ADDLW 6
         BTFSS STATUS,DC
         GOTO OUTPUT
         MOVWF CLKSEC
         MOVLW %01100000
         XORWF CLKSEC,W
         BTFSC STATUS,Z
         CLRF CLKSEC
OUTPUT:  MOVF CLKSEC,W
         MOVWF PORTB
         GOTO INTRPT
```

PATENT YOUR INVENTION



STEPHEN ARNOTT

Where to go with your bright idea – how to patent an invention

MOST of us have had an idea for an invention at some time or another but unlike the writer (whose words are automatically copyrighted) the would-be inventor must take steps to protect his idea with a patent. Each year around 20,000 patents are taken out by UK residents and of these around 4,000 are from individual inventors rather than businesses and universities. However, before you dash off to the Patent Office with a sheaf of diagrams it might be wise to check if your idea is patentable at all.

For an idea to be patentable it must satisfy a number of criteria.

A NEW IDEA

Obviously you must think your idea is "new" otherwise you wouldn't be bothering to consider a patent in the first place, however "newness" also requires you to have kept your idea a secret i.e. it must not have been publicly disclosed prior to patenting.

If you've had an idea for a new type of electric generator and published a letter in a trade or hobby journal describing it in detail then your invention is no longer new and not patentable. In the same way if you want to discuss your idea with friends or colleagues you must make it clear that you are telling them in confidence. Better still ask them to sign a confidentiality form (or just don't tell them anything at all).

Case History

Ron Hickman (a former Lotus designer) had to defend his most successful invention the Workmate in court after a UK manufacturing company started selling its own bootleg version. In its defence the company claimed that the Workmate was not "new" at all, arguing that the essential feature of the Workmate (the combination worktop and vice) had appeared decades previously in the Victorian book-press (a wooden vice commonly used by book-binders).

When an example of the book-press was exhibited in court, however, it proved to be totally dissimilar to the Workbench. Much to Ron's relief the judge was unimpressed by the company's lacklustre (not to say spurious) argument and the matter was soon resolved in his favour.

AN INVENTIVE STEP

Your idea must not be "obvious to someone with a good knowledge and experience of the subject". Defining "obvious" is often tricky as what's obvious to one person is frequently quite the opposite to another. An example of an obvious idea that doesn't include an inventive step might be making a rubber handle for a soldering-iron. Soldering-irons already have handles and rubber is frequently used to cover handles, so coating a soldering-iron handle in rubber might not be considered terribly imaginative or inventive (even if no-one had ever done it before).

Case History

James Dyson (inventor of the Dual-Cyclone vacuum-cleaner) first came to the public's attention in the 1970's when he invented the Ballbarrow – the barrow that replaced the wheel with a plastic ball. James had no problem patenting the idea in the UK but when he was forced to defend a patent infringement in the USA an American judge ruled (bizarrely) that swapping a wheel for a ball was an "obvious step". It was something that anyone might have thought up. The Ballbarrow's US patent was overturned meaning that any American manufacturer could make them without paying James a cent.

INDUSTRIAL APPLICATION

"Industrial application" means your idea must be practical, it must be useful in some way. For example, a perpetual motion machine would contravene the laws of physics. It would not work, it's useless and therefore unpatentable (in Victorian times there were so many patent applications for perpetual motion machines the Patent Office demanded to see a working model before they'd do the paperwork).

Another meaning of "industrial application" is that your idea must be manufacturable, it can't be something that might only ever exist on paper. For example, you wouldn't be allowed to patent the idea for a balloon made out of lighter-than-air concrete on the off-chance that someone in the future actually manages to invent lighter-than-air concrete.

Case History

Bob Symes (former *Tomorrow's World* presenter and President of the Institute of Inventors and Patentees) devised a polymer sandwich sheath which he thought would stop electrical insulators from picking up dirt (theoretically the sheath would produce a sphere of electrostatic "stand-off" repulsion). Bob thought his idea was feasible but didn't have the machinery to test it properly.

Bob sent his invention to a lab so they could try it out using their high-voltage equipment and it worked all too well – the technician carrying out the experiments "appropriated" the idea and ran off to the USA. Unfortunately Bob hadn't taken out a Patent Application – see below – which would have protected his idea while it went through the proofing process.

EXCLUDED INVENTIONS

The list of excluded inventions includes the following: Scientific discoveries, mathematical models, surgical methods, works of literature, methods of playing a game, a scheme etc. In other words you can't patent a concept, plan or theory, there has to be some sort of physical element involved.

Other inventions that fall into the excluded categories are those that "encourage offensive, immoral or anti-social behaviour" though what might be considered offensive or immoral is vague. If you were thinking of patenting a new type of car battery you're probably on safe ground, however if you're conducting DNA experiments that involve growing monkey heads on rabbits it's probably best to check with the Patent Office.

PATENT AGENTS

Once you've made sure your idea is patentable the next step is to contact the Patent Office and take out a Patent Application. You can do this in two ways, by yourself or by using the services of a Patent Agent.

Anyone who calls themselves a Patent Agent in the UK has to belong to the Chartered Institute of Patent Agents

(CIPA). The Institute (founded in 1891) is a professional body that regulates the activities of its members, all of whom have qualified to join through examinations in intellectual property law. Patent agents are all experienced in the perils and pitfalls of drafting a patent and most agents tend to specialise in particular branches of industry.

By contacting the Institute you can get a list of agents who are best qualified to help you patent your invention. This can be expensive however, at a very rough estimate employing an agent will set you back around £750 though most will offer a free initial consultation. If you've already spent a considerable amount of time and money on your invention then employing an agent is advisable, but it can be an interesting and informative experience to go through the patent process yourself.

THE SEARCH

If you want to have a go at drafting your own patent your first step is to undertake a "Patent Search". This involves looking through the records of past patents (filed in the UK and abroad) so see if anyone else has already had the same idea. Copies of patents are held at the Patent Library (see below for contact details) and your first job in the library is to determine which classification your idea comes under.

An international classification system groups inventions according to their function and you have to use the library reference material to find the most precise classification code you can for your idea. This isn't as complicated as it sounds and the library staff are always on hand to offer assistance.

Once you've found the correct classification for your invention your next job is to obtain a list of all the recent patents that have been filed under the same classification. Abbreviated descriptions of patents are stored on microfiche in the library and arranged according to their classification and year of registration.

Starting with the most recent year look at all the patent descriptions that are covered by your classification. Make a note of those that sound similar to your idea and write down their patent numbers. Patent numbers are unique number-letter codes that specify a patent and its country of origin. For example the number 'JP07277383-A' specifies a patent that originated in Japan.

Once you have a list of patent numbers (you might have found none, a handful, or dozens) use them to track down copies of the full patents. Some foreign patents are stored on CDs and microfiche but the majority are printed, bound in volumes and arranged according to their country of origin and patent number.

Different countries have different filing requirements but they invariably require the inventor to submit a diagram and a full written description of their invention. As a general rule patents descriptions are written in a form of legal gibberish that is extremely difficult to penetrate (hence the need for patent agents) but a quick look at the diagrams will usually tell you if a patent already covers your idea.

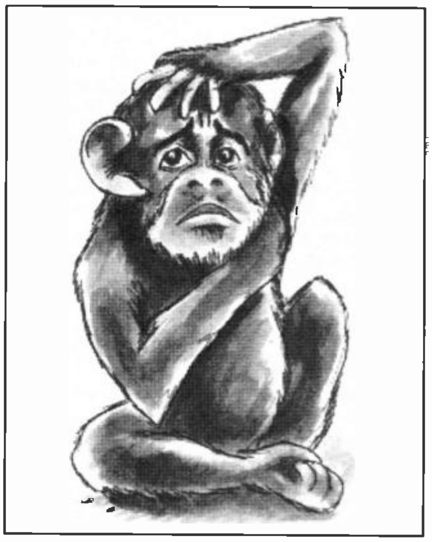
PATENT APPLICATION

Once you've completed your search (and hopefully discovered that no-one else has had the same idea) your next step is to write up a Patent Application. The Patent Office provides detailed literature explaining how to go about this but to put it simply you have to describe your invention in sufficient detail "for it to be made or carried out by suitably knowledgeable persons once they have read the description".

To make the description as unambiguous as possible you also have to include diagrams and a list of your "claims". Patent claims are the distinct technical features that make your idea different from any similar inventions and it's important to think about them carefully. It is these features that you "claim" make your invention unique, and it is these claims that will be attacked if your patent is ever challenged in court.

FILING FEE

Once you've prepared your Patent Application the documents have to be delivered to the Patent Office together with the relevant completed forms and a £25 filing fee. Your application expires twelve months after filing, giving you a year in which to find out if your invention has any commercial possibilities. If you decide to drop the idea your application will lapse automatically after the twelve months. If, however, you decide to persevere and take out a full patent you must pay an additional £130 for a "Preliminary Examination and Search".



In a Preliminary Examination officials from the Patent Office read your application to make sure it meets the formal filing requirements. They also carry out their own patent search to make sure your idea is original (if you've done the job properly the Patents Office search should duplicate your search).

Once the Preliminary Examination is complete your Patent Application will be published. Printed copies will be made available for sale in the UK and sent to the patent offices of other countries. A final stage involves paying a fee of £70 for a "Substantive Examination" in which a Patent Examiner gives your paperwork a rigorous final once-over to make sure it fulfils all the requirements of the Patent Act. Assuming it does, you now have a full UK patent on your invention, a document that grants you exclusive rights to exploit your idea for a maximum of 20 years, though unfortunately you'll have to pay additional annual fees in order to keep it renewed.

OVERSEAS PROTECTION

Apart from the UK it might also be wise to consider protecting your patent abroad. If you patent an invention in this country and nowhere else there's nothing to stop a foreign manufacturer from exploiting your idea (though they would be prevented from importing your invention into the UK).

If you want to prevent your invention being manufactured abroad you have to file separate annual patent claims in the Patent Offices of all the countries you wish to exclude and pay their filing fees. Another way of doing this that cuts down on the paperwork (though not the expense) is by taking out a general European patent under the European Patent Convention (the EPC – covering up to 23 European countries), or by taking out a Worldwide patent under the Patent Co-operation Treaty (the PCT – covering up to 90 countries).

MORE INFORMATION

As you've no-doubt gathered the patent process can be expensive and time-consuming, however it's important to remember that the initial Patent Application is fairly inexpensive and gives you a year in which to explore your invention's commercial possibilities. You can take your idea to a manufacturer secure in the knowledge that, although it doesn't confer any automatic legal protection, your application does at least prove who had the idea first. Who knows, with some hard work, a bit of luck, and a Patent Application the widget you created on your workbench might just be the start of something big.

If you'd like an information pack describing the patent process in detail contact the Patent Office, Central Enquiry Unit, Cardiff Road, Newport, South Wales, NP9 1RH. Tel: 0645-500-505.

For local patent information the Patent Information Network has branches in the Central Libraries of the following cities; Aberdeen, Belfast, Birmingham, Bristol, Coventry (Coventry University), Glasgow (Mitchell Library), Leeds (Leeds Public Libraries), Liverpool, Manchester, Newcastle, Plymouth, Portsmouth and Sheffield.

Other useful addresses are :

The Patent Library (British Science Library), 25 Southampton Buildings, Chancery Lane, London, WC2A 1AW. Tel: 0171 412 7919.

The Chartered Institute of Patent Agents, Staple Inn Buildings, High Holborn, London WC1V 7PZ. Tel: 0171 405 9450. E-mail: mail@cipa.org.uk.

The Institute offers a free advisory service on patents, trademarks and designs. For more information call your local office; London 0171 405 9450. Liverpool 0151 225 5442. Birmingham 0121 235 4537. Newcastle 0191 232 4601. East Anglia 01206 571 187.

The Institute of Patentees and Inventors is a non-profit organisation offering help and advice to the would-be inventor. You can contact them at the following address; Suite 505A, Triumph House, 189 Regent Street, London, W1R 7WF. Tel: 0171 434 1818. Email: paulamb@archer.win-uk.net. Web: http://www.invent.org.uk. □

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TEACH-IN '98

An Introduction to DIGITAL ELECTRONICS

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

TEACH-IN is a series designed to support candidates following City and Guilds (C&G) 726 Information Technology, with reference to the following specific syllabuses: ***7261/301 Introductory Digital Electronics, *726/321 Elementary Digital Electronics, *726/341 Intermediate Digital Electronics.**

Even if you are not undertaking the City and Guilds syllabus, there is much to be learned from *Teach-In*.

Lab Work

Throughout *Teach-In*, attempts are made to involve the student with practical "Lab Work" experiments and demonstrations, and complex mathematics and physics will be avoided unless really necessary – and even then, plenty of help is to hand! We make a point of identifying practical components in special sections of *Teach-In*, so that you will learn to recognise parts.

Part Six: SEQUENTIAL LOGIC

SO FAR in this series, we have seen how you can perform the processing of a set of logical signals by arranging collections of logic gates together. We have also found techniques which we can use to decide on the combination of elements we need to use to get the desired answer.

However, *combinational* circuits alone are not sufficient to solve many "real-world" problems. There are situations where circuits and systems have to perform certain sequences of operations, or where the output (or answer, if you like) depends on the particular sequences of inputs. Such circuits are called ***sequential*** circuits and differ from combinational circuits in that they have ***memory*** of their previous inputs and their own previous actions.

When the term "memory" is used in the context of electronics many people immediately think of things like RAMs (Random Access Memory) and disk drives. However, these are not what we are concerned with here. We will be looking at the (often quite small amounts of) memory which is contained within digital circuits.

Disk drives are complex electronic and mechanical systems whose control circuits will contain ***sequential logic***. RAM is more similar to the sort of memory we will be looking at but is arranged for bulk storage of information rather than performing basic logical operations.

Traffic Control

Consider a digital circuit for controlling a set of traffic lights. Remember that in the UK the three lights go through four states (combinations of on/off values), namely Red, Red/Amber, Green, Amber.

We cannot use a combinational circuit to do this because it would not be able to produce the sequence of values at the correct times. We can, however, devise a combinational circuit which, given the *current* state of the lights, works out what the *next* state of the lights should be for the correct sequence to be followed.

This circuit has three inputs for the current values of the three traffic lights and three outputs for their next values. A circuit "block" and partial Truth Table are given in Fig.6.1 and Table 6.1.

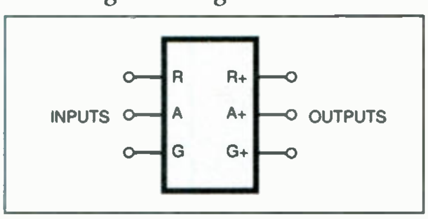


Fig.6.1. A combinational circuit which takes as its inputs the current pattern on the lights of a traffic light and outputs the next pattern in the sequence.

The table shows the values of the traffic light controls R (Red), A (Amber), G (Green) and the values they will take in the next step of the sequence, R+, A+, and G+ respectively, for each of the four states of a single traffic light. If the control value is 1 the light is on, if it is 0 the light is off.

Only four of the eight possible binary combinations of R, A and G are used so the full truth table could contain don't cares, but a better approach would be to make the next state of any "abnormal state" be Red, for obvious reasons. Have a go at designing the circuit if you want to practice your Boolean algebra and Karnaugh Maps (see Part 5). This circuit would take a few nanoseconds to do its job, but we would not want the lights to change that fast! That's where the memory comes in.

What's In Store

Now imagine we have a memory circuit with a set of logic inputs for the data which is to be remembered, a set of logic outputs for the data which is *currently* being remembered, and a control input which means "store now". When the "store now" signal is activated the input data is stored in the memory and appears on the outputs, and the previously stored data is lost.

We can connect the next state circuit between the memory's outputs and inputs as shown in Fig.6.2. Thus the memory holds the current state of the lights and has the next state available on its inputs. When we activate the "store now" control the memory will load the new state, the lights will change, and the combinational circuit will work out the new next state ready for the next change.

The "store now" control could be connected to a timer which produced regular pulses at an appropriate interval. It is perhaps not surprising therefore that the "store now" control is often called the *Clock* in real circuits.

Table 6.1: Current and Expected Lights Sequence

Current State of Traffic Lights	Current Value of Light Controls			Next Value of Light Controls		
	R	A	G	R+	A+	G+
RED	1	0	0	1	1	0
RED/AMBER	1	1	0	0	0	1
GREEN	0	0	1	0	1	0
AMBER	0	1	0	1	0	0

Quick thinking readers may be commenting that the time traffic lights spend in each state is not the same. This is not a fundamental difficulty with our circuit as we could use the current state to set the time period of the timer.

A more fundamental issue is that the "store now" clock signal must not run faster than the combinational logic can respond, or the wrong answer will be stored. This is not a problem with our simple traffic light controller but may be if you are trying to design the worlds fastest microprocessor!

Another thing worth worrying about is what happens when we first switch on. In general we have to assume that electronic memories power up with random data in them, that's why we suggested all abnormal states caused a jump to RED next. Think about it.

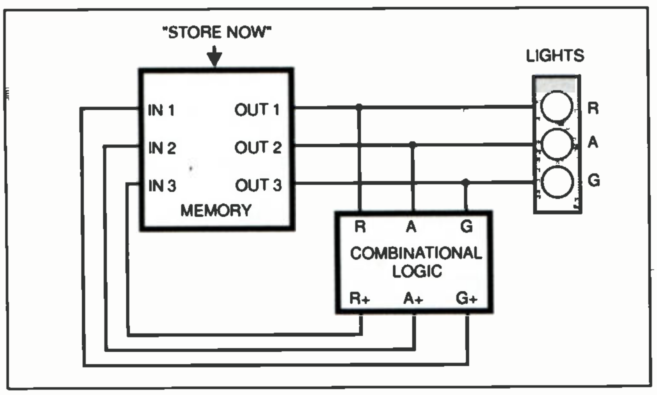


Fig.6.2. Simple sequential circuit to control a single traffic light. The memory holds the current pattern displayed by the lights and the combinational logic determines the next pattern in the sequence.

The preceding discussion has touched on some very important issues, to which we will return later in the series. First we will have a look at how we actually make the memories themselves. the various forms they take and basic operations they can perform.

Memories are Made of This

Think of two inverters in series (see Fig.6.3). A 1 in gives a 1 out and a 0 in gives 0 out. Not very interesting perhaps, but consider what happens when we connect the output back to the input (see Fig.6.4). There is no conflict since the "input" and "output" are both at the same state. If point A is made 1, it will stay there indefinitely. If we set A to 0, it will stay at 0. These two conditions are referred to as *stable states* and the circuit may be described as being *bistable*.

This ability to indefinitely hold one of two possible states is the basis of static digital memory, where the term *static* refers to the fact that the state is held permanently (as long as power is applied) and does not "fade" or need refreshing.

If for some reason the circuit in Fig.6.4 started with A and B both set at 1 or A and B both set at 0 then (assuming nothing was damaged) because this conflicts with the logic of the two inverters the situation would change to one of the stable states. Exactly which state (A=0 B=1 or A=1 B=0) you get depends on the factors such as the relative switching speeds of the two inverters.

If A and B are both 1 then both inverters will start switching their outputs to 0. If one is faster it will tend to push the other back towards 1 as the 0 appears on its output.

You might find it fun to consider what would happen if we started with A and B set at 1 and had two identical inverters and a perfectly symmetrical circuit. There is nothing to determine which way the result could go and it may take an infinite time to get there!

The two inverters would probably get stuck with both outputs half way between 0 and 1. If some asymmetry occurred, for example some external influence changed the temperature (and hence the electrical behaviour) of one of the inverters this would cause the circuit to switch to a stable state. This type of behaviour is called *metastability*.

You might think that this situation is somewhat fanciful, perfect symmetry being somewhat unlikely in real life, but this type of problem can occur in real circuits, and have serious consequences. What tends to happen is that near-symmetry means part of a circuit switches far more slowly than usual, or outputs an invalid logic level for a while.

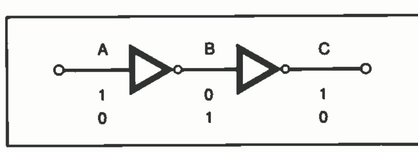


Fig.6.3. Two inverters.

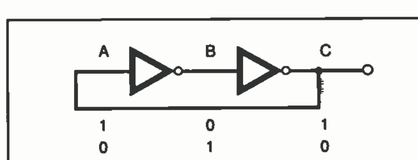


Fig.6.4. A bistable circuit, the basis of memory.

This error may quickly propagate through the rest of the system. Think of a set of circuits which control the interlocks on the nuclear reactor doors for example – if they suddenly head for the half way position you could have big problems!

Bargain Hunter

If you are having difficulty understanding this the following might help. Think of a shopper (a real one this time, not a charge carrier that we introduced way back in Part 1). Shoppers tend to go for the best bargain first.

If presented with two bargains, each of which is identical and the same distance away, the shopper would tend to be unable to decide which of the two bargains to go for. This would result in a period of hesitation until the person with the shopper pushes him or her in one direction or the other (you may even have been shopping with such a person).

The memory function provided by the circuit in Fig.6.4 is not particularly useful as there is no input by which it can be given a state to remember. With our inverter we can provide inputs in a number of ways:

Firstly, we could break the loop using a switch and employing another switch to insert the input. Secondly, gates can be used to modify the logic of the loop in order to enable the state to be set.

Latching the Data

How switches may be used to set the state of the loop in Fig.6.4 is shown in Fig.6.5. The two switches (S1, S2) are controlled together and are arranged so that when S1 is open S2 is closed and vice versa. When S1 is open and S2 is closed the input is isolated and the loop is closed. The loop stays in its current state and is unaffected by the input.

When S1 is closed and S2 is open the input is connected to the output via the two inverters. Thus the output will follow the input. When the switches change to S1 open and S2 closed the loop is formed. The gate capacitance of the inverters will hold the value while the change-over occurs until the loop locks the stored state in place.

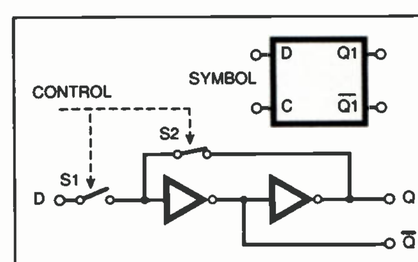


Fig.6.5. Latch circuit and symbol.

A memory circuit whose output is either the stored value or exactly follows the input is called a *transparent latch*. The input of such circuits is often called D, for data. The output is often called Q. We can also take NOT Q ($\overline{Q}$) as shown in Fig.6.5. We will investigate this latch in Lab Work.

THE AUTHORS

Teach-In has been co-written for *Everyday Practical Electronics* by Ian Bell, Rob Miles and Dr. Tony Wilkinson who are lecturers in the Department of Electronic Engineering at the *University of Hull*, England. Regular readers will know Alan Winstanley, of course, as the author of several columns in *EPE*. Alan has co-ordinated the series.

Propagation Delays and Timing Diagrams

If you look in a data book for one of the logic families, you will find tables of 'switching characteristics', or 'a.c. characteristics' containing numbers labelled with strange symbols such as t_{PHL}. These tables specify how fast the device in question responds to changes on its inputs and the maximum rates the inputs may change at. This topic explains some of these specifications, we will need more when we get to sequential circuits.

Gates and other digital circuits take time to respond to changes on their inputs: this time is called the propagation delay (symbol t_P) and is typically measured in nanoseconds (1 nanosecond = 0·000000001 seconds = 1×10^{-9} s). The propagation delay is a sort-of "thinking time" – nothing happens for a while, then the output responds. The propagation delays for the output responding by going high, or by going low, may be different due to different transistors switching inside the gates, thus we have to specify both the *propagation delay, high to low* (symbol t_{PHL}) and the *propagation delay, low to high* (symbol t_{PLH}). In these, the "high-to-low" and "low-to-high" refer to the output changing, not the input.

When, after the propagation delay, an output finally gets round to changing, it does not move from 0 to 1 or from 1 to 0 instantaneously, but takes a finite length of time to do this, known as the *transition time*, also typically measured in nanoseconds. Again the high-to-low and low-to-high times may be different so we have to specify separately the *transition time, high to low* (symbol t_{THL}) and the *transition time, low to high* (symbol t_{TLH}).

