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- **2 CHANNEL UHF RELAY SWITCH** Contains the same transmitter/receiver pair as 30A15 below plus the components and PCB to control two 240VAC/10A relays (also supplied). Ultra bright LEDs used to indicate relay status. **3082KT £26.95**
- **TRANSMITTER RECEIVER PAIR** 2-button keyboard style 300-375MHz Tx with 30m range. Receiver encoder module with matched decoder IC. Components must be built into a circuit like kit 3082 above. **30A15 £13.95**
- **TELEPHONE LINE RELAY SWITCH** Turn on/off 4 relays over your phone line from anywhere in the world. 4-digit security code. Line protection circuitry built-in (non-approved). PCB 78x105mm. **3086KT £39.95**
- **PC DATA ACQUISITION/CONTROL UNIT** Use your PC to monitor physical variables (e.g. pressure, temperature, light, weight, switch state, movement, relays etc.), process the information & use results to control physical devices like motors, sirens, relays, servo & stepper motors. Inputs: 16 digital & 11 analogue. Outputs: 8 digital & 1 analogue. Plastic case with printed front/rear panels, software utilities, programming examples & all components (except sensors & cable) provided. 12VDC. **3093KT £79.95**
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Great introduction to electronics. Ideal for the budding electronics expert! Build a radio, burglar alarm, wave detector, morse code practice circuit, simple computer circuits, and much more! No soldering, tools or previous electronics knowledge required. Circuits can be built and unassembled repeatedly. Comprehensive 68-page manual with explanations, schematics and assembly diagrams. Suitable for age 10+. Excellent for schools. Requires 2 x AA batteries. **ONLY £14.95** (phone for bulk discounts).

- **PC SERIAL PORT ISOLATED I/O BOARD** Provides eight 240VAC/10A relay outputs & 4 optically isolated inputs. Designed for use in various control & sensing applications e.g. load switching, external switch input sensing, contact closure & external voltage sensing. Controlled via serial port & a terminal emulator program (built into Windows). Can be used with ANY computer/operating system. Plastic case with printed front/rear panels & all components (except cable) provided. **3108KT £49.95**
- **UNIPOLAR STEPPER MOTOR DRIVER** for any 5/6/8 lead motor. Fast/slow & single step rates. Direction control & on/off switch. 2-phase & half-wave step modes. 4 LED indicators. PCB 50x65mm. **3109KT £14.95**
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- **12-BIT PC DATA ACQUISITION/CONTROL UNIT** Similar to kit 3093 above but uses a 12 bit Analogue-to-Digital Converter (ADC) with internal analogue multiplexer. Reads 8 single ended channels or 4 differential inputs or a mixture of both. Analogue inputs read 0-4V. Four TTL/CMOS compatible digital input/outputs. ADC conversion time <10µs. Software (C, QB & Win), extended D shell case & all components (except sensors & cable) provided. **3118KT £47.95**
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# SURVEILLANCE

High performance surveillance bugs. Room transmitters supplied with sensitive electret microphone & battery holder/clip. All transmitters can be received on an ordinary VHF/FM radio between 88-108MHz. Available in Kit Form (KT) or Assembled & Tested (AS).

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- **HARD-WIRED BUG/TWO STATION INTERCOM** Each station has its own amplifier, speaker and mic. Can be set up as either a hard-wired bug or two-station intercom. 10m x 2-core cable supplied. 9V operation. **3021KT £13.95 (kit form only)**
- **TVXS - TAPE RECORDER VOX SWITCH** Used to automatically operate a tape recorder (not supplied) via its REMOTE socket when sounds are detected. All conversations recorded. Adjustable sensitivity & turn-off delay. 115x19mm. **3013KT £7.95 AS3013 £19.95**



## TELEPHONE SURVEILLANCE

- **M7TX - MINIATURE TELEPHONE TRANSMITTER** Attaches anywhere to phone line. Transmits only when phone is used! Tune-in your radio and hear both parties. 300m range. Uses line as aerial & power source. 20x45mm. **3016KT £7.95 AS3016 £13.95**
- **TRI - TELEPHONE RECORDING INTERFACE** Automatically record all conversations. Connects between phone line & tape recorder (not supplied). Operates recorders with 1.5-12V battery systems. Powered from line. 50x33mm. **3033KT £7.95 AS3033 £16.95**
- **TPA - TELEPHONE PICK-UP AMPLIFIER/WIRELESS PHONE BUG** Place pick-up coil on the phone line or near phone earpiece and hear both sides of the conversation. **3055KT £10.95 AS3055 £19.95**
- **1 WATT FM TRANSMITTER** Easy to construct. Delivers a crisp, clear signal. Two-stage circuit. Kit includes microphone and requires a simple open dipole aerial. 8-30VDC. PCB 42x45mm. **1009KT £14.95**
- **4 WATT FM TRANSMITTER** Comprises three RF stages and an audio preamplifier stage. Piezoelectric microphone supplied or you can use a separate preamplifier circuit. Antenna can be an open dipole or Ground Plane. Ideal project for those who wish to get started in the fascinating world of FM broadcasting and want a good basic circuit to experiment with. 12-18VDC. PCB 44x146mm. **1028KT £23.95**
- **15 WATT FM TRANSMITTER (PRE-ASSEMBLED & TESTED)** Four transistor based stations with Philips BLY 88 in final stage. 15 Watts RF power on the air. 88-108MHz. Accepts open dipole, Ground Plane, 5/8, J, or YAGI configuration antennas. 12-18VDC. PCB 70x220mm. SWS meter needed for alignment. **1021KT £89.95**
- **SIMILAR TO ABOVE BUT 25W Output. 1028KT £79.95**