It is not only the outputs which have a non-zero transition time but the inputs do too. Sometimes the terms *rise time* and *fall time* are used to describe the transition times at the inputs, but rise and fall may also be used for output changes. Always check the "definition of terms" section that you will find in most databooks, to clarify this. Very slow input changes may cause problems for logic gates and the databook may specify the minimum input rise and fall times.

In Part 2 we discussed *RC* delays, and in Part 3 we saw that logic delays were also *RC* delays. In order to accurately specify delay we need to define reference points on the signal that is changing. The convention is to use the time taken to change from 10% to 90% of the final value (or vice versa) as the definition of transition times. Propagation delays are also measured with respect to particular points on the signals, but this varies with the technology, for example, for CMOS it is measured at 50% of the logic 1 level, and for LS TTL at the points where the input and output cross 1·3V.

In order to appreciate the timing effects in logic circuits it is useful to draw what is known as a *timing diagram*, which shows the sort of thing you would see on an oscilloscope screen if you examined the changing signals in a real logic circuit.

A timing diagram for an inverter, labelled with the propagation, transition, and rise and fall times just discussed is shown in Fig.6.6. Sometimes, simplified timing diagrams don't show the sloping edges, particularly if their main purpose is to illustrate the circuit's function rather than its delays. It is also possible to show multiple bits on one "line" of a timing diagram, for example Fig. 6.7 could be the timing diagram for a nibble (4 bits) passing through 4 parallel inverters. The boxes are used on the timing diagram for multiple bits as they are not necessarily all at 1 or 0. Timing diagrams using collections of signals like this often use the sloping edges of the signal changes to highlight the change to new data, even if transition times are not the main point of the diagram.

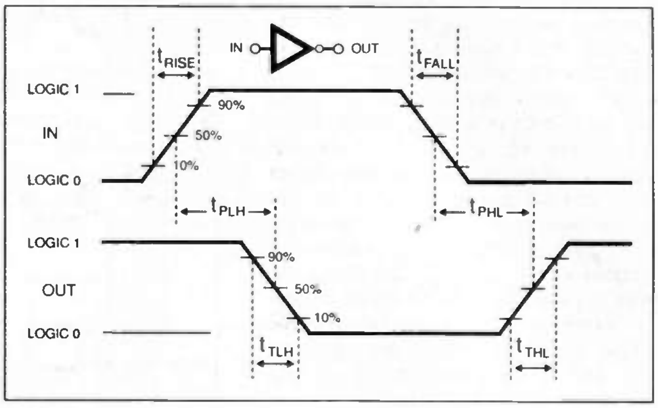


Fig.6.6 (above). Inverter timing diagram showing parameters.

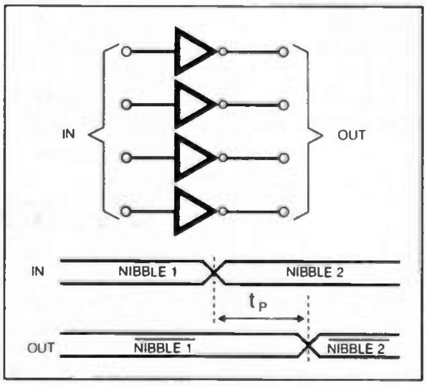


Fig.6.7 (right). Timing diagram for a multi-bit signal, in this case inversion of a nibble.

Gates of Hazard: glitches & static hazards

Propagation delays may be different from each input to the output of a circuit, and the propagation delays from a chosen input to each output of a multi-output circuit may also be different. This means that if all the inputs change at the same time, then the outputs will change at different times, not all at once. It also means that it is possible for a single output to switch between logic levels before "settling" to the final correct output.

Consider the simple AND gate circuit in Fig. 6.8. If all the inputs (A to D) change simultaneously from 1110 to 0001, and assuming that each individual gate takes 10ns in real life to react to changes on its input ($t_{PLH} = t_{PHL} = 10$ns) then the logic levels on the wires in the circuit will go through the following sequence.

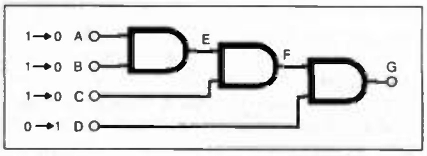


Fig.6.8. Example circuit.

	A	B	C	D	E	F	G
initially	1	1	1	0	1	1	0
just after input change	0	0	0	1	1	1	0
input change time + 10ns	0	0	0	1	0	1	1
input change time + 20ns	0	0	0	1	0	0	1
input change time + 30ns	0	0	0	1	0	0	0
input change time + 40ns	0	0	0	1	0	0	0

The output (labelled G) goes 1 for 20ns, despite the fact that the *logic* of the circuit requires both the old and the new inputs to produce a 0 at the output. This type of behaviour is called a *static hazard*, static because the output should not actually change, and a hazard because of the possible effects on other circuitry! The short pulse to logic 1 seen on the output G is called a *glitch* – a word which has now entered everyday language to mean a sudden irregularity or problem. Outputs which should stay at 1 can similarly produce static hazards with a logic 0 glitch pulse.

Another type of hazard can occur when an output *should* change but does not do so cleanly, for example instead of getting a simple change form 0 to 1 you get 010 then the final 1. This is called a *dynamic hazard*. Note that not all hazards and glitches cause problems, it depends on what they are connected to. In critical situations it is necessary to attempt to design hazard-free logic.

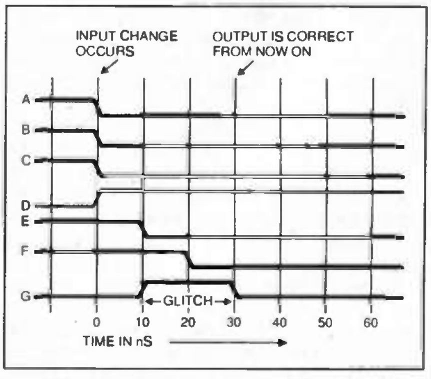


Fig.6.9. Timing diagram

The Set-Reset Flip-Flop

The circuit in Fig.6.10 replaces the loop inverters of Fig.6.5 with two NAND gates. If IN1 = IN2 = 1 the circuit is equivalent to the two inverter loop. However, if one of the inputs is zero the output is forced to either 1 or 0 irrespective of the stored value. If IN1 = 0 and IN2 = 1 an output of 0 is given. This is retained when IN1 returns to 1. If IN1 = 1 and IN2 = 0 an output of 1 is given. This is retained when IN2 returns to 1.

If you find this confusing, you might find it useful to "work through" these states on a piece of paper. The IN1 input going low forces a 0 to be stored and so this input is called RESET ($\overline{R}$). The IN2 input going low forces a 1 to be stored and so this is called SET ($\overline{S}$).

This type of circuit is called a *set-reset flip-flop* **(SR or RS Flip-Flop)** and its circuit is often drawn in the form shown in Fig.6.11. The Set and Reset inputs are *"active low"*, hence the *bars* drawn over them in the diagram. If you connect two NOR gates in the same configuration you get an SR flip-flop with *"active high"* inputs. You might find it interesting to draw this out and prove that it works!

The outputs of either inverter in Fig.6.11 may be used and are always complementary (*opposite* levels to each other). These are labelled Q and $\overline{Q}$.

If we set both inputs to zero then both outputs will go to 1. Note that we have said that the outputs are complementary, so we are not using the flip-flop correctly in this case, it is an "illegal state". Things get even worse if we return both inputs to 1 simultaneously. This is an example of a metastability problem as, although Q and $\overline{Q}$ are made complementary, their actual values are unpredictable. In the Lab Work we find that Lord Faversham Wills has found an application for this kind of flip-flop.

The 4043 and 4044 i.c.s are RS flip-flops with "active high" (1) and "active low" (0) inputs respectively.

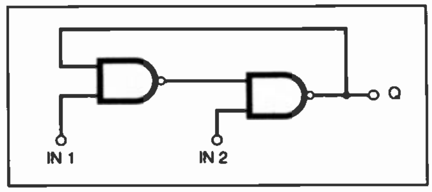


Fig.6.10. Set-Reset flip-flop.

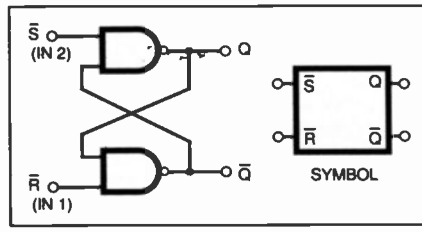


Fig.6.11. Set-Reset flip-flop circuit and symbol.

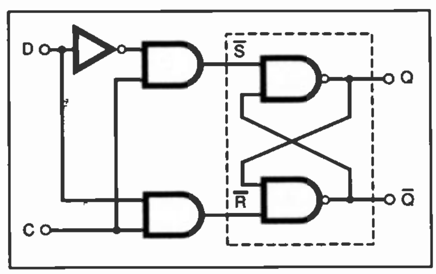


Fig.6.12. Data latch.

Another Data Latch

The RS flip-flop is different from the transparent Data Latch we described earlier in that separate signals are used to store 1 or 0. This is often very useful, but cannot be used to directly store the state of a single line. We can make a Data Latch from an RS flip-flop with the addition of extra gates as shown in Fig.6.12.

Here the input labelled C is the storage "Clock". When we want to store the state of the D input we make C high. Then if D is 1 the $\overline{S}$ input of the SR flip-flop is set to 0 and the $\overline{R}$ is set to 1. This results in a 1 being stored and output at Q.

Similarly, if D is 0 the SR flip-flop is reset. Like our first data latch, this one is transparent in that when C is high the Q output follows the value of D, i.e. if D changes whilst C is high, so does Q.

The 4042 quadruple D-latch i.c. uses a similar circuit to Fig.6.12. All four latches share the same clock input pin.

Give Me The Power, Give Me The POR!

In our traffic light example we mentioned that the memory holding the current pattern displayed on the lights will contain random data when power is first applied. If we did nothing about this the results could be disastrous, for example the lights may start-up Green when they should be Red, or display an abnormal pattern such as the Red *and* Green lights both being on at once.

We can be cunning with the design so that the circuit always jumps quickly from an abnormal state to a safe one, but it is better that this never happens in the first place. To do this we must apply a reset to the memory flip-flops at power up using a *Power On Reset* (**POR**) circuit. This is simply an *RC* circuit (see Part 2) connected to a buffer or inverter (see Fig.6.13) whose output provides a Reset signal for the whole circuit during and just after power-on.

It is not just small circuits with a few gates and flip-flops that need power-on reset, it is important in computers too. The microprocessor powers up with all its internal (on chip) memories in a random state and the memory (RAM) contains random data too. Left alone like this it would effectively start running a random program in a random part of memory, the result would probably be that the computer simply "locked-up" and did nothing, but it could be far more horrible.

When you switch on your PC a reset (like pressing the reset button) is automatically applied by the POR circuit. This puts the microprocessor and other chips in the correct initial state so they set off from the right starting point.

The RAM is not reset. RAM memory is different from flip-flop memory. Each storage bit has to be very small so that we can have large capacity memories, we cannot afford the space for resets in the RAM.

This does not matter, and anyway a memory full of zeros would be little better as a program than random bits. What actually happens is that the POR makes sure that the microprocessor finds a program (the BIOS) which is stored in a permanent memory which does not loose its data when power is removed. This program sorts out starting up the computer so that it is useable.

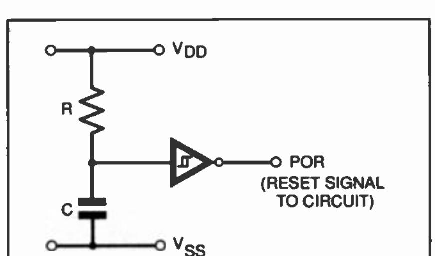


Fig.6.13. Power on reset.

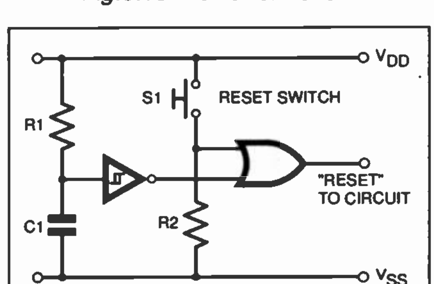


Fig.6.14. POR with manual reset.

Power On

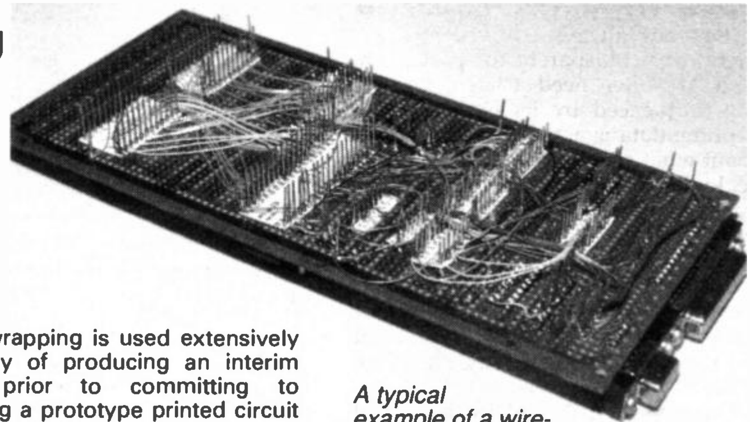
Now have look at the POR circuit in Fig.6.13. When the power is first applied the capacitor *C* is discharged (so the output from the circuit would be 1). The logic of the main circuit is arranged so that this signal resets all the flip-flops.

In the moments after the power supply is switched on capacitor *C* charges up through the resistor *R*, eventually crossing the logic threshold of the inverter and switching the reset signal to its inactive state (0 in our example). The main circuit is released from the reset condition and starts performing its intended function.

You may have noticed that the inverter in the POR circuit has a strange symbol on it, this is because it is a Schmitt trigger, rather than an ordinary inverter. Schmitt trigger gates are designed so that they are able to cope with slowly changing inputs which cause problems for normal logic gates that expect a fast transition from 0 to 1 and 1 to 0. Examples of Schmitt trigger gates include the 40106 hex inverting Schmitt trigger; the 4093 quad 2-input NAND Schmitt trigger; the 7414 hex inverting Schmitt trigger; the 7413 dual 4-input NAND Schmitt trigger, and the 74132 quad 2-input NAND Schmitt trigger.

Some circuits or systems require a *Manual* Reset as well as POR, your PC is an example. It is easy to add a manual reset switch using a gate to combine it with the POR signal as shown in Fig.6.14.

Check Out: Wire Wrapping



A typical example of a wire-wrapped prototype board.

A "solderless" breadboard – such as the type we suggested for our **Lab Work** experiments is an ideal way of constructing prototype or demonstration circuits. This allows you to reposition wires and experiment by swapping out components for alternatives, and several breadboards can be dovetailed together to accept larger circuits.

The down-side is that you only need one contact to be slightly unreliable (perhaps you exerted too much force and damaged a contact previously) for a circuit to behave somewhat erratically. This can be an intermittent fault which is all the more maddening. Also, it is not impossible to have the wire leads of adjacent components occasionally touching or shorting to other parts, so you have to keep an eye on everything to ensure that it all stays in place!

Overall though, solderless breadboards are a fine way of developing simple experimental circuits, and being re-usable they are an economical prototyping system too.

Wirewrapping

The subject of this *Check Out* topic is that of **wirewrapping**. This is a more advanced method of producing prototype circuits which is especially suitable when many integrated circuits (i.c.s) are involved. In these circumstances it could become more difficult to use solderless breadboards as reliability or complexity may be an issue, and the last thing you need when developing important prototypes is a circuit having intermittent or inconsistent behaviour.

Even if you haven't used such a system yourself, you may have seen wirewrapping systems used in an electronics workshop or at college or university. The advantage of wirewrapping is that it permits many integrated circuits to be connected reliably and relatively quickly in a "make it up as you go along" manner. (Some commercial equipment such as telephone exchanges were assembled by wirewrapping the components together.)

Wirewrapping is used extensively as a way of producing an interim circuit, prior to committing to producing a prototype printed circuit board, which itself can a very time-consuming process requiring computer-aided design equipment.

Development boards are assembled using special dual-in-line wire-wrap sockets to carry integrated circuits. These have much longer pins onto which short lengths of interconnecting wire can be wrapped with a special hand-tool.

The wire needs a short length of insulation to be stripped and then the bare wire end is twirled tightly around the appropriate pin. The other end is then routed to its destination where another wirewrapped joint is made; several wraps can be made on one pin so that wires can be interconnected.

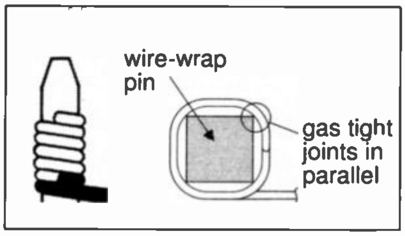


Fig.6.15. Making a wirewrap joint.

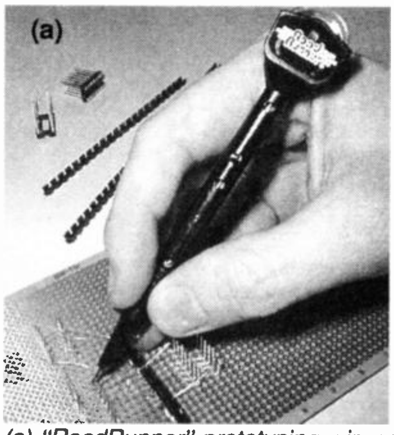
The underside of the circuit board will gradually assemble a *"rat's nest"* of wiring which isn't very pretty but this isn't important, although it is of course necessary to work methodically and not lose one's place. Some individual pins are usually soldered into place on the prototyping board, which may have a copper track pattern on the underside for soldering the sockets and for routing the power rails.

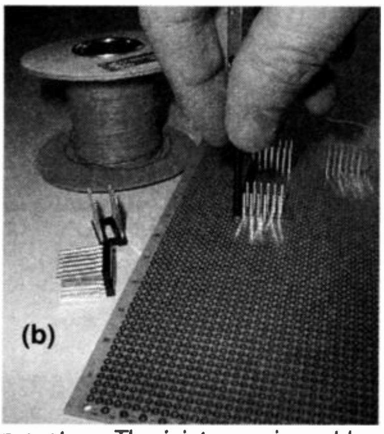
The best systems do not require any soldering, because the bare "wire-wrapped" joints form a highly-reliable gas-tight seal, which is just what you need! (See Fig.6.15.) The wire is wrapped so tightly around its pin/lead that the joint stands no chance of coming undone afterwards.

Other types (e.g. the *Roadrunner* system) use a fairly delicate wire covered with a thin enamel insulation. A dispenser pen is used to wrap the wire around a "protruding" component lead or i.c. pin, but the insulation is not removed beforehand. Instead the joint is soldered to form the connection and burn away the insulation. (The manufacturers warn that a toxic vapour is produced when the insulation is soldered through, so effective fume extraction may be needed.)

This is a cheaper system but it is obviously more time consuming. To help keep the interconnecting wires reasonably tensioned, a "comb" is used around which wires may be routed. This also helps to keep the delicate wiring tidy.

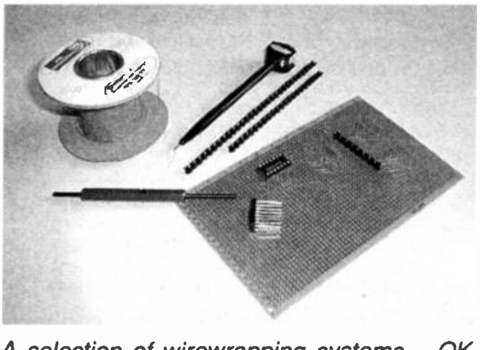
In better equipped workshops dealing with more complex circuitry, wirewrapping is performed using an expensive motorised tool. Check a professional catalogue for wirewrapping aids, including special prototyping boards, wirewrapping sockets and pins. Note that only specially-made wire should be used with the appropriate tool.





(a) "RoadRunner" prototyping wirewrap system. The joints require soldering afterwards. Note the black plastic wiring 'combs' which are used to tension and route the wires. (b) Non-solder professional wirewrap tool in action.

Hand-held wirewrapping tool and unwrapper.



A selection of wirewrapping systems – OK Industries and RoadRunner.

Edge Triggered Latches

It is not always convenient for a latch to be transparent for part of the time. We often need a latch which is only influenced by its Data input at the time data is actually stored. Think about what would happen to our Traffic Light Controller if the latch was transparent!

If we think about the latch in Fig.6.12, the point at which data is actually stored is where the clock *changes* from low to high. However, while the clock is high the output will change if the input changes. Now look at the circuit in Fig.6.16.

This uses two latches in series with opposite clocks. This circuit is never transparent as one latch is always holding when the other is transparent. For the sake of this exercise, assume that the latches are transparent (*pass the data through*) when their clock signal is low.

Let's look at the operation in more detail. If CLK1 is low then CLK2 is high and Latch 1 is transparent. At the same time CLK2 is high and Latch 2 is holding data.

We don't know what this data is but we will assume a 0 for convenience. This is illustrated by time A on the timing diagram (Fig.6.17). At this point any changes on the data (D) input only affect Q1 not the output of the circuit (time B on Fig.6.17).

When C changes from low to high, Latch 1 stores the value currently on D (a 1 in this case, at time C in Fig.6.17). Q1 will be held at this value while CLK1 is high. During this period Latch 2 is transparent and therefore the value just stored by Latch 1 will appear at Q. This value will not change if D changes as Q1 is held (time D).

When C goes low again the value of Q1, that is the value held in Latch 1, will be stored by Latch 2. As the output was already equal to Q1, Q will not change (time E). The change of (clock) C to low also makes Latch 1 transparent allowing any change on D through to Q1.

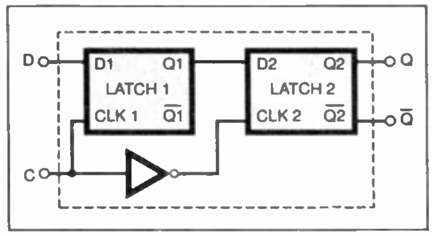


Fig.6.16. Edge triggered data latch.

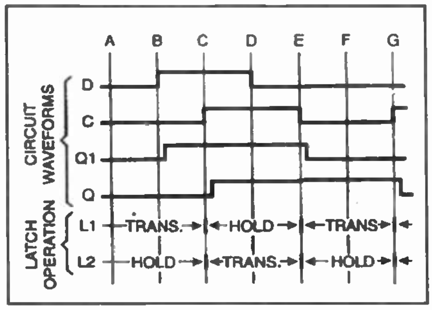


Fig.6.17. Edge triggered latch timing diagrams.

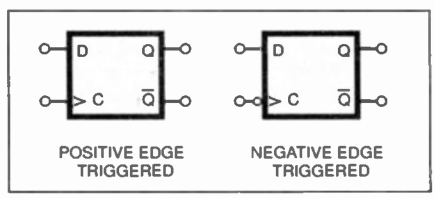


Fig.6.18. Edge triggered latch symbols.

This brings us back to our starting point, except in our example we now have a 1 rather than a 0 stored and output at Q (time F). A further change from 0 to 1 on C will load another 0 into the circuit (point G). The stored value and hence output of this circuit is only influenced by data when the clock changes from 0 to 1. For this reason it is described as being *positive edge triggered*.

On a latch or flip-flop circuit symbol a small triangle is sometimes placed at the clock input to indicate it is edge triggered. Negative (1 to 0) edge triggered flip-flop symbols have a "inversion circle" at the clock input. See Fig.6.18.

The CMOS 4013 i.c. is a dual, positive edge triggered, D-type flip-flop whose internal circuitry is based on Fig.6.5 and Fig.6.16.

Dynamic Memory

The memory circuits we have described so far do not need any extra action once the value has been set into them. For this reason they are called *static* memories. However, a large number of gates are used in such memories, and so the number of bits you can hold on a chip of a particular size is limited.

Computers often use a type of memory which is referred to as *dynamic*. Dynamic RAM is more compact, it stores data as a charge (recall the Lab Work in Part 4 where a bit could be set and retained on a CMOS input using a flying lead).

However, this charge will only be held for a finite time. Dynamic RAMS are made to work by a *refresh* system in which each bit in the memory is repeatedly read and replaced to keep the storage capacitance *charged up*. In addition to memories in computers it is possible to use dynamic data storage in processing circuits, but this beyond the scope of this course.

Now have a look at the Lab Work section and build up a simple Latching demonstration circuit and Power-On Reset.

The *Teach-In* writers are delighted to receive your comments, feedback and queries. you can write to us at *Teach-In* c/o the Editorial address, or E-mail **Teach_In98epemag.demon.co.uk.**

TEACH-IN '98

LAB WORK 6

Objectives: Demonstrate a power-on reset function; construct a transparent latch; apply sequential logic to build a "Quiz Master" circuit.

Lab 6.1 – Power-on Resets

A "power-on reset" using a "Schmitt" inverter gate is shown in Fig.6.19. A Schmitt trigger is one which converts a slowly rising or falling signal into a "snap-action" on-off. A Schmitt inverter (e.g. the TTL 74LS14) has Schmitt inputs which are capable of accepting varying voltages rather than a simple logic high or logic low. The neat thing is that they can convert this into a high-low digital output.

On power-up, C1 is uncharged (0V across it) and so the inverter input pin 1 is low. Hence the output (pin 2) is high and l.e.d. D1 is extinguished because there is no voltage across it – it is "high" at both ends. R1 and C1 form an *RC* network which produces a time delay, and C1 slowly charges through R1 until the inverter eventually decides a logic 1 has been achieved, and it switches state. Then its output will go low, so current sinks into pin 2 through the l.e.d. which now glows. The circuit will now stay in that state. The period during which the l.e.d. is extinguished, is the power-on reset which can be used to reset any logic circuitry immediately after powering up.

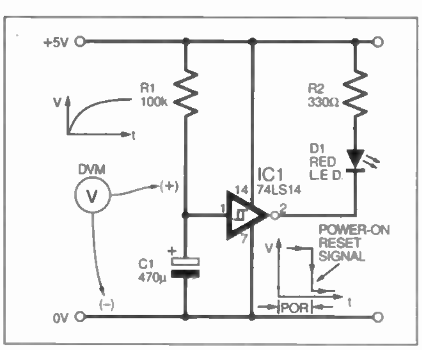
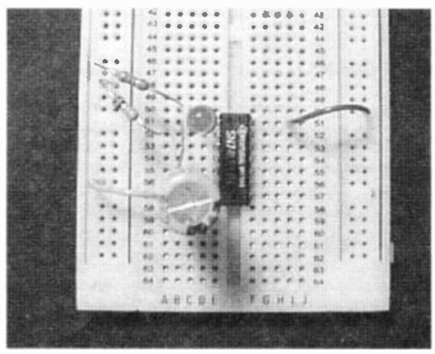


Fig.6.19. Power-on Reset circuit.



Power-on Reset breadboard layout.

Go ahead and assemble this on a breadboard using a 5V power supply. IC1 is "LS" (Low power Schottky) TTL which doesn't need anti-static precautions or unused inputs tied low. Measure the voltage across C1 with your digital voltmeter. Upon powering up, the voltage across the capacitor will slowly rise and after a few seconds, the l.e.d. will suddenly illuminate. If necessary, ensure that C1 is discharged by briefly shorting its wires together (a technique which should not be used except in low power circuits like this). Experiment with different values of capacitor or resistor.

- The delay of several seconds is far too long for most digital applications, and a power-on reset of a few milliseconds is usually adequate.
- The point at which the Schmitt inverter changes state is called its *threshold voltage*. Can you measure this with your digital multimeter? The difference between the switch-on and switch-off threshold voltages is called *hysteresis*.
- Schmitt trigger circuits can also be constructed using transistors or operational amplifiers. Such circuits might be seen in a street-light, for example, when the light suddenly switches on at dusk and off at dawn, with no in-between state.

Lab 6.2 – Build a Transparent Latch

In this experiment we will build a transparent latch based on Fig. 6.5 of the main tutorial. The switches S1 and S2 will be implemented using CMOS transmission gates (see *Teach-In* Part 5). The 4016 contains four transmission gates, each with input/outputs A and B and an enable (control) E (see Fig.6.20). The switches are on, connecting A and B when E is high. When E is low the switches are off, and a high impedance exists between A and B.

The purpose of Lab 6.2 is to study the formation of a latch and understand its operation, however we usually do not build latches from scratch but use one of the selection of latch and flip-flop chips which are available instead. These chips often contain several latches, sometimes with common inputs such as clocks.

Assemble the circuit of Fig. 6.20, using your 5V supply and breadboard, with two flying leads for data and clock. Take static precautions and tie unused CMOS inputs low as shown. Follow the power supply connections to the i.c.s. carefully.

Now verify the operation of the circuit as follows: connect clock high: connect data to high and low alternately. Note how the l.e.d. responds – it follows the data signal, so the latch is behaving transparently.

Connect data high (l.e.d. on) and take the clock low. Connect the data low, note that the l.e.d. does not change (a 1 is held in the latch).

You Will Need

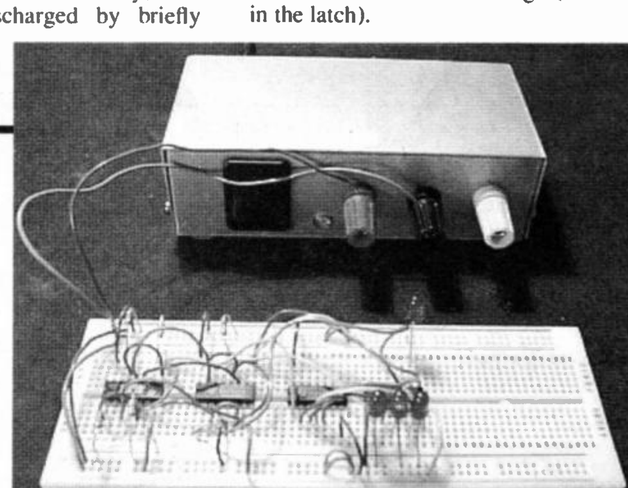
Resistors
100k (2 off)
330 ohm (4 off)
10k (5 off)
All 0.25W 5% carbon film

Capacitor
470µF electrolytic 10V

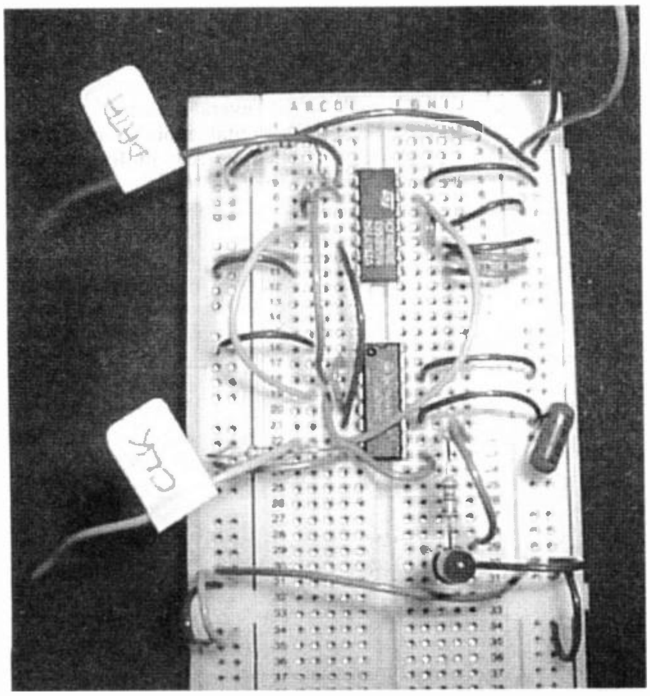
Semiconductors

74LS14	TTL hex Schmitt trigger inverter
4016	CMOS quad transmission gate
4049	CMOS hex inverter buffer/driver
4071	quad 2-input OR gate
4044	quad SR (NAND) flip-flop
4072	dual 4-input OR gate

Miscellaneous
Red l.e.d. (4 off); push-to-make switches (optional) (5 off); solderless breadboard; DVM; 5V power supply; hook-up wire.



Using the 5V Add-on Regulator, detailed in Lab Work 3, to power the Quiz Master breadboard demonstration.



Transparent latch circuit built on breadboard.

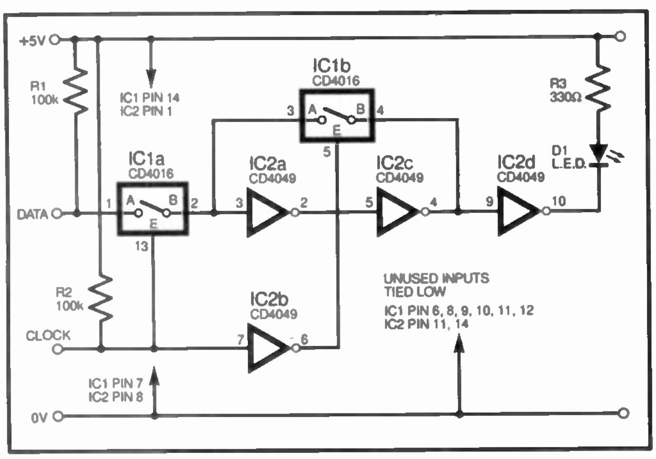


Fig.6.20. Transparent latch assembled from discrete gates.

Lab 6.3 – An Edge Triggered Latch

In this experiment we will build two transparent latches similar to those in Lab 6.2, and use them to form an edge triggered flip-flop as shown in Fig.6.16 of the main tutorial. Build the circuit in Fig.6.21 on your breadboard with the same CMOS chips as before (note that all gates are now used). Repeat the sequence of operations described for the transparent latch in the previous Lab. Note that the output no longer follows the data input when the clock is high. Verify that data is loaded when the clock changes from high to low.

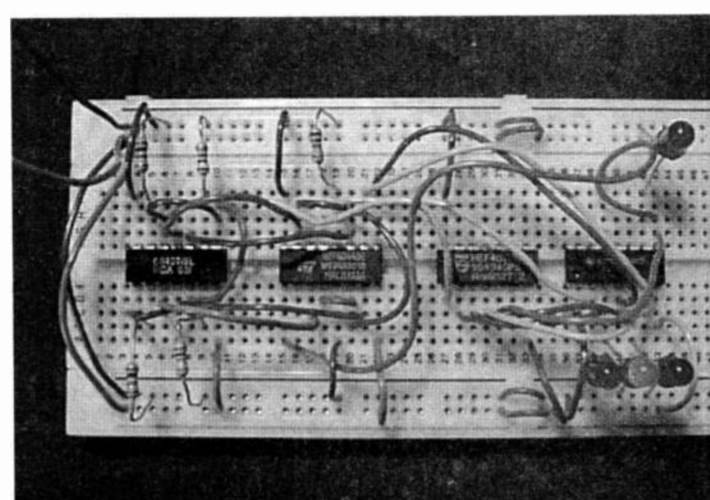
Lab 6.4 – His Lordship's Quiz Master circuit

Meantime, back at the residence of our favourite land-owning electronics fiend, Lord Faversham-Wills, his Lordship has settled down with his latest electronic creation. What better than an after-dinner family game? By popular demand (mainly because His Lordship kept fixing the results), his family insisted on an electronic form of "Quiz Master" to adjudicate in the family quiz, and so the circuit in Fig.6.22 was the eventual result.

The purpose of this Lab is to use SR flip-flops to build a fun and possibly useful circuit. The SR flip-flop has the property that once you "set" it, the flip-flop stays set until it is reset. Thus it can be used to "capture" a transient event (e.g. a pulse, or a momentary button press) and output a "permanent" signal. It makes no difference if the flip-flop is repeatedly activated, because it stays set, and only the reset signal will alter this.

In His Lordship's family quiz games, we need to know who pressed their button, and also who did so first. A button may only be pressed for a short time, so we could use an SR flip-flop connected to each contestant's button to "remember" the key press and then switch on a light or buzzer until it is reset by the quiz chairman (His Lordship, needless to say). This is useful, but what would be even more useful would be if we only flashed the light or sounded the buzzer for the team or individual who pressed first. We can do this with a bit of extra logic to make it "mutually exclusive".

If we connect an SR flip-flop to each contestant's button, and we detect when any of the SR flip-flops had been set (using the OR gate of IC3), then we can use this signal to "gate off" or lock out the signals from the other contestants, preventing them from setting their flip-flops and activating their buzzers or lights. The



Layout of components for the Quiz Master on the demo breadboard

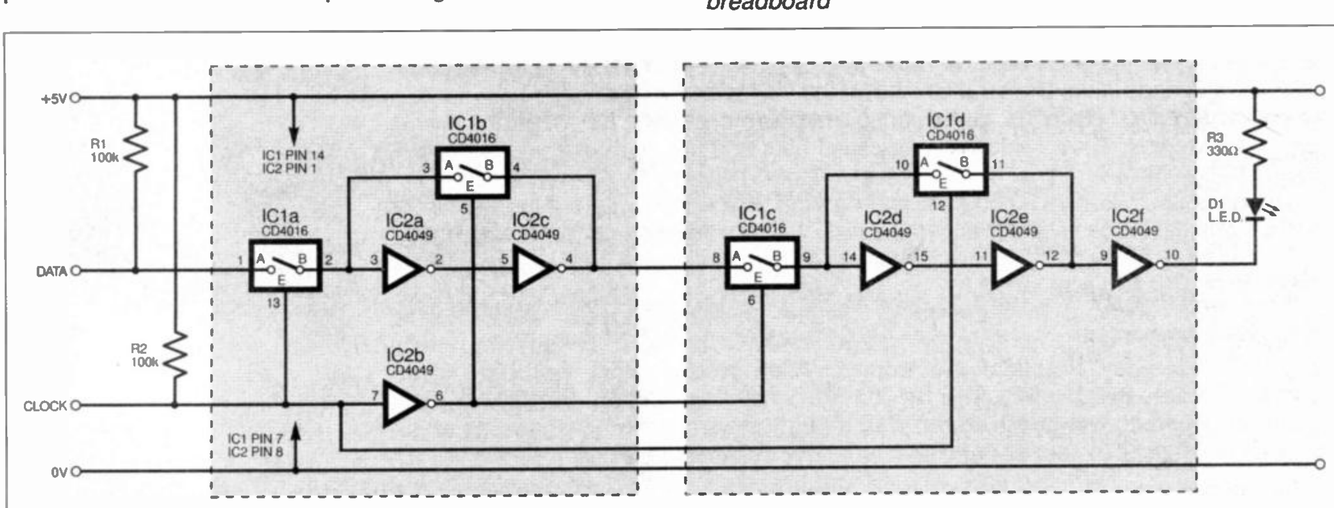


Fig.6.21. Circuit diagram for a negative-edge triggered latch constructed from two transparent latches.

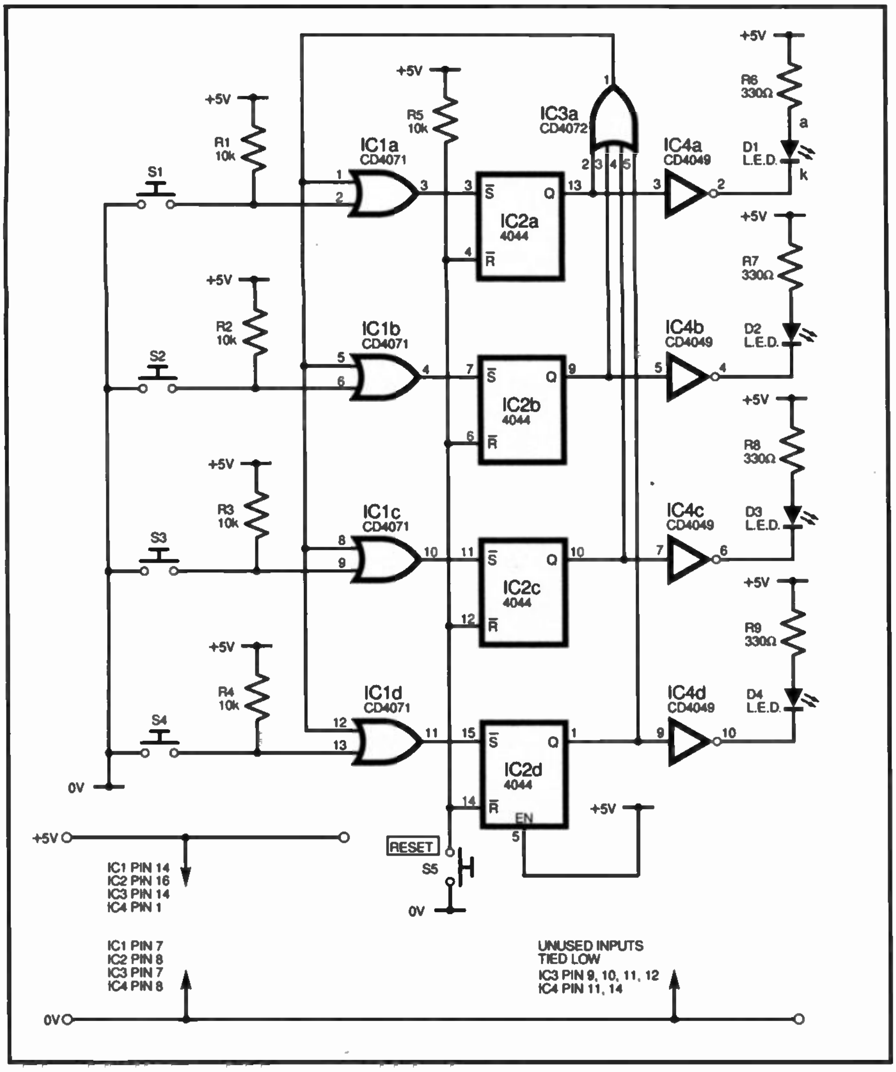


Fig.6.22. A Quiz Master circuit suitable for four players; His Lordship commands the Reset button.

reset pins of all the flip-flops are connected to another button (S5) which is pressed by His Lordship to ready the circuit for the next question.

What happens if two buttons are pressed at the same time? If they are within the time if takes for the circuit to gate-off, then both flip-flops will be set. The contestants would probably have to be within much less than a microsecond of each other for this to happen, so it would fair to consider it a tie! The key time is the propagation delay from the S input of the flip-flop, through the flip-flop, and the time through two OR gates back to the S inputs.

You can now proceed to build the circuit with CMOS chips per the circuit diagram and verify its operation. Follow the circuit diagram closely, especially the power supply connections. All five switches could be improvised with just one long flying lead wired to 0V, for now.

The circuit may power up in a random state, so use S5 to reset it (an excellent example of why a power-on reset is useful!). Then test by taking one input to 0V and see the corresponding l.e.d. illuminate. The circuit should lock in this state until reset at S5. Also try taking two inputs to 0V simultaneously, and see how impossible it is to beat the system, no matter how hard you try.

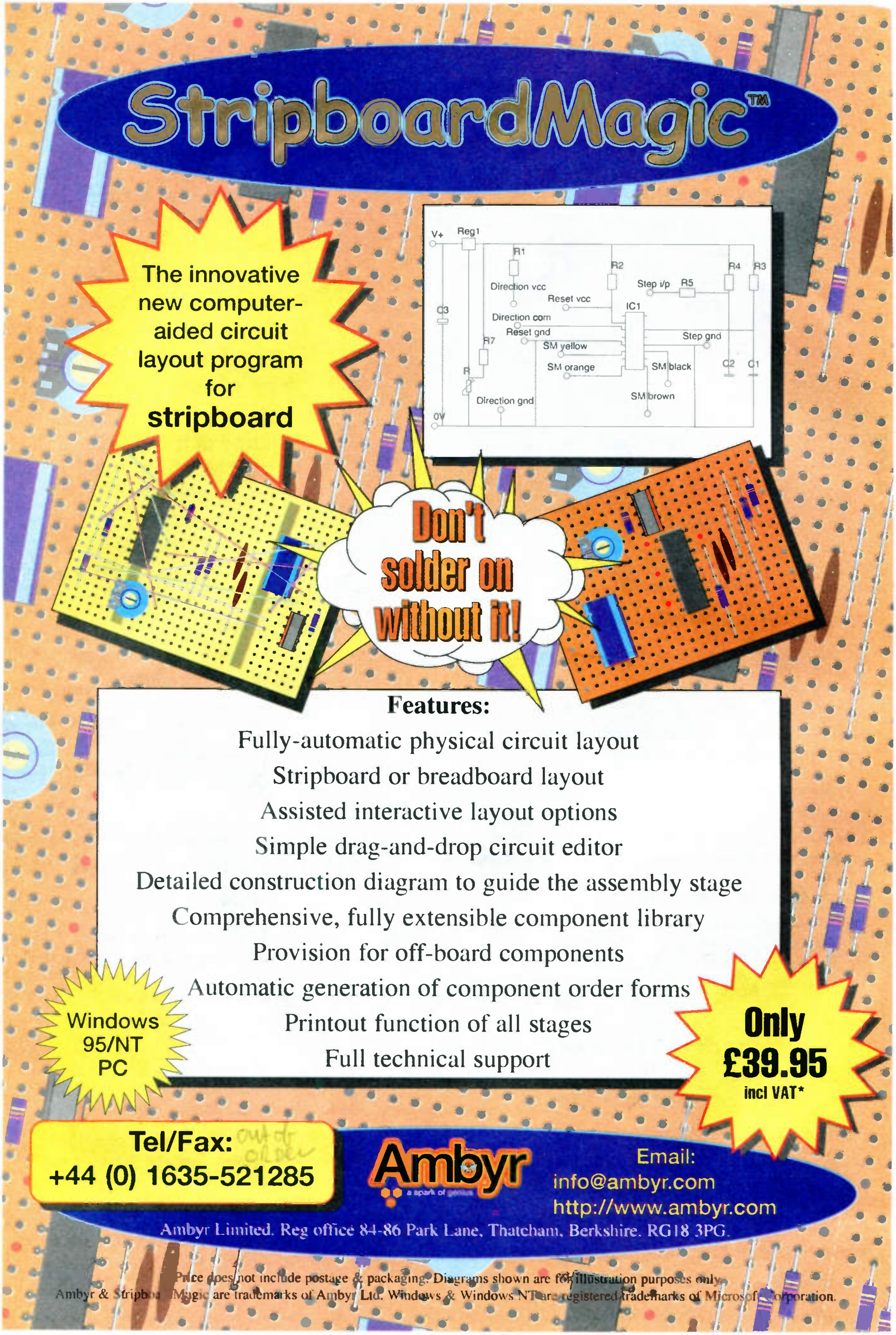
- If you feel ambitious build two copies of the circuit so that you can have two teams of four contestants. Use the signal from the 4-input OR gates to control two team buzzers (with different sounds). Can you work out how to change the logic so that the two teams' circuits lock each other out? You will need an extra couple of OR gates for this.
- If you feel confident enough, try to translate this circuit onto a stripboard layout and "hard wire" it.
- More ambitious readers could try to incorporate a power-on reset signal too.

End of Lab 6 Tasks

At the end of **Lab 6**, you have now investigated and demonstrated transparent and edge-triggered latch circuits, which form the basic element of memories. You have also constructed a power-on reset.

The *Teach-In* writers are happy to receive your queries, feedback and comments. Write to them c/o the Editorial address, or **E-mail Teach_In@epemag.demon.co.uk.**

In Lab Work 7: We continue with further investigation of sequential logic, by checking out further types of latch and we examine various types of clock generator circuits.



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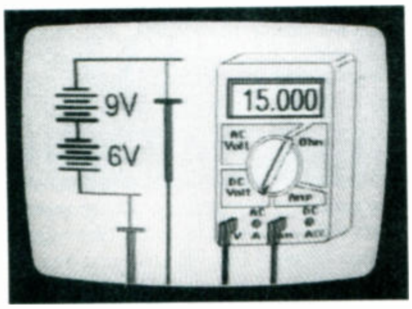

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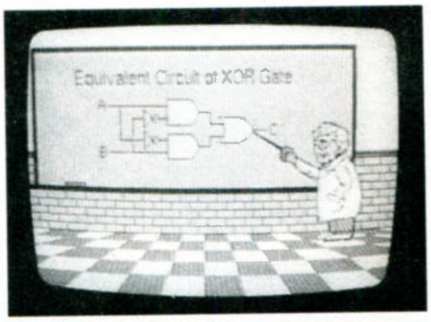

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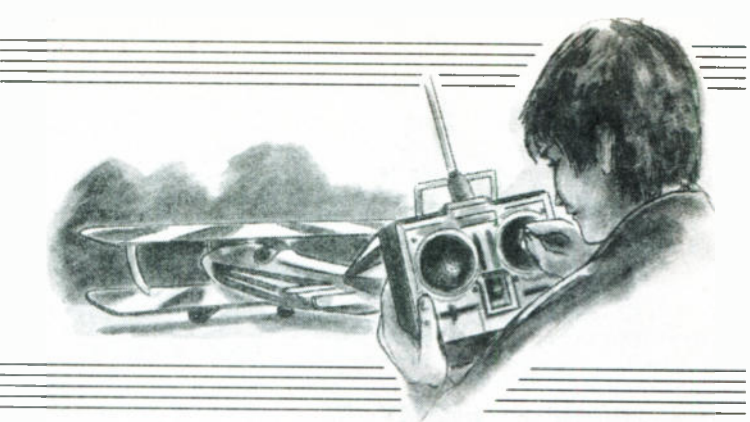
E22

RC-METER



TONY HART

An accurate microcontrolled test meter for your A.M. Pulse Proportional Radio Control System and more.

THE RC-Meter incorporates an accurate 50MHz 5-digit frequency meter for measuring transmitter frequency, a pulse width meter and a servo tester. A liquid crystal display (l.c.d.) is used to show the modes and measurements.

Over the past 20 years or so during which the author has been using radio control (RC) equipment, he has accumulated a box full of bits and pieces such as old crystals, servos and receivers.

Recently, he had to equip a small model boat with a 2-channel radio system made up from some of these parts. However, when he came to find crystals for the transmitter and receiver, low and behold, most of the markings had been rubbed off!

After finding what looked like a matching pair of crystals, he then found that the transmitter would not function correctly. This was traced to the transmitter crystal – it had probably been dropped and damaged.

This and other problems with his old gear prompted him to think about designing a small portable meter that could perform a few simple checks on RC equipment in the field or workshop.

RC-METER FACILITIES

The meter has been designed to enable rapid testing of the operation of a.m. (amplitude modulation) pulse proportional radio control transmitters, receivers and servos.

A waveform schematic of the typical frame format of a 4-channel a.m. pulse proportional radio control transmitter is shown in Fig.1.

The transmitter frequency, number of channels, frame time and individual channel pulse widths of up to eight channels can be displayed simply by holding the RC transmitter close to the unit.

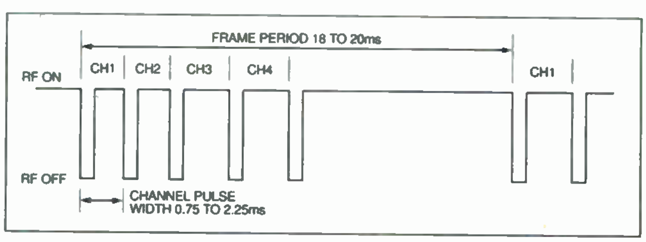


Fig.1. Typical frame format of a 4-channel a.m. pulse proportional RC transmitter.

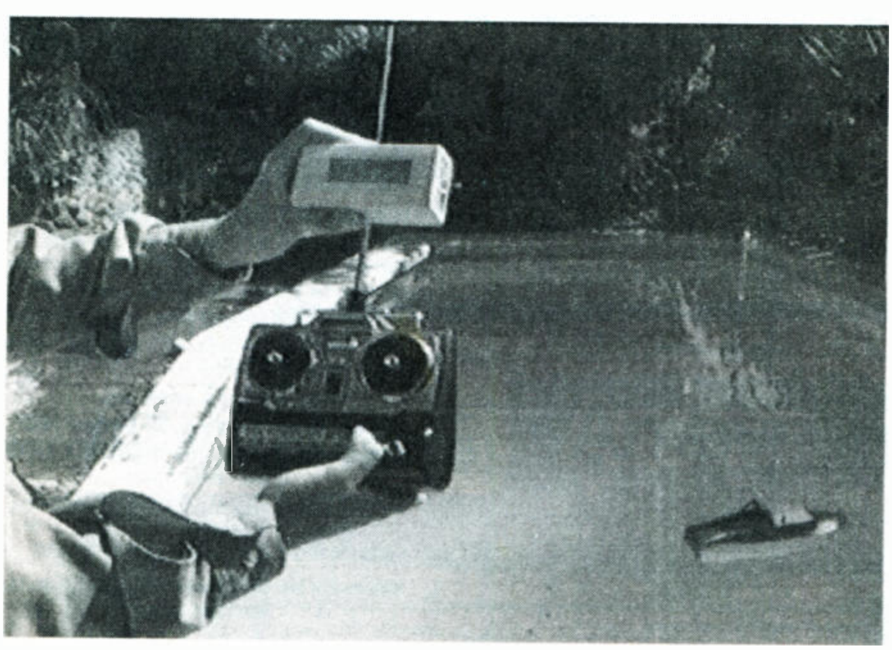
The transmitter pulse detector system will only detect pulse data from radio control transmitters using 100 per cent amplitude modulation. However, the frequency readout will operate as long as at least 4ms of transmitted signal is detected, and so can still be used with modern f.m. (frequency modulated) transmitters.

By connecting a flying lead from one of the radio control receiver's channel outputs, the meter can display the received pulse width and frame time.

The meter can also produce a servo drive signal, mimicking the output of a receiver. The servo is plugged into the meter and a pulse is generated every 18ms. The pulse width is increased or decreased by pressing an Up or Down switch respectively. The pulse width range is from 0·75ms to 2·25ms.

OPERATING MODES

There are four operating modes, Modes 0 to 3. Mode change is accomplished by pressing switches, one to go up a mode, and the other to go down a mode. When in Mode 3, pressing both switches resets the unit to Mode 0 when powered from an external power source, or off when battery powered.



MODE 0

Mode 0 is the mode entered on power-up. Initially, the l.c.d. shows the Mode 0 "welcome" message (see Photo 1) for about one second. (Note that the display layouts in Photos 1 to 6 differ slightly from those in the final model.)

When the transmitter aerial is held close to the meter, the l.c.d. shows the transmitter frequency in megahertz (MHz), the pulse frame time in milliseconds (ms), and the channel number.

If the transmitted signal does not contain a.m. pulse data, then the number of channels and frame time readings are not displayed. The frequency of just about any

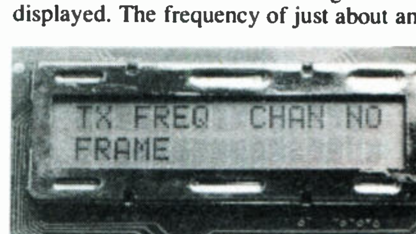


Photo 1. Mode 0 "welcome" message.

transmitter operating between 20MHz and 50MHz can be measured, providing the power is great enough.

For example, it is possible to measure the operating frequency of cordless phones and CB radios. The frequency resolution is 1kHz and the accuracy will be better than 0·01 per cent but could be better if the 10MHz is trimmed and calibrated correctly

Photo 2. Typical display of a 6-channel transmitter in Mode 0.

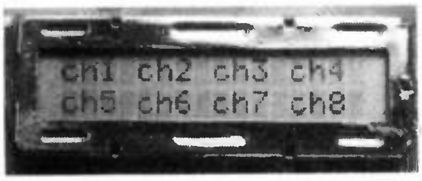


Photo 3. Mode 1 "welcome" message.

Photo 4. Typical display of a 6-channel transmitter in Mode 1.

against a good frequency meter. The frame period resolution is 0·1ms. A typical display of a 6-channel transmitter is shown in Photo 2.

MODE 1

In Mode 1, the l.c.d. shows the transmitted pulse widths for all transmitter channels (up to eight channels displayed). On entry to Mode 1, the Mode 1 welcome message (see Photo 3) is first displayed for about one second.

The screen then displays the individual channel pulse widths in milliseconds. For example, a 6-channel transmitter may produce a display as shown in Photo 4.

The displayed values of the frame and pulse width measurements in Modes 0 and 1 are only accurate to about 0·1ms, but are useful for indicating whether a particular control is in normal or reverse mode and giving the required pulse width range. Greater accuracy is achieved in Mode 2 when measuring the actual receiver output and frame rate.

MODE 2

In Mode 2, the l.c.d. shows the pulse width and frame time of the receiver channel connected to the RC-Meter's receiver socket via a flying lead. The resolution of both measurements is 0·01ms. A typical display is shown in Photo 5.

MODE 3

The RC-Meter generates and supplies pulses to a servo plugged into the servo socket. The l.c.d. shows the pulse width

Photo 5. Typical display in Mode 2.

Photo 6. Typical display in Mode. 3.

and frame time (set to 18ms) generated by the RC-Meter (see Photo 6).

The pulse width can be adjusted up or down between 0·75ms and 2·25ms by pressing either switch.

MICROCONTROLLER

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

The design is centred around a PIC16C84 microcontroller, IC2. This is operated at a clock frequency of 10MHz, as set by crystal X1 in association with capacitors C5 and C6. C5 is a trimmer capacitor which allows the clock frequency to be adjusted to precisely 10MHz, achieving a frequency readout accuracy of better than 0·01 per cent, although small variations of frequency will still occur

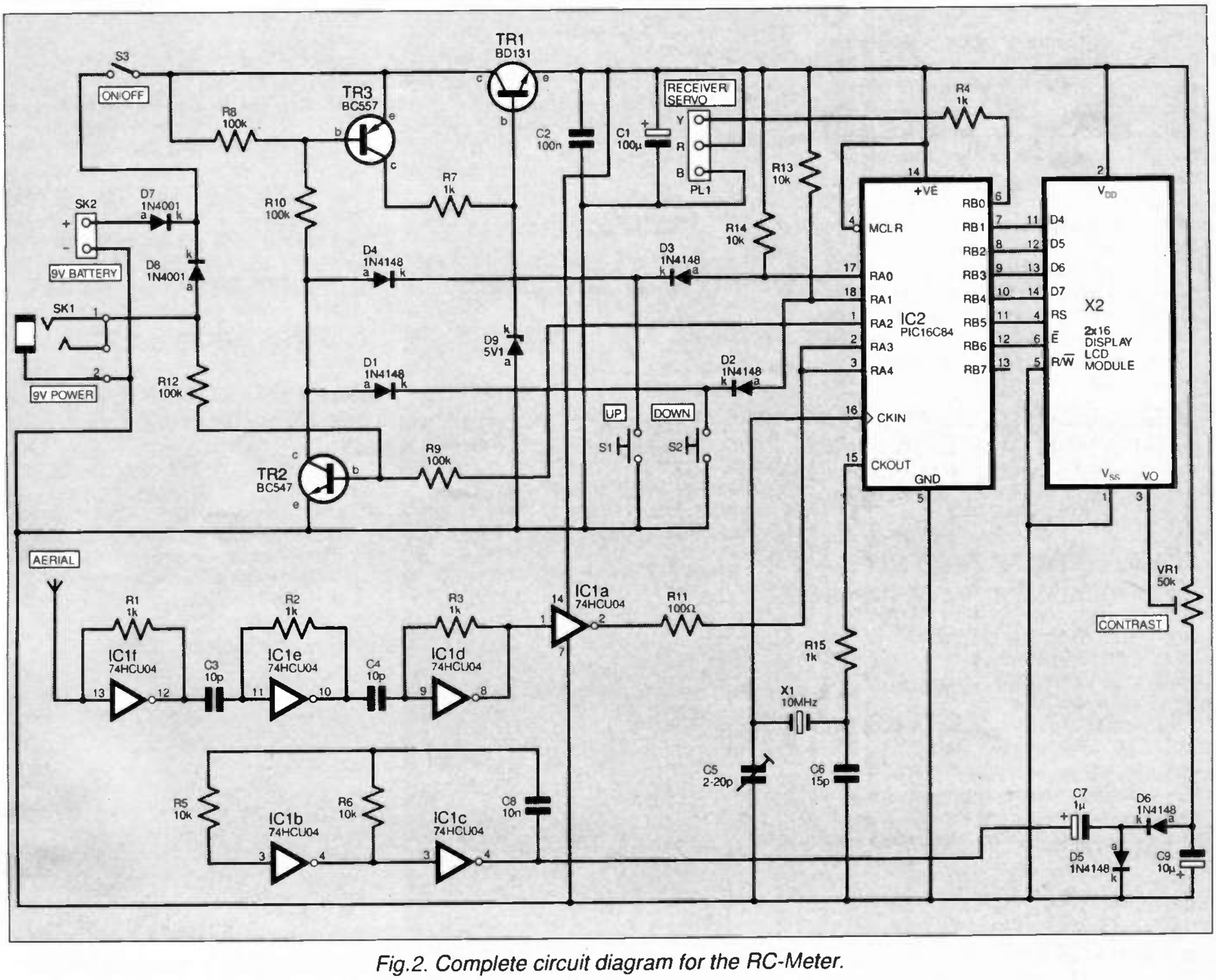


Fig.2. Complete circuit diagram for the RC-Meter.

with temperature and ageing. It is essential that the high speed version of the PIC is used (PIC16C84-10).

Two push-switches, S1 and S2, control the mode of operation and allow the pulse width supplied to the servo in Mode 3 to be reduced or increased.

HIGH FREQUENCY AMPLIFIER

In Modes 0 and 1, the transmitter signal is picked up and amplified by a high frequency linear amplifier based on HCMOS inverters IC1f, IC1e and IC1d. The digital output from the amplifier at IC1a is applied to the PIC's port pins RA3 and RA4 (RTCC input) via resistor R11.

CMOS logic gate inverters make very good amplifiers when operated in their linear region, which is achieved simply by applying feedback from the gate output to the gate input. The drawback of the use of logic gates in linear mode is that current consumption is quite high as both the *n* and *p* channel devices within each gate are conducting simultaneously. The higher the operating voltage, the faster the device and the greater the quiescent current.

For this reason the power rail has been kept down to 4·5V rather than 5V. It is important to stress that the *unbuffered* device (74HCU04) should be used in this application. If the more common 74HC04 is used, the result is less stable and prone to all sorts of undesirable effects, due to extra gate delays and higher gains within each feedback loop.

In this design three stages of amplification are required. The input to the first amplifier is simply a 10cm length of wire attached to the printed circuit board which acts as an aerial to pick up the r.f. (radio frequency) output from the radio control transmitter under test without any physical contact. If extra sensitivity is required, simply use a longer length of wire for the aerial.

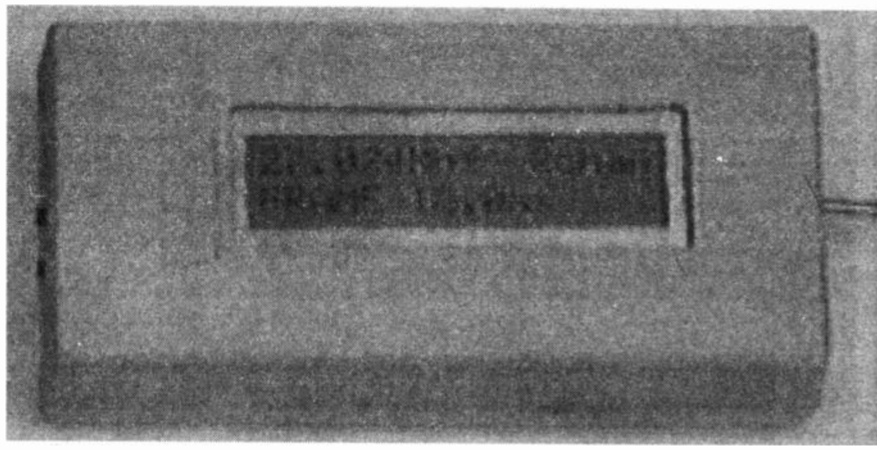
The three amplifier stages are coupled by 10pf capacitors, producing a band pass amplifier with a frequency response from about 16MHz up to 50MHz covering radio control bands throughout the world. The lower frequency limit is determined by the 2nd stage C3/R2 and the 3rd stage C4/R3. The high frequency limit is determined by the roll-off of the gates themselves. The fourth inverter, IC1a, converts the amplifier output to decent logic levels that will drive the PIC's RTCC input.

FREQUENCY METER

The idea for the frequency meter came from an application note in Microchip's *Embedded Control Handbook*. The PIC16C84 has one 8-bit timer (RTCC) which can be used with an 8-bit asynchronous prescaler.

An external clock applied directly to the RTCC without the prescaler is first synchronised to the internal clock of the PIC. This limits the counting of input pulses to about one quarter of the PIC's clock frequency, which in this case would be 2·5MHz.

However, the prescaler is totally asynchronous and will count up to 50MHz. The prescaler output is configured by software to be connected to the RTCC input. With an input of 50MHz, the RTCC input is thus only 195kHz, which is well within the RTCC counting capability.



The PIC's port pin RA3 is also connected to the prescaler input and is used to gate the input frequency for a precise measuring time. Pin RA3 is normally configured as an output set for logic 0, which shorts the input frequency from R11 to ground.

To measure the frequency, the RTCC is first cleared by a software instruction (which also clears the prescaler). Then for precisely 1ms, pin RA3 is set as an input. During this period, the input frequency from the amplifier toggles the prescaler and RTCC.

After the 1ms gating period, the input to the RTCC is halted by setting RA3 to be an output again, once more shorting R11 to ground. A 16-bit value of the input frequency is now captured in the prescaler and the RTCC. The eight bits of the most significant byte (msb) are in the RTCC and are easily read by a software instruction.

The prescaler cannot be directly read by software. Instead, the prescaler is incremented by toggling RA3 high and low until the RTCC increments, showing that the prescaler has rolled over from 255 decimal to zero.

The number of toggles required to cause the RTCC to roll over is subtracted from 256. This represents the value stored in the prescaler at the moment that the gate closed. The 16-bit binary value formed by the RTCC and prescaler is then converted to a 5-digit decimal number for display on the l.c.d.

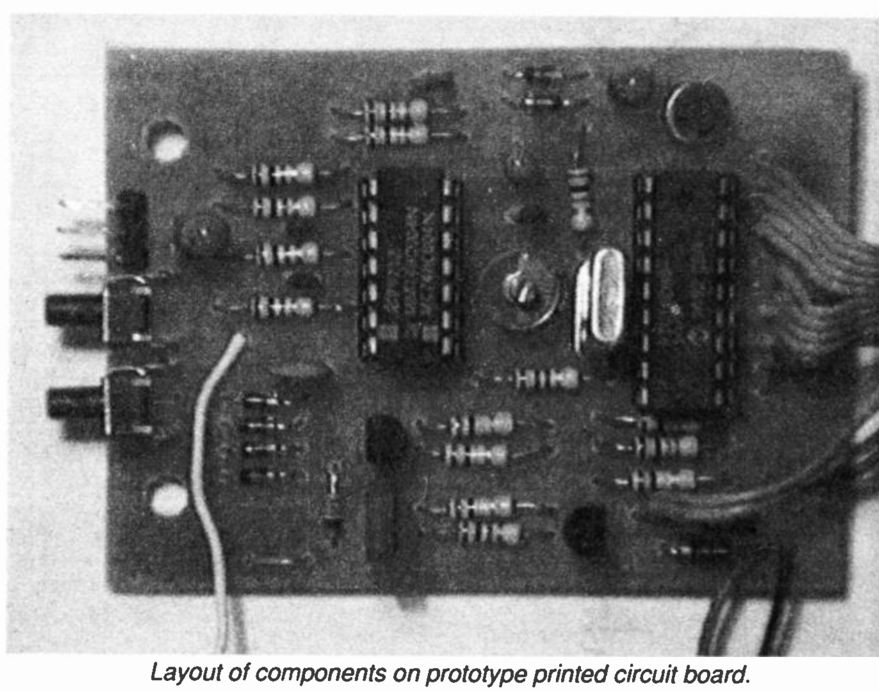
DISPLAY MODULE

The l.c.d. module, X2, is used in its 4-bit mode. It has two lines each of sixteen characters. The interface between the PIC and the l.c.d. module consists of the four data lines D4 to D7, the enable signal E and the RS line.

The l.c.d. also has a read/write line, R/W. In this application the PIC only needs to write data to the l.c.d. so the R/W line is permanently held in the write mode by being connected to the 0V power line.

The RS line tells the l.c.d. to accept control data when at logic 0 or character data when at logic 1. Examples of control data are Clear Screen or Home Cursor. Character data is that which is to be displayed on the screen. Because only four data lines are used, 8-bit data is sent as two 4-bit operations.

When character or control data is sent to the l.c.d., the PIC first outputs the four high bits (most significant nibble) as well as the RS line. After a short delay to allow the data lines to settle, the PIC pulses the E line to logic 1 and then back to logic 0. This latches the four bits of data into the l.c.d. After a further short delay the process is repeated but with the four low bits (least significant nibble).



Layout of components on prototype printed circuit board.

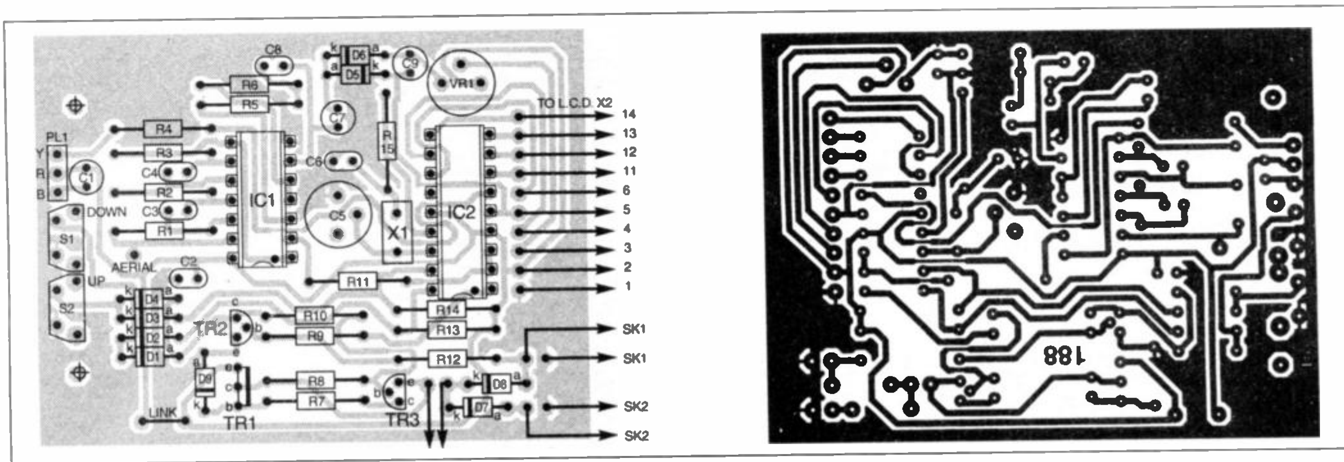


Fig.3. Printed circuit board component layout and full size underside copper foil track master pattern.

The l.c.d. then combines the two 4-bit nibbles into an 8-bit data word. If RS is high, the data is used as a pointer to a look-up table which contains all the characters of the alphabet (ASCII codes) and displays the character at the current cursor position on the screen. If the RS line is low during the data transfer, the l.c.d. executes the required control function.

CONTRAST BIAS

An Hitachi LM016L l.c.d. module was used in the prototype. This display is designed for 5V operation and does not require a negative voltage for screen contrast adjustment. However, it is possible that some alternative HD44780 compatible l.c.d. displays available from other manufacturers may require a negative bias and to accommodate this requirement a negative bias generator has been included in the circuit.

Inverters IC1b and IC1c form a low frequency oscillator running at approximately 5kHz. The oscillator output drives the negative inverter circuit made up of capacitors C7 and C9 and diodes D5 and D6. The negative voltage is applied to one end of the contrast potentiometer VR1 and the other end is connected to the positive power rail. The contrast drive can be adjusted from about −3·5V to +4.5V.

AUTOMATIC POWER DOWN

The unit can be powered from an internal 9V PP3 size battery or from an external 9V supply via a 2·1mm power connector. When the unit is operating, the current consumption is about 60mA. However, when a servo is connected in Mode 3 the consumption can be appreciably higher when the servo motor is rotating. For this reason it is best to use either a rechargeable nickel cadmium battery, or an alkaline battery.

Because of the relatively high power consumption and to avoid wasting expensive batteries if you forget to switch off, the meter has been designed to automatically switch itself off after approximately one minute.

However, if the meter is powered from an external supply via the power socket, then the auto power-off feature is disabled. This allows the meter to be in continuous use in the workshop without having to keep switching it back on.

The meter is turned on by setting the power switch S3 on and then pressing either S1 or S2. This pulls the collector of transistor TR2 to ground via either diode D4 or D1, respectively, and switches TR3 on via R10. When TR3 turns on, current is applied to the Zener diode D9 and power transistor TR1 via R7.

The emitter voltage of TR1 will be approximately 0·6V lower than the Zener voltage, i.e. about 4·5V. As soon as TR1's emitter voltage gets above about 3V, the PIC boots up and runs a setup routine. This configures the I/O (input/output) pins and pulls pin RA2 high. When the switch is released, transistor TR2 is held on via resistor R9, latching the power supply on.

The PIC runs a software timer which controls when pin RA2 is pulled low to turn the power off. The auto power-off timer works by decrementing the value in a file register every time the software checks for switch S1 or S2 being pressed. If either is pressed, the timer value is reset to a default level.

When the timer value decrements to zero, RA2 is forced low which switches off transistors TR2 and TR3, and therefore TR1's emitter drops to zero volts. In the power-down mode less than 1µA is drawn from the battery.

If the meter is supplied from an external supply via the power socket, TR2 is forced on permanently via resistor R12 and the auto power-off feature is disabled.

Diodes D7 and D8 prevent damage to the meter if the battery or external power supply are connected with the wrong polarity.

CONSTRUCTION

The printed circuit board (p.c.b.) holds all the components except the l.c.d. module, switch S3 and socket SK1. Details of the p.c.b. are shown in Fig.3. This board is available from the *EPE PCB Service*, code 188.

Assemble the p.c.b. with components in any order you wish, leaving IC1 and IC2 until last as these are the most likely devices to be damaged by static if adequate antistatic precautions have not been taken. Use i.c. sockets so that the chips can be added after testing that the voltage regulator circuit functions correctly.

Connector PL1 is a 3-way pin-strip with a bend in the legs 2mm from the solder end to produce a right angled socket.

Attach the connecting leads from the p.c.b. to the l.c.d. module, the switch and external power socket as shown in Fig.4 – 10-way ribbon cable helps here. Some displays have 14 pins on the left of the screen, others have the pins beneath the

COMPONENTS

Resistors — See SHOP TALK Page

R1 to R4, R7, R15	1k (6 off)
R5, R6, R13, R14	10k (4 off)
R8 to R10, R12	100k (4 off)
R11	100Ω

All 0·25w 5% carbon film.

Potentiometer

VR1	50k preset, min. round

Capacitors

C1	100µ elect. radial, 16V
C2	100n ceramic disc
C3, C4	10p ceramic plate (2 off)
C5	2p to 20p min. film dielectric trimmer
C6	15p ceramic plate
C7	1µ elect. radial, 16V
C8	10n ceramic disc
C9	10µ elect. radial, 16V

Semiconductors

D1 to D6	1N4148 signal diode (6 off)
D7, D8	1N4001 rectifier diode (2 off)
D9	5V1 Zener diode
TR1	BD131 *npn* power transistor
TR2	BC547 *npn* transistor
TR3	BC557 *pnp* transistor
IC1	74HCU04 unbuffered hex inverter
IC2	PIC16C84-10 (see text)

Miscellaneous

S1, S2	6mm push-to-make switch (2 off)
S3	min. s.p.s.t. toggle switch
PL1	3-way 0·1inch pin-strip
SK1	2·1mm power socket
SK2	PP3 battery clip
X1	10MHz crystal
X2	2-line 16-character l.c.d. module (see text)

Printed circuit board, available from the *EPE PCB Service*, code 188; plastic case, 120mm × 60mm × 40mm; 14-pin d.i.l. socket; 18-pin d.i.l. socket; 10-way ribbon cable; servo connector, 0·1 inch female (2 off).

Approx Cost Guidance Only £35

display. Both pin patterns are shown in Fig.4.

The position of the l.c.d. viewing cut-out is traced onto the box base and the corners are drilled inside the marked trace. A coping saw blade can then be used to cut between the holes to make a hole slightly smaller than the required cut-out size. The hole can then be finished off with a file.

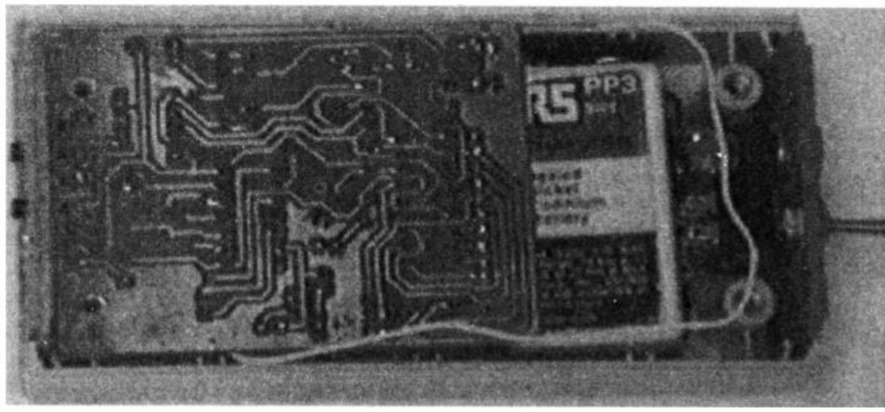
The l.c.d. module is glued over the cut-out. The author suggests the use of a hot glue gun to dab blobs of glue on the corners of the display's own p.c.b. You then have a few seconds to hold the display over the cut out and get it correctly positioned before the glue sets. Be careful not to get any hot glue near the display electronics or the l.c.d. screen.

On the prototype, the p.c.b. is held in the box by being trapped between the pillars holding one end of the box together. This necessitates filing down the two pillars at one end of the box lid by just over 1mm (about the thickness of the p.c.b.). When the lid is screwed down to the base, the p.c.b. is then held firmly between the top and bottom pillars.

It is best to drill the holes in the p.c.b. where the pillars are rather than rely on hole positions shown on the p.c.b. as the box may not be exactly the type specified.

At this stage, the holes can be drilled in the end plate for switches S1, S2 and connector PL1. The other end plate holds power socket SK1 and on/off switch S3, but as these are not rigidly connected to the p.c.b. their position is not so important.

The interconnecting flying lead is made up of two 0·1 inch 3-way RC female sockets wired back to back by black, red and yellow (or white) wires as shown in Fig.5. Ensure that the receiver's ground (black) is connected to PL1 (B) and the yellow pulse output is connected to PL1 (Y). If the RC-Meter is powering the receiver then the red lead must be connected to PL1 (R).



If the receiver is powered from the model's batteries, then only the signal and ground leads should be connected, otherwise the RC-Meter 4·5V supply may short to the model's supply. It is recommended that a lead is made up that does not include the central red positive wire.

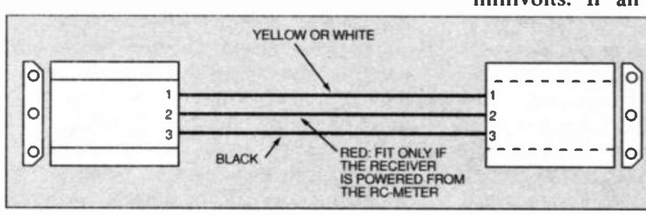


Fig.5. Interconnecting flying lead configuration.

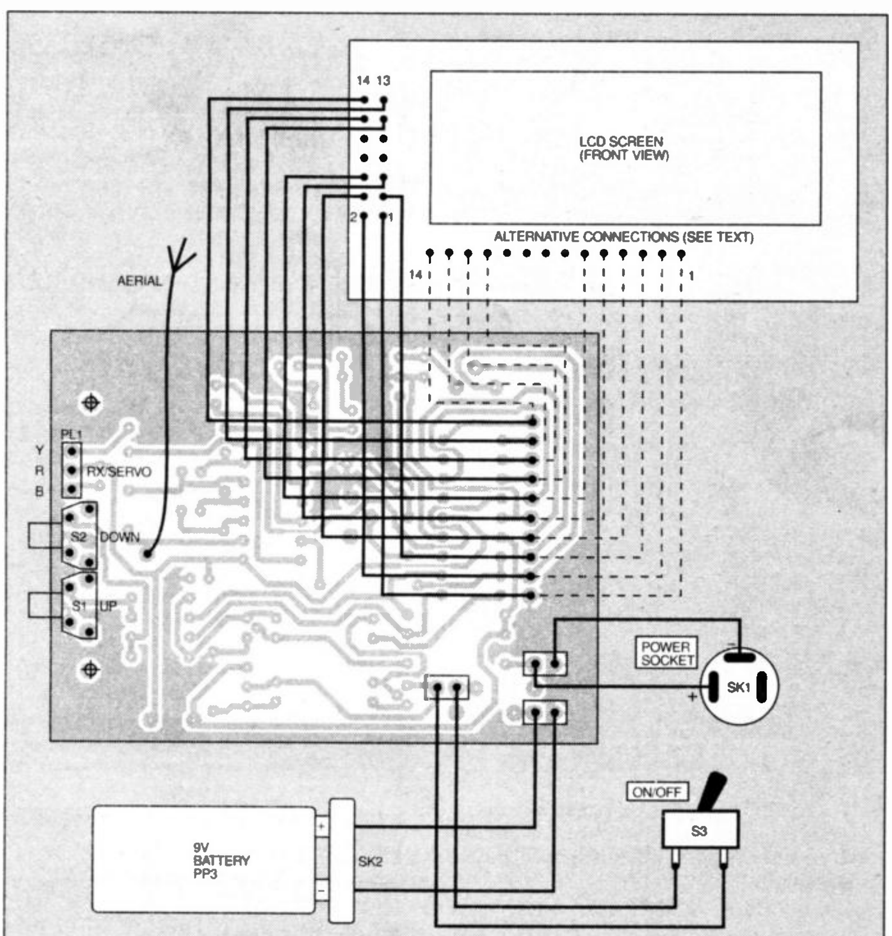


Fig.4. Details of the interwiring between the p.c.b. and the off-board components.

TESTS AND ADJUSTMENTS

Before placing everything into the case, visually check for solder shorts, etc., and double check the placement of all components and the p.c.b. connections. It is sensible to omit IC1 and IC2 before first connecting the battery.

Apply power from the battery or external socket, press either S1 or S2 and check that the rail voltage across IC1 socket pins 7 and 14 is 4·5V, within a few hundred millivolts. If all is OK, switch off and insert IC1 (pre-programmed) and IC2.

Switch on again and press either switch. Adjust the screen contrast preset potentiometer, VR1, for the best character display. Initially, the display will produce the Mode 0 message and then show a frequency readout of 00·000MHz after a second or so.

Place the meter close to a radio control transmitter and the l.c.d. should display a stable frequency and pulse information. If a calibrated frequency meter or generator is available, adjust trimmer capacitor C5 until a precise frequency readout is displayed, otherwise set C5 to its mid position where the vanes are half crossed.

If everything appears to operate correctly, install the parts into the case. It was the author's intention to squeeze the components into as small a box as possible, producing a tight fit with the p.c.b. slightly overlapping the PP3 battery. The result is a neat unit that can easily fit a pocket.

The aerial lead must be placed close to one edge of the case for maximum sensitivity. Once everything is in position, screw the case lid and base together, trapping the p.c.b. between the case pillars as the screws are tightened.

SOFTWARE

The PIC program has been written using MPASM. When programming the PIC the fuses should be set as follows: WDT off, OSC HS, POR on.

Details of how to obtain the software and pre-programmed PICs are given in the *Shoptalk* column – see elsewhere in this issue.

The software is separated into four modes of operation:

Modes 0 and 1 execute the software routine MEASURE which calls FMETER and PULSES.

The frequency measurement is synchronised to occur about 2ms before the end of the frame when the Channel 1 pulse will occur. The software detects when high frequency data is being received by the aerial and starts to measure the frequency about 2·5ms after continuous reception. If the aerial signal disappears briefly before 2·5ms (as it will between channel pulses of 100 per cent amplitude modulation systems) the frequency measurement is delayed.

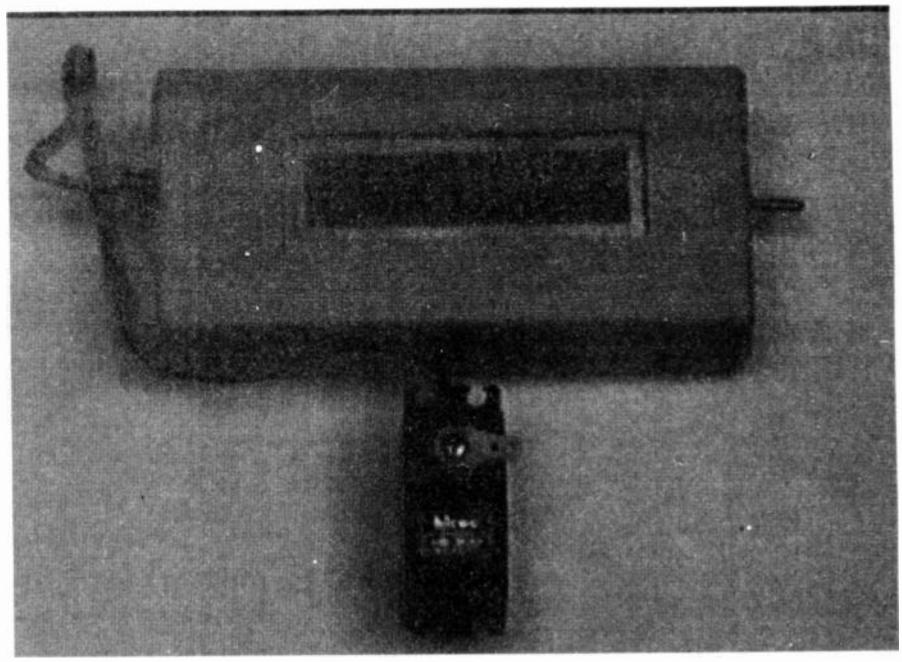
Generally, there is a period of greater than 4ms of transmission time at the end of each frame, even on an 8-channel transmitter, during which a frequency measurement can be made without interruption.

When RA4 is set for input mode, the aerial output enters the PIC and the received pulses increment the internal prescaler and RTCC counters.

Pulse widths are measured by counting the number of loops the software makes within the PULSES routine between successive transmitter *off* times. Each loop takes about 50µs, so measured counts are halved before display.

The start of each frame is recognised as the first transmitter off/on pulse after a continuous *on* lasting more than about 3ms. The first transition is then taken as the start of the Channel 1 pulse. After executing the MEASURE routine several times, the frequency, frame period and all the channel pulse widths are stored in PIC memory.

In Mode 0, the frequency, number of channels and frame time are displayed. Only the frequency is displayed if no pulse information is detected, allowing the meter to be used as a general purpose radio frequency meter if required.



Mode 1 software routine is exactly the same as Mode 0, except that only the channel pulse widths are displayed.

Mode 2 routine configures Port B pin RB0 to be an input to accept the output from a radio control receiver connected to SK1. It sets up an accurate interrupt to occur every 10µs which increments a counter.

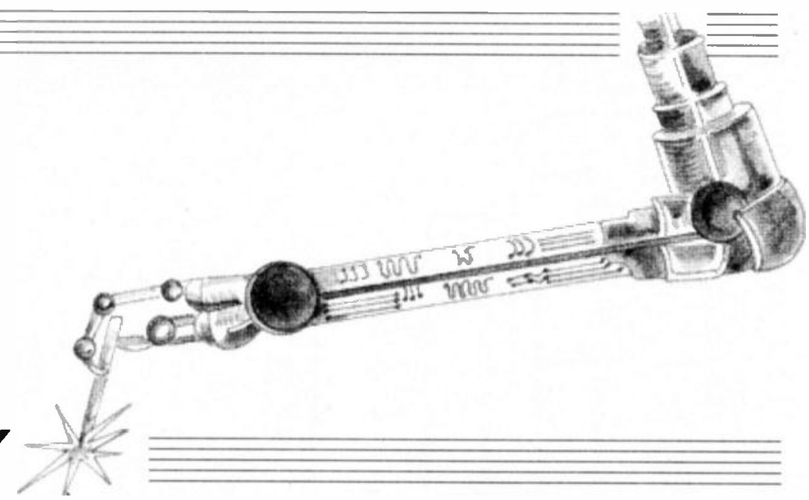
The routine then saves the counter value when the receiver signal goes from *on* to *off* and *off to on*, displaying the counter values on the l.c.d. after conversion from binary to decimal. The resolution is 0·01ms.

Mode 3 sets up Port B pin RB0 to output a pulse to a servo connected to socket SK1. The routine uses the same 10µs interrupt used in Mode 2 to generate a pulse varying from 0·75ms to 2·25ms every 18ms.

This routine is slightly different from Modes 0 to 2 in that the routine loops within itself and never returns to the main routine unless both switches S1 and S2 are pressed together. □

Regular Clinic

CIRCUIT SURGERY



ALAN WINSTANLEY

Our monthly column of readers' comments and queries deals with a logic counting and decoding problem, looks at ways of connecting the sides of double-sided boards together and at humidity detectors .

Adding and Counting Malaise

This month, with the help of the Department of Electronic Engineering at the University of Hull, we look at another digital logic application, this time using combinational and sequential logic to resolve a query involving adding and displaying the result on a 7-segment display. A teacher from Malaysia has a particularly tricky problem trying to count and display what appears to be an electronic form of "attendance register". ***P. Tanablan*** writes:

I am teaching in Sekolah Menengah Kebangsaan Mantin (National type secondary school Mantin) about 30 miles from Kuala Lumpur, Malaysia and have been a regular reader of EPE *for the past three years. My knowledge of electronics is about average and I am turning to* Circuit Surgery *in the hope of some advice.*

A project we are developing must, at the throw of a switch, count the number of l.e.d.s that have been switched on by my students as they enter the class, and it must then display the total. I have tried a board with 100 l.e.d.s operating a counter/adder, then multiplexer, decoder and finally three 7-segment displays.

I tried building this project using half and full adders but so far the results have been disappointing. I do not want to use a microcontroller. Any help with the design will be greatly appreciated by my students.

This is a counting problem, but somewhat different from those we looked at a couple of months ago. In fact, as the reader suggests, this problem can be solved with a combinational adder circuit or a counter. This month we will look at the combinational logic solution. Next month we will see how the problem can be solved using a sequential circuit which will be easier to build using discrete logic such as 4000 series CMOS.

Firstly, you don't need a microcontroller. Although the reader does not explain why the results were disappointing when using adders, it may have something to do with the need to provide a BCD output, something which is not straightforward with the binary adders available in the discrete logic families.

The large number of inputs to this circuit makes it complex and raises some interesting design issues. More on the logic design in moment, but first we will consider the input switches and l.e.d.s.

Care may be needed to ensure that the l.e.d. voltage drop does not result in a degraded logic level at the input, for example a 1·8V forward drop across an l.e.d. with its anode connected to 5V would result in 3·2V at the cathode, which is below the valid input logic 1 level of 3·5V for 4000 series CMOS powered from a 5V supply. On a 10V supply, however, the l.e.d. drop would not invalidate the logic 1 level of 7V (data based on Philips HE4000B series specs). It all depends on how you wire the switch, l.e.d. and resistor.

The reader also says the circuit must count the switches "at the throw of a switch". Actually it is quite easy to make the display update continuously as input switches are turned on or off, and of course a combinational circuit will give the new count value as soon as the gates have had time to respond. Therefore we will interpret this requirement as meaning "controls which can latch or blank the display as required" and look at this issue next month. We also assume that the multiplexer in the suggested scheme is a display multiplexer, and not part of the calculation circuit.

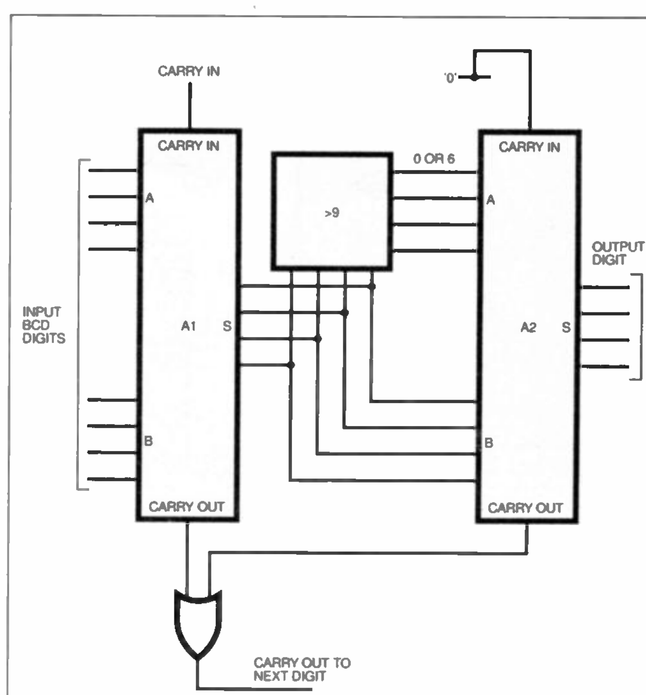


Fig.2. A one digit BCD adder. A1 and A2 are 4-digit full adders, the >9 circuit outputs binary 6 if its output is greater than 9 but otherwise outputs 0.

Combinationally

The problem can be solved "combinationally" as it effectively requires the addition of 100 simultaneously available 1-bit binary numbers. We will first look at doing this in binary and then address the need for a decimal display. One combination approach is to use a tree of adder circuits. This has 100 inputs at the first "level" and 7 outputs from the final level which carry a binary number up to decimal 100 (1100100 binary) indicating the number of 1s on the inputs.

An outline diagram of one suggested combinational solution is shown in Fig.1 opposite. At the first level, 50 1-bit adders each add two of the bits to give 50 2-bit numbers which may take values 0,1 or 2 (half adders could be used for this). Pairs of these 2-bit numbers are connected to 25 2-bit adders, each of which outputs a 3-bit

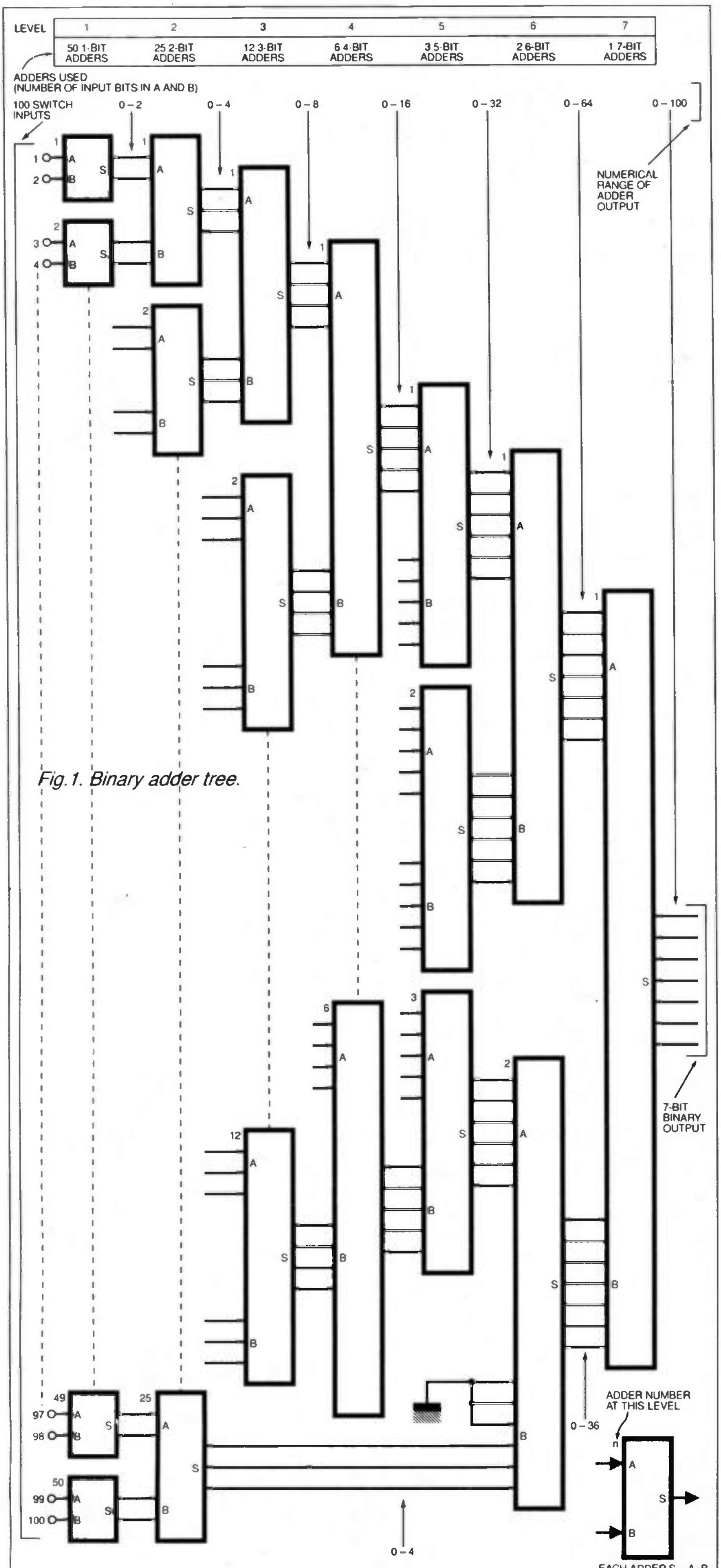


Fig. 1. Binary adder tree.

number ranging from 0 to 4. (Note that the possible range here is less than that for the adder itself.)

Then, leaving one of these 3-bit numbers aside for the moment, we connect the other 24 in pairs to twelve 3-bit adders (output ranges 0 to 8). We repeat this pattern with six 4-bit adders and three 5-bit adders. We connect the output of two of the 5-bit adders to a 6-bit adder (whose outputs may range from 0 to 64). The other 5-bit output and the 3-bit value we left behind earlier are connected to a 6-bit adder (whose output may range from 0 to 36).

The last two adders (6-bit and 5-bit) are connected to a 6-bit adder, whose outputs (including the carry) provide the 7-bit binary number ranging from 0 to 100. As you can see this implies a large circuit so we cannot draw a full schematic, but the block diagram is shown in Fig. 1 and should be studied with reference to the above description.

The adders' full ranges are not used, so there are possible variations on this theme which may make more efficient use of fewer adders, for example, by connecting the unused carry-in inputs of some of the adders to the circuit inputs. We leave you to think about this.

BCD for Display

To obtain BCD (binary coded decimal) for digital display purposes, we could convert the binary output to BCD, for example, using an EPROM look-up table. To convert the adder circuit to work directly in BCD we first note that up to the level in which adders are outputting numbers in the range 0 to 8 (the twelve 3-bit adders) then the circuit is the same. After this we need a layer of 1-digit BCD adders (with carry out) then three layers of 2-digit BCD adders.

BCD adders can be made using binary adders plus a "correction" circuit. The correction circuit detects if the output from a digit is greater than decimal 9 (an "illegal" BCD state) and if it is, it adds decimal 6 to this value and produces a carry to the next digit. The addition of 6 may also produce a carry which must be added to the next digit. This is done for each digit with the carrys rippling through from least to most significant as usual.

The simplest way to do this in discrete logic would be to use a comparator to detect the greater than 9 and another adder to add the 6 when required (it would otherwise add 0), see Fig. 2. This results in more than twice as many chips than for binary addition, though!

Another combinational solution to the reader's problem would be to use 98 "add-one-bit" circuits and a half adder. This is illustrated in Fig. 3 – the "add one" circuits have to get bigger as you go down the chain. So what's an "add-one" circuit?

Well, you find them inside synchronous counters, which is the combinational logic that takes the current number and works out what the next number should be. This is actually very simple – let's look at binary counting:

0	0000	6	0110
1	0001	7	0111
2	0010	8	1000
3	0011	9	1001
4	0100	10	1010
5	0101	...etc.	

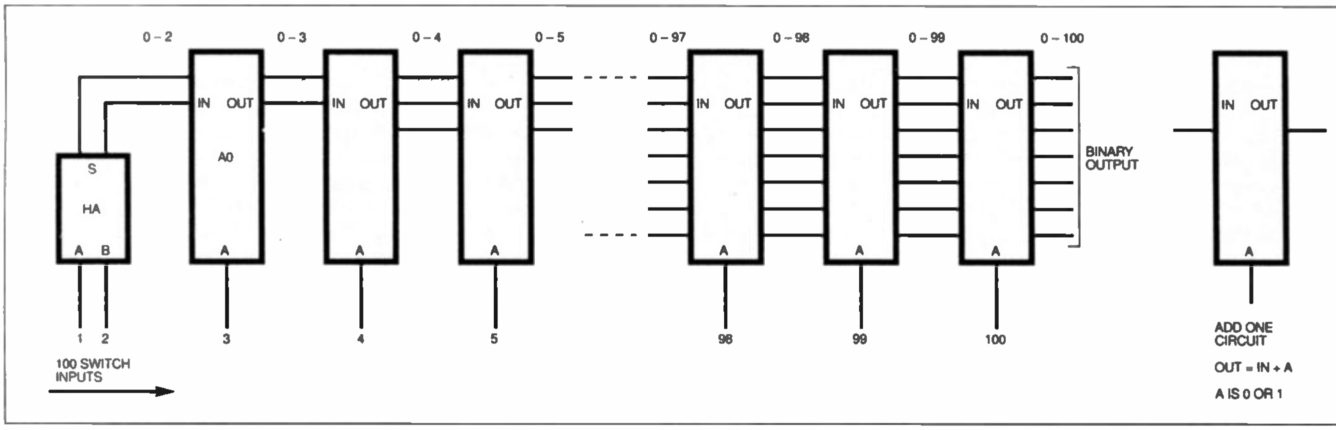


Fig.3. "Add one" chain to add number of switches closed.

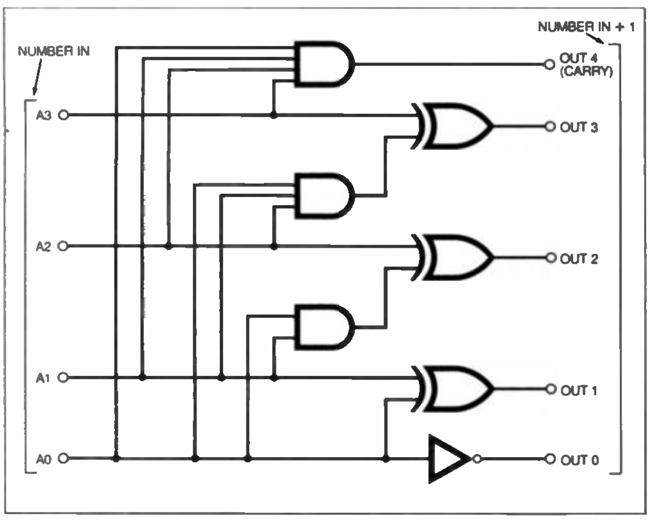


Fig.4. Basic binary "add one" circuit.

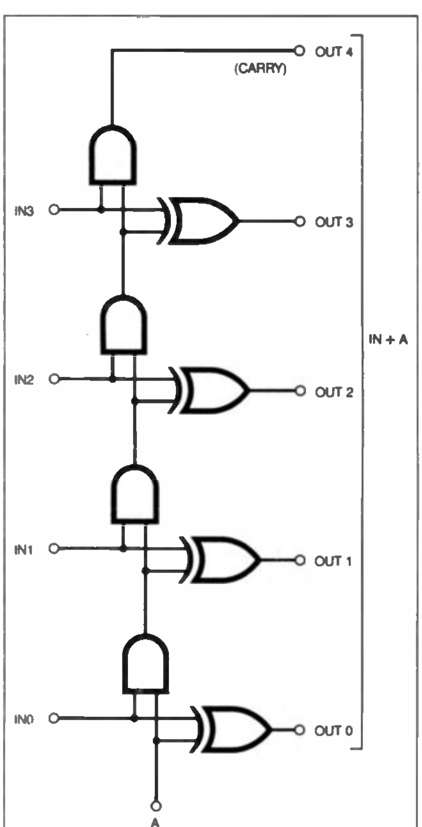


Fig.5. Add 1-bit circuit to use in chain of Fig.3. 4-bit version.

We notice a pattern to when the bits change. Firstly the least significant bit (units) always inverts or toggles (changes 0 to 1 or 1 to 0) when we add 1 or count up 1. The next bit (the 2s) inverts when the units is one but not when it is zero: for example if we have 3 (0011) the units bit is one so the 2s inverts to 0 in the next number, i.e. 4 (0100). In 4, the units is zero so in the next number the 2s stay the same, 0 in this case, in 5 (0101). In the next bit, the 4s only inverts when the previous two bits are both 1. Logically speaking, this is an AND condition – toggle bit-3 if bit-1 AND bit-2 are 1. This kind of pattern is repeated for higher bits.

The general rule is that a given bit inverts as we add 1 or counts up 1 if all less significant bits in the current value are 1. This translates into a simple circuit – the all 1s condition is detected using AND gates and the invert/don't-invert of the bits controlled by XOR gates. Fig. 4 shows a basic 4-bit add-one circuit. To use this, our application needs to be able to add either one or zero, so we need an extra input which forces all the AND outputs to zero if we want to add zero (i.e. do nothing).

We need an XOR on the units now too, so that we can control it as well. We can also chain the 2-input AND gates rather than using multi-input ANDs. This leads to Fig. 5 which is a "4-bit add-one-bit" circuit. We can add up the 100 bits using these circuits as shown back in Fig. 3. In next month's *Circuit Surgery*, we examine this in further depth, also describing sequential methods as a solution to the reader's problem. *Ian Bell.*

Going Via P.C.B.s

Here's an interesting query from a regular reader who is engaged in fabricating printed circuit boards in a workshop. ***Joseph Zammit*** in Malta, asks:

I am working on a double-sided p.c.b. which uses integrated circuits. Usually I use sockets for my i.c.s. but I'm finding it difficult to solder sockets, since their pins aren't long enough: when I solder one side I can't solder the other side to make double-sided connections where necessary. Are there any sockets with extra-long pins or is there another solution? Thanks for your help.

Unless you are a commercial producer, double-sided boards can be a bit of a challenge to fabricate because you need to ensure both sides are accurately "registered" or aligned properly. Their main advantage is that you can switch conductor paths through to the opposite side of the board where there's more room to route the copper tracks, so you can produce complicated circuits which would be difficult or impossible using a single-sided board.

A connection from one side of the board to the other is made using what the p.c.b. industry calls a "via". There are various ways of creating a via between the two sides. Commonly, you can cheat by using resistor leads: solder the lead to copper pads on both sides of the board, always assuming that you intend the resistor to be an integral part of the "through connection". Computer-aided design software helps you to sort all this out.

Alternatively rather than using a component pin or lead, you can take a via out to a less populated area. Drill the via and then connect the pads together by soldering a specially-made "track pin" straight through the board, or just solder a link wire. Manufacturers of commercial boards will incorporate PTH technology (plated-through holes), filling the via holes with a conductor. These are seen as tiny holes with a solder-colour lining.

Double-Sided Soldering

The principle of double-sided soldering is sometimes applied to i.c. sockets, where both sides of the board are connected together using the pin of the i.c. socket (obviously this means that the pin of the chip is intended to be connected too).

You've hit the nail on the head with your question – usually, i.c. socket pins lie flush with the board so it's very hard to make the connection on the surface (component) side. Sockets were never intended for this, though if you use turned-pin types they will give you a little more scope for tack-soldering the component side of the pin to the board.

The answer in your case would be to use a wire-wrapping socket which has much longer pins, designed for accepting multiple turns of wirewrapping on the underside. By standing the socket off the p.c.b. slightly, you can easily access the pins and solder them both sides as needed. You can also buy single in-line wire-wrapping sockets which you chop to the appropriate size of chip.

Help With a Humid Hut

Simon Green writes by E-mail:

My son has recently moved into a substantial insulated timber summerhouse. It has all the "mod cons" so he even has his computer set up there! One problem – humidity! It can get a little damp this time of year and what we need is a humidity switch that will turn on and off a 13 amp plug connected to an electric oil radiator. Do you know of any circuits or commercially available kits?

We reckoned you would be better trying to switch a de-humidifier rather than trying to merely dry the hut out with an electric heater because you will probably create condensation problems: that moisture has to go somewhere!

We couldn't find a humidity switch kit although ready-made digital humidity modules are available e.g. Maplin list a Min/Max Humidity Module ZA38R which has a continuous l.c.d. readout of %Relative Humidity (RH); it has a complex BCD output which requires further decoding before it can operate a load. A higher-specification version including a temperature display is also available from Maplin, their code ZA39N.

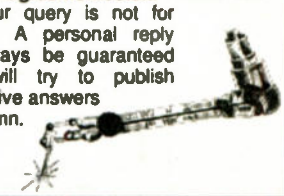
Humidity sensors themselves are capacitive or resistive in operation, with the latter offering the cheapest option though capacitive types are less prone to temperature errors. You could try the Humidity/Temperature Module listed by Farnell Components (Tel. 0113 263 6311), Part No. 540-997 which currently costs just over £20. This has a 0 to 3·3V d.c. output corresponding linearly to 0 to 100% RH ±5%, and temperature is sensed by an on-board thermistor (which unlike the humidity sensor, is non-linear).

It is a simple matter to provide a 5V power supply and a driver for a mains load using, say, a relay with mains-rated contacts. Individual sensors made my Philips and others, are also distributed by Farnell.

Finally, we wish your son lots of happy hours working in the summerhouse, but do take care to ensure that everything is soundly earthed and comprehensive protection is provided using a residual-current device (RCD, also called ELCB) circuit breaker!

CIRCUIT THERAPY

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



Techniques

ACTUALLY DOING IT!

by Robert Penfold

A PREVIOUS *Techniques* article about construction methods produced some correspondence regarding alternatives to the standard methods of stripboard and custom printed circuit boards. Electronic projects featured in magazines almost invariably use one or other of these methods, but it is true that there are some practical alternatives.

I think it is fair to say that there are often no real alternatives to stripboard and custom printed circuit boards when producing a design that must be easy to copy. Matters are rather different if you are producing your own projects from scratch, or your own circuit board layouts from published circuits, and no clones will ever have to be made. The priority for most constructors is producing something that can be built quickly and easily, and that will work when it is finished. Making "pretty" board designs that are easy for others to copy is not usually a requirement.

Plain Truth

At one time plain matrix board was popular for the construction of all manner of projects. At a glance this material looks much the same as ordinary stripboard, and it has holes of about one millimetre in diameter drilled on the same 2.54 millimetre (0.1 inch) matrix. It differs from stripboard only in that it does not have any copper strips!

Building circuits without the aid of copper strips to carry the interconnections may seem to be bordering on the impossible, but it is actually quite easy. Pieces of wire on the underside of the board are used to connect everything together in the required fashion.

This method of construction was very popular about 20 to 30 years ago, when most components had long leadout wires. These were often adequate to provide the connections, with little or no added connecting wire being necessary. These days things are very different, and many components (capacitors in particular) are supplied with very short leadout wires that would be better described as printed circuit pins. With these it is necessary to resort to link-wires made from about 24 s.w.g. (0·56 millimetre diameter) tinned copper wire. Fig.1 shows a simple preamplifier circuit, and Fig.2 shows a plain matrix board layout for this circuit. The dotted lines represent the connecting wires on the underside of the board.

I suppose that this method of construction is a bit crude when compared to stripboard or custom printed circuit boards, but it does have definite advantages and should not be dismissed out of hand. It is usually quite easy to convert a circuit diagram into a physical board layout, as in most cases the board layout can closely follow the circuit diagram (as in our simple preamplifier example).

Trying to keep the physical layout too close to the circuit layout is probably a mistake with any form of construction, and it can be helpful to move some of the components into positions that reduce the length of the underside wiring. This keeps stray capacitance to a minimum, and reduces the risk of short circuits in the wiring. In our example layout, R4, R5 and C3 have been moved to the left-hand side of IC1 whereas they are on the right-hand side in the circuit diagram. This simple change helps to keep the underside wiring very straightforward.

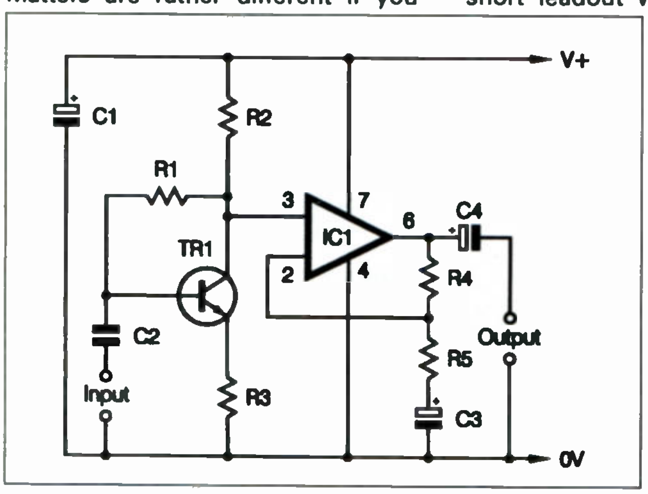


Fig.1 Example of a simple preamplifier circuit.

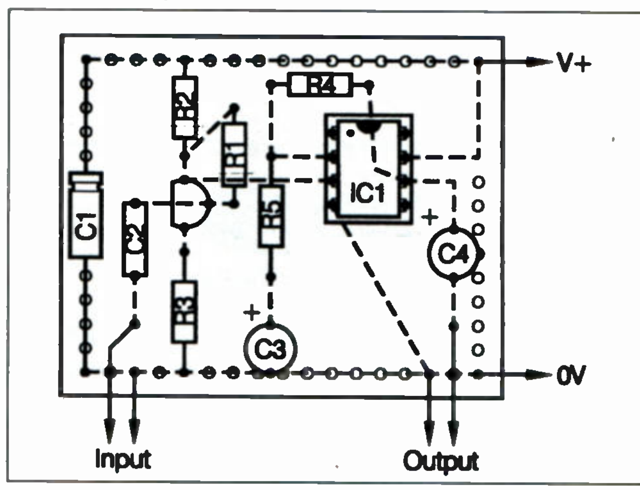
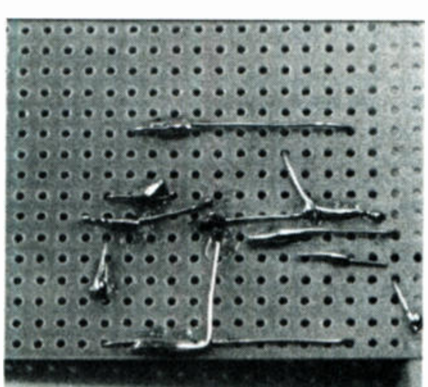


Fig.2. Plain matrix board layout for the circuit in Fig.1.



The beginnings of a plain matrix board layout. This is a crude but very effective form of construction.

Double Crossing

Unlike stripboard and custom printed circuits, with this system it is possible to have the copper "tracks" cross over one another. As the "tracks" are actually just pieces of wire, insulating one of the wires with plastic sleeving ensures that there are no short-circuits at any crossover points. Alternatively, insulation tape can be laid over an existing wire so that a new one can be run over the top of it. It is actually possible to have several layers of wiring, provided each layer is insulated from the next, but it can be difficult to correct mistakes or make changes if you get carried away with this technique.

It is also possible to thread wires through the board and on to the topside of the board, and then back down to the underside again. This offers another means of avoiding unwanted connections, giving what

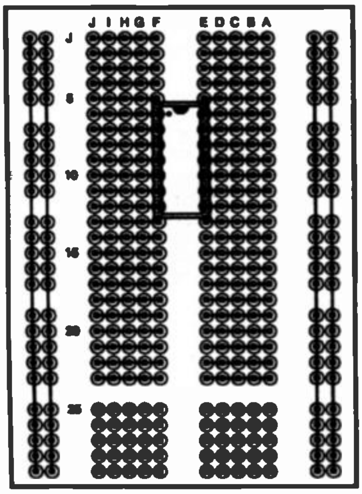
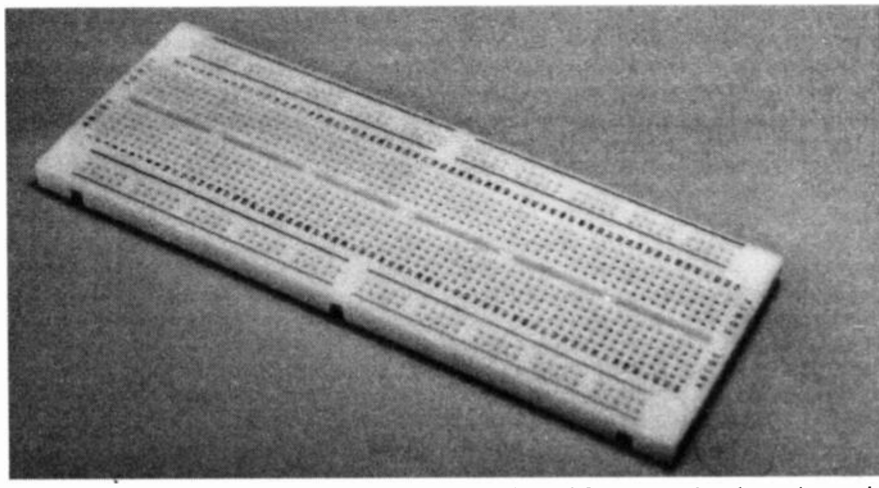


Fig.3. Typical layout for a solderless breadboard. The lines represent internal connections between the sockets.



Layout of a basic solderless breadboard designed for mounting i.c.s down the centre.

is effectively a double-sided printed circuit board without all the hassle normal associated with making double-sided boards. Circuits that would be decidedly awkward with other construction methods are often relatively easy when using plain matrix board.

Stray Capacitance

For some types of circuit, such as sensitive audio and test gear, and radio frequency designs, stripboard is far from ideal due to the stray capacitance from one copper strip to the next. Even if a layout has everything connected together in the correct fashion, the unit may still fail to work due to instability caused by all these unseen but ever-present capacitors. A custom printed circuit board largely avoids this problem, but designing and making the board is relatively time consuming and expensive. Also, it is difficult to modify a circuit that is built on a custom board. In most cases even minor modifications require a new board to be made.

Plain matrix board gives the low levels of stray capacitance associated with custom printed circuits, together with the speed, convenience, and low cost. It would probably not be the best choice for something like a logic circuit or a large linear design. However, for someone interested in experimenting with radio frequency circuits or simple linear circuits it remains a practical choice. In fact for prototyping radio frequency designs it probably remains the best choice. If you have never used plain matrix boards it is certainly worth giving them a try out.

Solderless Breadboards

No doubt most readers will have seen various solderless prototyping boards in components catalogues. These are commonly called breadboards, which is a term that apparently has its roots in the early days of electronics when prototype equipment was often wired up on wooden boards into which small nails or pins were hammered. The wooden boards resembled breadboards, and this nickname is still with us today even though modern prototyping boards bear only the vaguest resemblance to breadboards.

Those who have never used solderless breadboards could be forgiven for not taking them very seriously. Components and link-wires simply push into spring contacts, and metal strips buried within the boards help to connect everything together in a manner reminiscent of stripboard. When changes are needed you simply unplug some of the components and link-wires and add the new ones. It is a sort of electronic equivalent of toy building bricks.

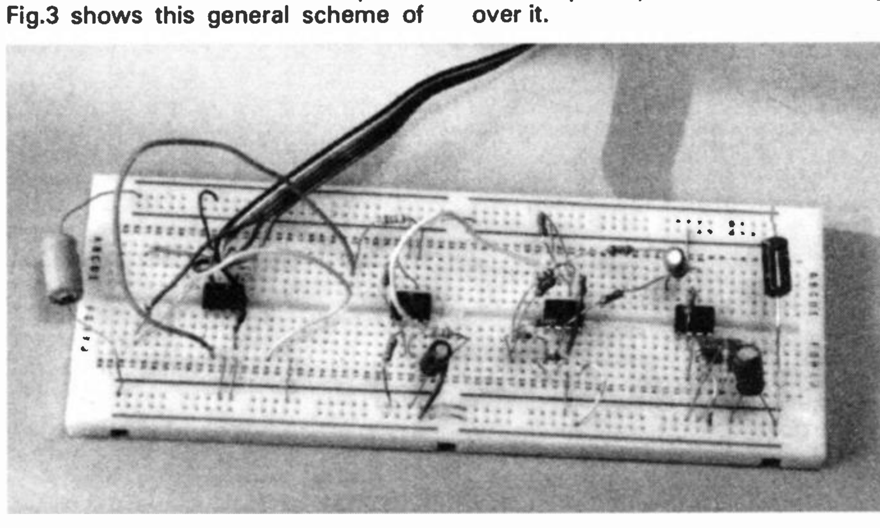
Solderless breadboards are definitely not toys though, and they enable circuits to be built far more quickly than with any other construction method. I have used them extensively, and they must have saved me a vast amount of time.

Most breadboards have two strips of contacts running along opposite edges of the board, and these are primarily intended to take supply rails. The middle part of the board has pairs of four contacts, and this is where most of the action takes place. Fig.3 shows this general scheme of things. While solderless breadboards can be used for discrete circuits, they are very much designed with integrated circuits in mind. The integrated circuits fit into the centre part of the board (see Fig.3), and boards for 0·3 and 0·6 inch wide d.i.l. chips are available.

With the integrated circuits in place it is just a matter of building up the circuit around them. A large number of link-wires are normally required. Pieces of tinned copper wire are adequate for short links, but it is essential to use insulated wire for the longer links. Packs of link-wires are available, but pieces of single-strand p.v.c. insulated connecting wire work just as well. Cut an assortment of lengths and remove about six millimetres of insulation from both ends of each wire.

Breadboard Layouts

Working out layouts for breadboards is very simple, as there is no need to bother about making things look pretty. Wires and components can be placed over the tops of integrated circuits. If a large number of components connect to pins on opposite sides of an integrated circuit it would probably be best to route some of the connections around the device rather than having too many components criss-crossing over it.



Circuit with four i.c.s wired up on solderless breadboard.

Trying to produce a neat looking result is unlikely to succeed, and can actually reduce the chances of the circuit working by increasing problems with stray capacitance. Making sure that all the components and links are present and in the correct places is far more important than producing neat results.

Solderless breadboards enable circuits to be quickly built, tested, and if necessary they can be modified extensively. The components and linkwires simply plug into the boards, and unplug again if a change is required, or if you simply wish to dismantle one circuit and build another.

A single board will only take small circuits, but any number of boards can be clipped together to accommodate larger circuits. I have used them for circuits containing up to about 20 integrated circuits and 200 components in total, but they could probably be used for more complex circuits. They are not ideal for high frequency circuits where the capacitance between rows of adjacent contacts can be problematic, but they can be used for most other types of circuit.

Solder Breadboards

Circuits built on solderless breadboards may have an air of the Heath Robinson about them, but they represent the quickest and easiest way of perfecting most types of circuit. It has to be emphasised though, that they are not intended as a means of permanent construction. Components and wires become detached too easily, and projects built on solderless breadboards would literally fall apart in normal use. The idea of these boards is to provide a quick means of perfecting circuits, which can then be built onto some form of "proper" circuit board. Because the circuits have been fully tried and tested, provided due care is taken when designing the board layouts, the final projects should all work first time.

There are proprietary printed circuit boards that try to give you the best of both worlds by using soldered construction with the very simple contact arrangement used for solderless breadboards. Making wholesale changes to component layouts is less easy with this method of construction as it involves desoldering components. On the other hand, once the circuit and board design have been perfected you are left with an assembly that can be fitted into a case and used in the final project.

There are various forms of these soldered breadboards available. Some closely follow the contact arrangements used for solderless breadboards while others use modified arrangements. "Tripad", for example, is rather like ordinary stripboard but it has the strips divided into three-hole lengths. Availability of these soldered breadboards seems to be relatively volatile and prospective users need to study a few catalogues to determine exactly what is on offer at the time.

These boards seem to be well suited to logic circuits, but can be difficult to use with linear circuits that have large numbers of discrete components. For circuits of this type, ordinary stripboard would certainly be my first choice for a quick but permanent method of prototyping projects. Like using solderless breadboards, the best approach to working out the component layout is probably to put in the integrated circuits first, and then build up the circuit around them.

With solderless breadboards you can make changes very quickly and easily, and there is usually no point in working out a "paper" layout before progressing to the "real thing." With the soldered variety it is advisable to work out at least a basic outline to check the feasibility of the layout before proceeding to the building stage.

Everyday Practical Electronics Books

ELECTRONIC PROJECTS – BOOK 1
Published by *Everyday Practical Electronics* in association with Magenta Electronics.
Contains twenty of the best projects from previous issues of EE each backed with a kit of components. The projects are: Seashell Sea Synthesiser, EE Treasure Hunter, Mini Strobe, Digital Capacitance Meter, Three Channel Sound to Light, BBC 16K Sideways Ram, Simple Short Wave Radio, Insulation Tester, Stepper Motor Interface, Eprom Eraser, 200MHz Digital Frequency Meter, Infra Red Alarm, EE Equaliser Ioniser, Bat Detector, Acoustic Probe, Mains Tester and Fuse Finder, Light Rider – (Lapel Badge, Disco Lights, Chaser Light), Musical Doorbell, Function Generator, Tilt Alarm, 10W Audio Amplifier, EE Buccaneer Induction Balance Metal Detector, BBC Midi Interface, Variable Bench Power Supply, Pet Scarer, Audio Signal Generator.
128 pages (A4 size) **Order code EP1** £2.45

ELECTRONICS TEACH-IN 88/89 – INTRODUCING MICROPROCESSORS
Mike Tooley BA (published by *Everyday Practical Electronics*)
A complete course that can lead successful readers to the award of a City and Guilds Certificate in Introductory Microprocessors (726/303). The book contains everything you need to know including full details on registering for assessment, etc. Starting with basic terminology, integrated circuits, logic families and numbering systems the text builds in stages, with revision and assessments built in, up to programming, languages, flow charts, etc. The course is ideal for the newcomer to the subject.
80 pages (A4 size) **Order code TI-88/89** £2.45

TEACH-IN No. 7 plus FREE Software
ANALOGUE AND DIGITAL ELECTRONIC COURSE
(Published by *Everyday Practical Electronics*)
Alan Winstanley and Keith Dye B.Eng(Tech)AMIEE
The highly acclaimed *Teach-In* series, which included the construction and use of the *Mini Lab* and *Micro Lab* test and development units, has been put together in book form. Additionally EPT Educational Software have developed a GCSE Electronics software program to compliment the course and a FREE DISC covering the first two parts of the course is included with the book.
An interesting and thorough tutorial series aimed specifically at the novice or complete beginner in electronics. The series is designed to support those undertaking either GCSE Electronics or GCE Advanced Levels, and starts with fundamental principles.
If you are taking electronics or technology at school or college, this book is for you. If you just want to learn the basics of electronics then this is for you. If you are teaching electronics or technology you must make sure you see it. *Teach-In No. 7* will be invaluable if you are considering a career in electronics or even if you are already training in one. The Mini Lab and software enable the construction and testing of both demonstration and development circuits. These learning aids bring electronics to life in an enjoyable and interesting way: you will both see and hear the electron in action! The Micro Lab microprocessor add-on system will appeal to higher level students and those developing microprocessor projects.
152 pages (A4 size) **Order code TI7** £3.95

DIRECT BOOK SERVICE

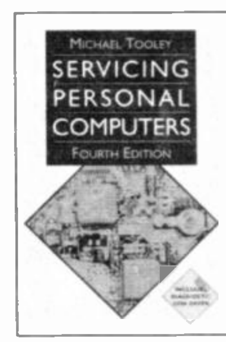
The books listed have been selected by Everyday Practical Electronics editorial staff as being of special interest to everyone involved in electronics and computing. Books are supplied by mail order direct to your door. Full ordering details are given on the last book page.

For another selection of books see the next two issues of **EPE.**

Testing and Test Gear

HOW TO USE OSCILLOSCOPES AND OTHER TEST EQUIPMENT
R. A. Penfold
This book explains the basic function of an oscilloscope, gives a detailed explanation of all the standard controls, and provides advice on buying. A separate chapter deals with using an oscilloscope for fault finding on linear and logic circuits, plenty of example waveforms help to illustrate the control functions and the effects of various fault conditions. The function and use of various other pieces of test equipment are also covered, including signal generators, logic probes, logic pulsers, and crystal calibrators.
104 pages **Order code BP267** £3.50

SERVICING PERSONAL COMPUTERS – 4th EDITION
Mike Tooley BA



The revised and enlarged forth edition has been completely re-written to cover the latest technology, such as 32-bit microprocessors and serial communications servicing. It includes a diagnostic disk offer. Essential for anyone concerned with the maintenance of personal computer equipment or peripherals, whether professional service technician, student or enthusiast.
387 pages Hardback **Order code NE15** £30

Computers and Computing

MULTIMEDIA ON THE PC
Ian R. Sinclair
In this book, you'll find out what a CD ROM is, how it works, and why it is such a perfect add-on for a PC, allowing you to buy programmes, text, graphics and sound on a CD. It also describes the installation of a CD ROM drive and a sound card, pointing out the common problems that arise, and then shows how to use them to create a complete multimedia presentation that contains text, photos, a soundtrack with your own voice recorded as a commentary, even animation and edited video footage.
184 pages **Order code PC112** £11.95

A CONCISE INTRODUCTION TO MS-DOS
N. Kantaris
(Revised Edition Covers Version 6.2)
This guide is written with the non-expert, busy person in mind and, as such, it has an underlying structure based on "what you need to know first, appears first". Nevertheless, the guide is also designed to be circular, which means that you don't have to start at the beginning and go to the end. The more experienced user can start from any section.
176 pages **Order code BP232** £4.99

UNDERSTANDING PC SPECIFICATIONS
R. A. Penfold (Revised Edition)
If you require a microcomputer for business applications, or a high quality home computer, an IBM PC or compatible is often the obvious choice. They are competitively priced, and are backed up by an enormous range of applications programs, hardware add-ons, etc. The main difficulty for the uninitiated is deciding on the specification that will best suit his or her needs. PCs range from simple systems of limited capabilities up to complex systems that can happily run applications that would have been considered beyond the abilities of a microcomputer not so long ago. It would be very easy to choose a PC system that is inadequate to run your applications efficiently, or one which goes beyond your needs and consequently represents poor value for money.
This book explains PC specifications in detail, and the subjects covered include the following: Differences between types of PC (XT, AT, 80386, etc); Maths co-processors; Input devices (keyboards, mice, and digitisers); Memory, including both expanded (EMS) and extended RAM; RAM disks and disk caches; Floppy disk drive formats and compatibility; Hard disk drives (including interleave factors and access times); Display adaptors, including all standard PC types (CGA, Hercules, Super VGA, etc); Contains everything you need to know if you can't tell your EMS from your EGA!
128 pages **Order code BP282** £4.95

Radio, TV, Satellite

PROJECTS FOR RADIO AMATEURS AND S.W.L.S.
R. A. Penfold
This book describes a number of electronic circuits, most of which are quite simple, which can be used to enhance the performance of most short wave radio systems.
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.
92 pages **Order code BP304** £3.95

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 aerials etc.
150 pages **Order code BP257** £4.99

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 costruct, full wiring diagrams etc. are provided, and they are suitable for complete beginners. The receivers only require simple aerials, 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 aerials; 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.
88 pages **Order code BP275** £3.95

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Theory and Reference

Bebop To The Boolean Boogie

By Clive (call me Max) Maxfield

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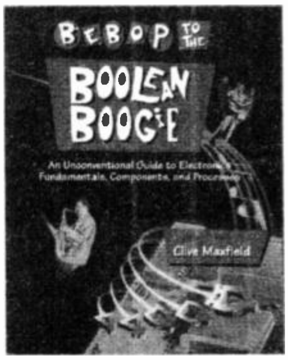
An Unconventional Guide to Electronics Fundamentals, Components and Processes



Bebop to the Boolean Boogie (An Unconventional Guide to Electronics)

This book gives the "big picture" of digital electronics. This indepth, highly readable, up-to-the-minute guide shows you how electronic devices work and how they're made. You'll discover how transistors operate, how printed circuit boards are fabricated, and what the innards of memory ICs look like. You'll also gain a working knowledge of Boolean algebra and Karnaugh maps, and understand what Reed-Muller logic is and how it's used. And there's much, MUCH more (including a recipe for a truly great seafood gumbo!). Hundreds of carefully drawn illustrations clearly show the important points of each topic. The author's tongue-in-cheek British humor makes it a delight to read, but this is a REAL technical book, extremely detailed and accurate. A great reference for your own shelf, and also an ideal gift for a friend or family member who wants to understand what it is you do all day....

DIGITAL ELECTRONICS – A PRACTICAL APPROACH
With FREE Software: Number One Systems – EASY-PC Professional XM and Pulsar (Limited Functionality)
Richard Monk

Covers binary arithmetic, Boolean algebra and logic gates, combination logic, sequential logic including the design and construction of asynchrenous and synchrenous circuits and register circuits. Together with a considerable practical content plus the additional attraction of its close association with computer aided design including the FREE software.

There is a 'blow-by-blow' guide to the use of EASY-PC Professional XM (a schematic drawing and pringed circuit board design computer package). The guide also conducts the reader through logic circuit simulation using Pulsar software. Chapters on p.c.b. physics and p.c.b. production techniques make the book unique, and with its host of project ideas make it an ideal companion for the integrative assignment and common skills components required by BTEC and the key skills demanded by GNVQ. The principal aim of the book is to provide a straightforward approach to the understanding of digital electronics.

Those who prefer the 'Teach-In' approach or would rather experiment with some simple circuits should find the book's final chapters on printed circuit board production and project ideas especially useful.

250 pages **Order code NE28** **£16.99**

Bebop Bytes Back

By Clive "Max" Maxfield and Alvin Brown

ORDER CODE BEB2

£29.95

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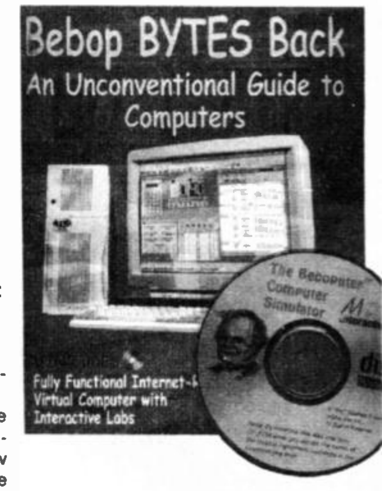
An Unconventional Guide To Computers



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Fully Functional Internet-Ready Virtual Computer with Interactive Labs

Bebop BYTES Back (An Unconventional Guide to Computers)

This follow-on to Bebop to the Boolean Boogie is a multimedia extravaganza of information about how computers work. It picks up where "Bebop I" left off, guiding you through the fascinating world of computer design . . . and you'll have a few chuckles, if not belly laughs, along the way. In addition to over 200 megabytes of mega-cool multimedia, the accompanying CD-ROM (for Windows 95 machines only) contains a virtual microcomputer, simulating the motherboard and standard computer peripherals in an extremely realistic manner. In addirion to a wealth of technical information, myriad nuggets of trivia, and hundreds of carefully drawn illustrations, the book contains a set of lab experiments for the virtual microcomputer that let you recreate the experiences of early computer pioneers. If you're the slightest bit interested in the inner workings of computers, then don't dare to miss this one!

DIGITAL GATES AND FLIP-FLOPS
Ian R. Sinclair

This book, intended for enthusiasts, students and technicians, seeks to establish a firm foundation in digital electronics by treating the topics of gates and flip-flops thoroughly and from the beginning.

Topics such as Boolean algebra and Karnaugh mapping are explained, demonstrated and used extensively, and more attention is paid to the subject of synchronous counters than to the simple but less important ripple counters.

No background other than a basic knowledge of electronics is assumed, and the more theoretical topics are explained from the beginning, as also are many working practices. The book concludes with an explanation of microprocessor techniques as applied to digital logic.

200 pages **Order code PC106** **£8.95**

Audio and Music

AN INTRODUCTION TO LOUDSPEAKERS AND ENCLOSURE DESIGN
V. Capel

This book explores the various features, good points and snags of speaker designs. It examines the whys and wherefores so that the reader can understand the principles involved and so make an informed choice of design, or even design loudspeaker enclosures for him – or herself. Crossover units are also explained, the various types, how they work, the distortions they produce and how to avoid them. Finally there is a step-by-step description of the construction of the *Kapellmeister* loudspeaker enclosure.

148 pages **Order code BP256** **£3.99**

ACOUSTIC FEEDBACK – HOW TO AVOID IT
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 a reduced 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.

Also included is the circuit and layout of an inexpensive but highly successful twin-notch filter, and how to operate it.

92 pages **Temporarily out of print**

PREAMPLIFIER AND FILTER CIRCUITS
R. A. Penfold

This book provides circuits and background information for a range of preamplifiers, plus tone controls, filters, mixers, etc. The use of modern low noise operational amplifiers and a specialist high performance audio preamplifier i.c. results in circuits that have excellent performance, but which are still quite simple. All the circuits featured can be built at quite low cost (just a few pounds in most cases). The preamplifier circuits featured include: Microphone preamplifiers (low impedance, high impedance, and crystal). Magnetic cartridge pick-up preamplifiers with R.I.A.A. equalisation. Crystal/ceramic pick-up preamplifier. Guitar pick-up preamplifier. Tape head preamplifier (for use with compact cassette systems).

Other circuits include: Audio limiter to prevent overloading of power amplifiers. Passive tone controls. Active tone controls. PA filters (highpass and lowpass). Scratch and rumble filters. Loudness filter. Audio mixers. Volume and balance controls.

92 pages **Order code BP309** **£4.99**

COMPUTERS AND MUSIC – AN INTRODUCTION
R. A. Penfold

Computers are playing an increasingly important part in the world of music, and the days when computerised music was strictly for the fanatical few are long gone.

If you are more used to the black and white keys of a synth keyboard than the QWERTY keyboard of a computer, you may be understandably confused by the jargon and terminology bandied about by computer buffs. But fear not, setting up and using a computer-based music making system is not as difficult as you might think.

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

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ELECTRONIC PROJECTS FOR GUITAR
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 stripboard 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; Tremelo unit; DI box.

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HIGH POWER AUDIO AMPLIFIER CONSTRUCTION
R. A. Penfold

Practical construction details of how to build a number of audio power amplifiers ranging from about 50 to 300/400 watts r.m.s. includes MOSFET and bipolar transistor designs.

96 pages **Order code BP277** **£3.95**

Circuits, Data and Design

PRACTICAL ELECTRONIC FILTERS
Owen Bishop
This book deals with the subject in a non-mathematical way. It reviews the main types of filter, explaining in simple terms how each type works and how it is used.
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 rythm sequencer and a multi-voiced electronic organ.
Concluding the book is a practical step-by-step guide to designing simple filters for a wide range of purposes, with circuit diagrams and worked examples.
88 pages Order code BP299 **£4.99**

ELECTRONIC HOBBYISTS DATA BOOK
R. A. Penfold
This book should tell you everything you are ever likely to want to know about hobby electronics, but did not know where to ask or refer. Comprehensive contents pages makes it easy to quickly locate the data you require.
The subjects covered include: Common circuits, and related data (including helpful graphs and tables of values); Colour codes for resistors, capacitors and inductors; Pinout details for a wide range of CMOS and TTL devices, plus basic data on the various logic families; Pinout details and basic data for a wide range of operational amplifiers; Data and leadout information for a wide range of transistors, FETs, power FETs, triacs, thyristors, diodes, etc; General data including MIDI message coding, radio data, ASCII/Baudot coding, decibel ratios, etc.
242 pages Order code BP396 **£5.95**

50 SIMPLE LED CIRCUITS
R. N. Soar
Contains 50 interesting and useful circuits and applications, covering many different branches of electronics, using one of the most inexpensive and freely available components – the light-emitting diode (LED). Also includes circuits for the 707 common anode display.
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CIRCUIT SOURCE BOOK 1
A. Penfold
Written to help you create and experiment with your own electronic designs by combining and using the various standard "building block" circuits provided. Where applicable, advice on how to alter the circuit parameters is given.
The circuits covered in this book are mainly concerned with analogue signal processing and include: Audio amplifiers (op.amp and bipolar transistors); audio power amplifiers; d.c. amplifiers; highpass, lowpass, bandpass and notch filters; tone controls; voltage controlled amplifiers and filters; triggers and voltage comparators; gates and electronic switching; bargraphs; mixers; phase shifters, current mirrors, hold circuits, etc.
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 **£4.99**

A BEGINNER'S GUIDE TO TTL DIGITAL ICs
R. A. Penfold
This book first covers the basics of simple logic circuits in general, and then progresses to specific TTL logic integrated circuits. The devices covered include gates, oscillators, timers, flip/flops, dividers, and decoder circuits. Some practical circuits are used to illustrate the use of TTL devices in the "real world"
142 pages Order code BP332 **£4.95**

HOW TO USE OP.AMPS
E. A. Parr
This book has been written as a designer's guide covering many operational amplifiers, serving both as a source book of circuits and a reference book for design calculations. The approach has been made as non-mathematical as possible.
160 pages Order code BP88 **£3.99**

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.
Over 170 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.
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ANDROIDS, ROBOTS AND ANIMATRONS NEW
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Build your own working robot or android using both off-the-shelf and workshop constructed materials and devices. Computer control gives these robots and androids two types of artificial intelligence (an expert system and a neural network). A lifelike android hand can be built and programmed to function doing repetitive tasks. A fully animated robot or android can also be built and programmed to perform a wide variety of functions.
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ELECTRONIC PROJECTS FOR EXPERIMENTERS
R. A. Penfold
Many electronic hobbyists who have been pursuing their hobby for a number of years seem to suffer from the dreaded "seen it all before" syndrome. This book is fairly and squarely aimed at sufferers of this complaint, plus any other electronics enthusiasts who yearn to try something a bit different. No doubt many of the projects featured here have practical applications, but they are all worth a try for their interest value alone.
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 Order code BP371 **£4.95**

PRACTICAL FIBRE-OPTIC PROJECTS
R. A. Penfold
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.
The projects include:- Simple audio links, F.M. audio link, P.W.M. audio links, Simple d.c. links, P.W.M. d.c. link, P.W.M. motor speed control, RS232C data links, MIDI link, Loop alarms, R.P.M. meter.
All the components used in these designs are readily available, none of them require the constructor to take out a second mortgage.
132 pages Order code BP374 **£4.95**

ELECTRONIC PROJECT BUILDING FOR BEGINNERS
R. A. Penfold
This book is for complete beginners to electronic project building. It provides a complete introduction to the practical side of this fascinating hobby, including the following topics:
Component identification, and buying the right parts; resistor colour codes, capacitor value markings, etc; advice on buying the right tools for the job; soldering; making easy work of the hard wiring; construction methods, including stripboard, custom printed circuit boards, plain matrix boards, surface mount boards and wire-wrapping; finishing off, and adding panel labels; getting "problem" projects to work, including simple methods of fault-finding.
In fact everything you need to know in order to get started in this absorbing and creative hobby.
135 pages Order code BP392 **£4.95**

A BEGINNER'S GUIDE TO MODERN ELECTRONIC COMPONENTS
R. A. Penfold
The purpose of this book is to provide practical information to help the reader sort out the bewildering array of components currently on offer. An advanced knowledge of the theory of electronics is not needed, and this book is not intended to be a course in electronic theory. The main aim is to explain the differences between components of the same basic type (e.g. carbon, carbon film, metal film, and wire-wound resistors) so that the right component for a given application can be selected. A wide range of components are included, with the emphasis firmly on those components that are used a great deal in projects for the home constructor.
166 pages Order code BP285 **£4.99**

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SEE PREVIOUS PAGE FOR FULL ORDERING DETAILS

PCB SERVICE

Printed circuit boards for certain EPE constructional projects are available from the PCB Service, see list. These are fabricated in glass fibre, and are fully drilled and roller tinned. All prices include VAT and postage and packing. Add £1 per board for airmail outside of Europe. Remittances should be sent to **The PCB Service, *Everyday Practical Electronics,* Allen House, East Borough, Wimborne, Dorset BH21 1PF. Tel: 01202 881749; Fax 01202 841692 (NOTE, we cannot reply to orders or queries by Fax); E-mail: editorial@epemag.wimborne.co.uk .** Cheques should be crossed and made payable to *Everyday Practical Electronics* **(Payment in £ sterling only).**

NOTE: While 95% of our boards are held in stock and are dispatched within seven days of receipt of order, please allow a maximum of 28 days for delivery – overseas readers allow extra if ordered by surface mail.

Back numbers or photostats of articles are available if required – see the *Back Issues* page for details.

Please check price and availability in the latest issue.

Boards can only be supplied on a payment with order basis.

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We have a few p.c.b.s left from past projects these are being offered at the knock down price of **£2.00** each – *no matter what size they are* **(some of these boards are worth over £15.00 each)** while stocks last. This price includes VAT and UK post – overseas orders please add 50p postage (or £1 per board for airmail postage).

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Back numbers or photostats of articles are available see the *Back Issues* page for details.

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MIDI Pedal	MAY'95	938	£7.78
Club Vote Totaliser		939	£6.05
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PIC-DATS 4 -channel Light Chaser		942	£7.90
HV Capacitor Reformer	JULY'95	943	£5.60
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Automatic Curtain Winder		946	£6.75
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IR Remote Control – Transmitter		948	£5.76
Receiver		949	£6.14
Personal Practice Amplifier		950	£6.09
Low-Range Ohmmeter Adaptor	SEPT'95	926	£5.55
Simple Theremin		952	£6.68
Vandata – Boot Control Unit		953	£10.52
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Treble Booster			
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Capacitor Check		955	£5.76
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Transmitter		961	£8.04
Receiver		962	£7.66
*EPE Met Office – Sensor/Rainfall/Vane		963/965	£11.33
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Analogue Frequency Meter **FEB'96**	957	£6.70
Vari-Speed Dice (Teach-In '96)	974	£5.69
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★PIC-Electric Meter – Sensor/PSU– Control/Display	977/978 (pr)	£9.90
Multi-Purpose Mini Amplifier **MAR'96**	976	£6.12
★PIC-Electric – Sensor/PSU – Control/Display	977/978 (pr)	£9.90
High Current Stabilised Power Supply	979	£6.62
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Infra-Zapper Transmitter/Receiver (Teach-In '96)	981/982 (pr)	£8.01
Mind Machine Mk III – Programmer **APR'96**	983	£7.36
Bat Band Converter/B.F.O.	984a/b	£5.80
Hearing Tester	985	£6.87
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B.F.O. and Bat Band Converter **MAY'96**	984a/b	£5.80
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Mind machine Mk III – Tape Controller	989	£6.70
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Sarah's Light **JUNE'96**	996	£7.17
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★PulStar	998	£6.60
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Ultra-Fast Frequency Generator **JULY'96**		
and Counter – Oscillator/L.C.D. Driver	994/995 (pr)	£12.72
Timed NiCad Charger	100	£6.99
Single-Station Radio 4 Tuner	101	£7.02
Twin-Beam Infra-Red Alarm –Transmitter/Receiver	102/103 (pr)	£10.50
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Garden Mole-Ester	106	£6.07
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★PIC-Tock Pendulum Clock **SEPT'96**	109	£6.31
Power Check	110	£6.42
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Draught Detector	112	£6.22
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Vehicle Alert	117	£6.55
10MHz Function Generator– Main Board	118	£7.33
– PSU	119	£5.39
Tuneable Scratch Filter **NOV'96**	115	£7.83
★Central Heating Controller	120	£7.85
D.C. to D.C. Converters – Negative Supply Generator	122	£5.96
– Step-Down Regulator	123	£6.01
– Step-Up Regulator	124	£6.12
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(double-sided p.t.h.)	121	£22.00
★PIC Digital/Analogue Tachometer	127	£7.23
Stereo Cassette Recorder		
Playback/PSU	128	£7.94
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★Earth Resistivity Meter **JAN'97**		
Current Gen. – Amp/Rect.	131/132 (pr)	£12.70
Theremin MIDI/CV Interface (double-sided p.t.h.)	130 (set)	£40.00
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PsiCom Experimental Controller	137	£6.78
Oil Check Reminder **MAR'97**	125	£7.16
Video Negative Viewer	135	£6.75
Tri-Colour NiCad Checker	138	£6.45
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★PIC-Agoras – Wheelie Meter **APRIL'97**	141	£6.90
418MHz Remote Control – Transmitter	142	£5.36
– Receiver	143	£6.04
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Quasi-Bell Door Alert **MAY'97**	133	£6.59
2M F.M. Receiver	144	£7.69
★PIC-A-Tuner	149	£7.83
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Child Minder Protection Zone **JUN'97**		
– Transmitter	153	£6.58
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PROJECT TITLE	Order Code	Cost
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Micropower PIR Detector – 1 **JULY'97**	152	£6.69
Infra-Red Remote Control Repeater		
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Karaoke Echo Unit – Echo Board	159	£6.40
– Mixer Board	160	£6.75
Computer Dual User Interface	161	£6.70
★PEsT Scarer	162	£6.60
Variable Bench Power Supply **AUG'97**	932	£3.00
Universal Input Amplifier	146	£6.55
Micropower PIR Detector – 2 Controller	163	£6.72
★PIC-OLO	164	£7.02
Active Receiving Antenna **SEPT'97**	140	£6.59
Soldering Iron Controller	157	£6.63
★PIC Noughts & Crosses Game	165	£7.82
Micropower PIR Detector – 3		
Alarm Disarm/Reset Switch	166	£5.72
Ironing Safety Device	167	£5.12
Remote Control Finder **OCT'97**	168	£6.32
Rechargeable Handlamp	169	£6.23
★PIC Water Descaler	170	£6.90
★EPE Time Machine **NOV'97**	171	£8.34
Auto-Dim Bedlight	172	£6.63
Portable 12V PSU/Charger	173	£6.61
Car Immobiliser **DEC'97**	175	£7.00
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Surface Thermometer **JAN'98**	174	£7.64
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Waa-Waa Pedal (Multi-project PCB) **FEB'98**	932	£3.00
★Virtual Scope		
Digital Board	176	£14.49
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★Water Wizard	180	£7.69
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★★EPE PIC Tutorial **MAR'98**	182	£7.99
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★Audio System Remote Controller – PSU	185	£7.05
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(Multi-project PCB)	932	£3.00
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★RC-Meter	188	£7.66

EPE SOFTWARE

Software programs for *EPE* projects are available on 3.5 inch PC-compatible disks or via our Internet site. Those marked with a single asterisk ★ are all on one disk, order code PIC-DISK1, this disk also contains the *Simple PIC16C84 Programmer* (Feb '96). The *EPE PIC Tutorial* (★★) files are on their own disk, order code PIC-TUTOR. The disks are obtainable from the *EPE PCB Service* at £2.75 each (UK) to cover our admin costs (the software itself is *free*). Overseas (each): £3.35 surface mail, £4.35 airmail. All files can be downloaded *free* from our Internet FTP site: **ftp://ftp.epemag.wimborne.co.uk.**

EPE PRINTED CIRCUIT BOARD SERVICE

Order Code   Project   Quantity   Price

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Name...

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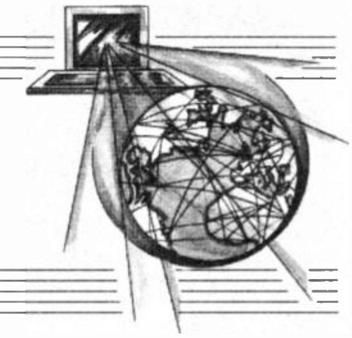
SURFING THE INTERNET



NET WORK

ALAN WINSTANLEY

NET WORK is the monthly Internet column specially written for *EPE* readers. Remember that *EPE* extends its range of services to cover on-line ordering of Back Issues, printed circuit boards and subscription purchases, all available by our online secure server. Check the Home Page of our web site at **http://www.epemag.wimborne.co.uk.**

We also post the vast majority of source codes for our PIC-related projects on our FTP site, **ftp://ftp.epemag.wimborne.co.uk**. How do you use it? Simply type the FTP site URL into your browser or FTP software, then select **/pub** for the public directory. From there you can navigate around. For example PIC projects are stored in **/pub/PICS**. Open the "folder" related to your PIC project and download all the files contained therein.

Last month we added to our FTP site **/PICS/Remote** (*Audio System Remote Controller*) and **/PICS/PICtutor** (*PIC Tutorial series*) which contains **pictutor.zip** which covers the entire PIC learning course. You need *WinZip*, *PKZIP* or similar shareware to unzip them onto your hard disk. Try **www.winzip.com** and **www.pkware.com** for details, as file "zipping" is an extremely common technique for bundling and compressing files together. (Or try a cover disk of your favourite computer magazine, as WinZip will be found there.)

This month's PIC files will be found at **PICS/RCMeter.**

Version Four-free Zone

I am currently celebrating more than three months without feeling the need to install *Microsoft Internet Explorer 4.0* in my 18-month old Windows 95 system, and I can't say that I feel like I am missing out on anything. Opinions and feedback that I receive continue to be mixed. Some describe the latest version as "rock solid" but then again an experienced engineer phoned and breathlessly warned me against using it, because he had spent all afternoon having to reconfigure his Windows machine due to problems he claimed were caused by MSIE 4 conflicting with his software.

Nevertheless, the gap in the marketplace between *Internet Explorer* and *Netscape Navigator/Communicator* continues to narrow to the point where it's roughly a fifty-fifty bet whether a viewer of your web pages will use either one.

Netscape has responded late in the day by adopting an "Unlimited Distribution" policy to encourage free distribution of Netscape Communicator, and furthermore it plans to release the actual source code for *Communicator 5.0*, its next generation browser, free as well. You can still expect to see *Netscape* browsers in the marketplace, perhaps as a customised "own label" browser bundled with demo. software or similar.

Presently the fur is continuing to fly as far as Microsoft's anti-trust tangle with the Department of Justice is concerned, with Microsoft having been accused of forcing PC makers to install *Internet Explorer* (and its desktop icon) on new PCs which shipped with Windows 95, or risk losing their Windows license. Microsoft's response was that the PC maker was always free to install *Netscape* in addition to *Internet Explorer* if they so desired, and that the consumer/end-user was free to adapt their desktop operating system anyway, e.g. by installing *Navigator* and giving *Explorer* the boot (as it were).

It took a federal order to force Microsoft to offer PC makers two options to inhibit the presence of *Internet Explorer* in new Windows machines. It is no big deal really: *Internet Explorer* will still be there as an "unconnected" component part of the Windows GUI, only its icon and maybe a few files can now be de-emphasised by the PC manufacturer who can still keep his Windows licence intact. You can bet that many, if not most, new Windows PCs will still ship with *Microsoft Internet Explorer* fully enabled, especially for the consumer market. As Microsoft admits, URLs-with-everything technology is now seen as an integral part of operating systems and there is already a taste of this in *Office 97* and *Internet Explorer 4.0*.

Further patches have been released to plug some new security loopholes found in *Internet Explorer 4.0*. Macintosh owners who use *Outlook Express 4.0* with MSIE 4 have to contend with the fact that under some circumstances, E-mail can be sent to people to whom you did not intend! This relates to the Address Book and how you fill in the "Name" fields. Updates for the Power PC or the 68000 versions can be obtained from Microsoft's web site. A further security patch for Windows users has also been released, which prevents a form of malicious executable code being run on MSIE 4, crashing it in the process. Updates for MSIE 4.0 and 4.01 are available. See **www.microsoft.com** for details.

Demon Internet - more of the same

London's Demon Internet Service claims to be the UK's largest dial-up ISP, so after an absence of two years I recently dropped in on *demon.service*, the newsgroup in which customers voice their complaints. Nothing has changed much; grumbles about the inconsistency of Demon's service are as widespread as ever, and "route-ing problems" (Demon-speak for poor connectivity) are being blamed on excessive demand from customers (presumably a side effect of the national advertising campaign in *The Daily Telegraph*). The dial-in service has certainly been quite patchy in my experience, and generally inconsistent with the occasional good run in between.

Several other things in *demon.service* and *demon.news* remained largely as before: users complaining loudly whenever anyone posted an article with a signature (.sig) one pixel greater than four lines in length, the height of disrespect to Demon users, as if it will have any tangible effect on bandwidth; also, hardened users, acting like dogs with bones, heaping abuse on less capable fellow Demon customers with a particularly unprintable term of endearment (not), in a discreditable way which I found unique to *demon.service*.

The only other comment which came out in these Demon newsgroups was that now, if you depend on having a reliable Internet service connection, the consensus is that you need *two* Internet Service Providers, one as a back up for the other. Something I discovered two years ago.

Latest Links

On to this month's list of sites I suggest might be worth looking at. An excellent effort by IBM is their site "How chips are made" available at **www.chips.ibm.com/technology/makechip/**. A compelling site entitled the "Slide Rule Trading Post" is maintained by Andrew Davie, where there is the Slide Rule Enthusiast's Repository (!) including a Java-enabled Internet Slide Rule, no less! Andrew also maintains the absolutely fascinating Museum of Soviet Calculators on the Web – MOSCOW – a web site I dwelled on for ages with its fearsome-looking desktop and pocket calculators. See what a Russian nine-segment display looks like! More on **www.comcen.com.au/~adavie/slide/calculator/soviet.html**.

Two amended URLs for sites I have previously highlighted: thanks to Thomas Stratford who says that Crocodile Clips is actually on **www.crocodile-clips.com/education**; also the BeMa "Electronics Guide" has moved to Demon Internet's Netherlands service at **www.pages.demon.nl/TheElectronicGuide**. An educational and electronic site has been created at **http://library.advanced.org/10784/** where you will find an Electropaedia and a basic glossary. One of my all-time favourites is still the Science Hobbyist website maintained by science-exhibit designer William Beaty, something you must see at **www.eskimo.com/~billb/**. Read about Van de Graaff generators, Jacob's ladders, Tesla coils and loads more fun besides!

If you have any sites you'd like to share via the *Net Work* column, E-mail **alan@epemag.demon.co.uk**. More for the Internet user next month.

SURVEILLANCE
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No. 1 for Kits

Whether your requirement for surveillance equipment is amateur, professional or you are just fascinated by this unique area of electronics SUMA DESIGNS has a kit to fit the bill. We have been designing electronic surveillance equipment for over 12 years and you can be sure that all our kits are very well tried, tested and proven and come complete with full instructions, circuit diagrams, assembly details and all high quality components including fibreglass PCB. Unless otherwise stated all transmitters are tuneable and can be received on an ordinary VHF FM radio.

Genuine SUMA kits available only direct from Suma Designs. Beware inferior imitations!

UTX Ultra-miniature Room Transmitter
Smallest room transmitter kit in the world! Incredible 10mm x 20mm including mic. 3V-12V operation. 500m range.......... £16.45

MTX Micro-miniature Room Transmitter
Best-selling micro-miniature Room Transmitter. Just 17mm x 17mm including mic. 3V-12V operation. 1000m range.......... £13.45

STX High-performance Room Transmitter
High performance transmitter with a buffered output stage for greater stability and range. Measures 22mm x 22m, including mic. 6V-12V operation, 1500m range. £15.45

VT500 High-power Room Transmitter
Powerful 250mW output providing excellent range and performance. Size 20mm x 40mm. 9V-12V operation. 3000m range.......... £16.45

VXT Voice-Activated Transmitter
Triggers only when sounds are detected. Very low standby current. Variable sensitivity and delay with LED indicator. Size 20mm x 67mm. 9V operation. 1000m range. £19.45

HVX400 Mains Powered Room Transmitter
Connects directly to 240V A.C. supply for long-term monitoring. Size 30mm x 35mm. 500m range.......... £19.45

SCRX Subcarrier Scrambled Room Transmitter
Scrambled output from this transmitter cannot be monitored without the SCDM decoder connected to the receiver. Size 20mm x 67mm. 9V operation. 1000m range...... £22.95

SCLX Subcarrier Telephone Transmitter
Connects to telephone line anywhere, requires no batteries. Output scrambled so requires SCDM connected to receiver. Size 32mm x 37mm. 1000m range......... £23.95

SCDM Subcarrier Decoder Unit for SCRX
Connects to receiver earphone socket and provides decoded audio output to headphones. Size 32mm x 70mm. 9V-12V operation.......... £22.95

ATR2 Micro-Size Telephone Recording Interface
Connects between telephone line (anywhere) and cassette recorder. Switches tape automatically as phone is used. All conversations recorded. Size 16mm x 32mm. Powered from line.......... £13.45

★★★ Specials ★★★

DLTX/DLRX Radio Control Switch
Remote control anything around your home or garden, outside lights, alarms, paging system etc. System consists of a small VHF transmitter with digital encoder and receiver unit with decoder and relay output, momentary or alternate, 8-way d.i.l. switches on both boards set your own unique security code. TX size 45mm x 45mm. RX size 35mmx 90mm. Both 9V operation. Range up to 200m.
Complete System (2 kits).......... £50.95
Individual Transmitter DLTX.......... £19.95
Individual Receiver DLRX.......... £37.95

MBX-1 Hi-Fi Micro Broadcaster
Not technically a surveillance device but a great idea! Connects to the headphone output of your Hi-Fi, tape or CD and transmits Hi-Fi quality to a nearby radio. Listen to your favourite music anywhere around the house, garden, in the bath or in the garage and you don't have to put up with the DJ's choice and boring waffle.
Size 27mm x 60mm. 9V operation. 250m range.......... £20.95

UTLX Ultra-miniature Telephone Transmitter
Smallest telephone transmitter kit available. Incredible size of 10mm x 20mm! Connects to line (anywhere) and switches on and off with phone use. All conversation transmitted. Powered from line. 500m range.......... £15.95

TLX 700 Micro-miniature Telephone Transmitter
Best-selling telephone transmitter. Being 20mm x 20mm it is easier to assemble than UTLX. Connects to line (anywhere) and switches on and off with phone use. All conversations transmitted. Powered from line. 1000m range.......... £13.45

STLX High-performance Telephone Transmitter
High performance transmitter with buffered output stage providing excellent stability and performance. Connects to line (anywhere) and switches on and off with phone use. All conversations transmitted. Powered from line. Size 22mm x 22mm. 1500m range.......... £16.45

TKX900 Signalling/Tracking Transmitter
Transmits a continuous stream of audio pulses with variable tone and rate. Ideal for signalling or tracking purposes. High power output giving range up to 3000m. Size 25mm x 63mm. 9V operation.......... £22.95

CD400 Pocket Bug Detector/Locator
LED and piezo bleeper pulse slowly, rate of pulse and pitch of tone increase as you approach signal. Gain control allows pinpointing of source. Size 45mm x 54mm. 9V operation.......... £30.95

CD600 Professional Bug Detector/Locator
Multicolour readout of signal strength with variable rate bleeper and variable sensitivity used to detect and locate hidden transmitters. Switch to AUDIO CONFORM mode to distinguish between localised bug transmission and normal legitimate signals such as pagers, cellular, taxis etc. Size 70mm x 100mm. 9V operation.......... £50.95

QTX180 Crystal Controlled Room Transmitter
Narrow band FM transmitter for the ultimate in privacy. Operates on 180MHz and requires the use of a scanner receiver or our QRX180 kit (see catalogue). Size 20mm x 67mm. 9V operation. 1000m range.......... £40.95

QLX180 Crystal Controlled Telephone Transmitter
As per QTX180 but connects to telephone line to monitor both sides of conversations. 20mm x 67mm. 9V operation. 1000m range.......... £40.95

QSX180 Line Powered Crystal Controlled Phone Transmitter
As per QLX180 but draws power requirements from line. No batteries required. Size 32mm x 37mm. Range 500m.......... £35.95

QRX 180 Crystal Controlled FM Receiver
For monitoring any of the 'Q' range transmitters. High sensitivity unit. All RF section supplied as pre-built and aligned module ready to connect on board so no difficulty setting up. Output to headphones. 60mm x 75mm. 9V operation.......... £60.95

A build-up service is available on all our kits if required.

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PIC projects each have their own folder; navigate to the correct folder and open it, then fetch all the files contained within. *Do not try to download the folder itself!*

EPE text files: **/pub/docs**
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EPE TENS Unit user advice: **tens.doc** and **tens.txt**
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projects

New Project Kits from Maplin

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– No home or professional studio should be without one!

FEATURES:
- Rapidly and clearly identifies connections on most audio cables
- Will test very long cables
- Clear led readout
- Robust design

PROJECT RATING 3 Average

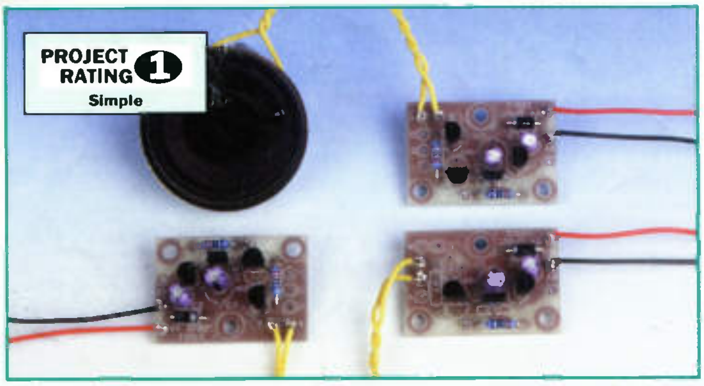
IDEAL FOR:
- PA/Sound engineers
- Gigging bands
- Fault diagnosis

Kit includes all components, PCB, fixing hardware, case, front panel label and full instructions.

AUDIO LEAD CHECKER KIT LU26D £19.99
Construction details: Audio Lead Checker Leaflet XZ20W 80p
Issue 114 / June 1997 Electronics & Beyond XD14Q £2.25

MELODY GENERATOR KIT

PROJECT RATING 1 Simple



FEATURES
- Ideal beginners project
- Safe, low voltage operation
- Low current giving long battery life
- Directly drives speakers (included) or piezo sounders
- Large range of melodies supported (15 available)

APPLICATIONS
- Children's toys
- Teaching nursery rhymes
- Turn ordinary cards and gifts into novel presents

Kit includes all components, PCB, speaker, connecting wire and full instructions. One or two 1.5V batteries are required (not supplied).

MELODY GENERATOR KIT:

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LU68 Greensleeves	LU69 Love Me Tender	LU70 Jingle Bells
LU75 Merry Christmas	LU76 12 Days of Christmas	LU77 You Are My Sunshine
LU80 I Just Called	LU81 Twinkle Twinkle	LU84 I'd Like To Teach
LU90 White Christmas	LU91 Warning Tone	LU92 Wedding March

All at £4.99

Construction details: Melody Generator Leaflet XZ47B 50p
Issue 120 / December 1997 Electronics & beyond XD20W £2.65

These kits are:
- Supplied with high-quality fibre-glass PCBs – pre-tinned, with printed legend and solder resist
- Supplied with comprehensive instructions and a constructors' guide
- Covered by the Maplin Get-You-Working Service and 12-month warranty

Kits do not include tools or test equipment. Kits may require additional components or products, depending on application, please refer to construction details or contact the Maplin Technical Support Helpline (Tel: 01702 556001) if in doubt.

PROJECT RATING 1 Simple

NATIONAL LOTTERY PREDICTOR KIT

FEATURES
- Ideal beginners project
- Simple to use – one switch operation
- Automatic switch off saves batteries
- Full source code available

APPLICATIONS
- Use to choose your lottery numbers!
- Excellent introduction to microcontrollers
- Use in other games

Kit Includes all components, PCB, fixing hardware and full instructions. Two AAA batteries are required (not supplied).

NATIONAL LOTTERY PREDICTOR KIT LU61R £9.99
Construction details: National Lottery Predictor Leaflet XZ46A 50p
Issue 120 / December 1997 Electronics & beyond XD20W £2.65

PAL COLOUR ENCODER KIT

FEATURES
- PAL and NTSC compatible
- TTL compatible inputs
- 64 colour palette
- Composite video and UHF outputs
- Analogue or digital RGB inputs
- Optional S-video output

PROJECT RATING 3 Average

APPLICATIONS
- Colour bar generation
- RGB to composite and UHF conversion
- Computer displays

Kit includes all components, PCB, Modulator, hardware to connect the Maplin Colour Bar Generator LT50E and full instructions. A +12V DC @ 300mA, regulated supply is required (not supplied).

PAL COLOUR ENCODER KIT LU74R £24.99
Construction details: PAL Colour Encoder Leaflet XZ41U 80p
Issue 115 / July 1997 Electronics & beyond XD15R

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