- **STEREO VU METER** shows peak music power using 2 rows of 10 LED's (mixed green & red) moving bar display. 0-300u. **3089KT £10.95**
- **AM RADIO KIT** 1 Tuned Radio Frequency front-end, single chip AM radio IC & 2 stages of audio amplification. All components inc. speaker provided. PCB 32x102mm. **3063KT £9.95**
- **DRILL SPEED CONTROLLER** Adjust the speed of your electric drill according to the job at hand. Suitable for 240V AC mains powered drills up to 700W power. PCB: 48mm x 65mm. Box provided. **6074KT £17.90**
- **3 INPUT MONO MIXER** Independent level control for each input and separate bass/treble controls. Input sensitivity: 240mV. 18V DC. PCB: 60mm x 185mm. **1052KT £16.95**
- **ELECTRONIC SIREN** 5 Watt. Impressive SW power output. Suitable for alarm systems, car, motorbikes, etc. Output frequency 1-2kHz. 6-12V DC. PCB: 37mm x 71mm. Siren not provided. **1003KT £5.95**
- **NEGATIVE/POSITIVE ION GENERATOR** Standard Cockcroft-Walton multiplier circuit. Mains voltage experience required. **3057KT £9.95**

## 30-in-ONE Electronic Projects Lab



- **LED DICE** Classic intro to electronics & circuit analysis. 7 LED's simulate dice roll, slow down & land on a number at random. 555 IC circuit. **3003KT £7.95**
- **STAIRWAY TO HEAVEN** Tests hand-eye co-ordination. Green switch with green segment of LED lights to climb the stairway - miss & start again! Good intro to several basic circuits. **3005KT £7.95**
- **ROULETTE LED 'Ball'** spins round the wheel, slows down & drops into a slot. 10 LED's. Good intro to CMOS decade counters & Op-Amps. **3006KT £9.95**
- **DUAL LED DICE** PIC 16C54 circuit performs similar function to 3003KT above but two dice. Good intro to micro-controllers. **3071KT £11.95**
- **9V XENON TUBE FLASHER** Transformer circuit steps up 9V battery to flash a 25mm Xenon tube. Adjustable flash rate (0.25-2 Sec's). **3022KT £10.95**
- **LED FLASHER** 1 5 ultra bright red LED's flash in 7 selectable patterns. **3037MKT £4.50**
- **LED FLASHER 2** Similar to above but flash in sequence or randomly. Ideal for model railways. **3052MKT £4.50**
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- **ATMEL 89C051 PROGRAMMER** Simple-to-use yet powerful programmer for the Atmel 89C1051, 89C2051 & 89C4051 uC's. Programmer does NOT require special software other than a terminal emulator program (built into Windows). Can be used with ANY computer/operating system. **3121KT £34.95**

- **3V/1.5V TO 9V BATTERY CONVERTER** Replace expensive 9V batteries with economic 1.5V batteries. IC based circuit steps up 1 or 2 AA batteries to give 9V/18mA. **3035KT £4.95**
- **STABILISED POWER SUPPLY 3-30V/2.5A** Ideal for hobbyist & professional laboratory. Very reliable & versatile design at an extremely reasonable price. Short circuit protection. Variable DC voltages (3-30V). Rated output 2.5 Amps. Large heatsink supplied. You just supply a 24VAC/3A transformer. PCB 55x112mm. Mains operation. **1007KT £17.50. Custom Designed Box 2007 £34.95**
- **STABILISED POWER SUPPLY 2-30V/5A** As kit 1007 above but rated at 5Amp. Requires a 24VAC/5A transformer. **1096KT £29.95. Custom Designed Box 2096 £34.95**
- **RFI POWER SUPPLY** Designed to power RF transmitters/receivers. Blocks high frequencies & eliminates problems like noise, overheating, standing waves, etc. Output: 12-14VDC/3A. Thermal/short circuit protection & electronic stabilisation. You just supply a 18VAC/3A transformer. PCB 72x82mm. **1171KT £24.95**
- **MOTORBIKE ALARM** Uses a reliable vibration sensor (adjustable sensitivity) to detect movement of the bike to trigger the alarm & switch the output relay to which a siren, bikes horn, indicators or other warning device can be attached. Auto-reset. 6-12VDC. PCB 57x64mm. **1011KT £11.95 Box £5.95**
- **CAR ALARM SYSTEM** Protect your car from theft. Features vibration sensor, courtesy/boot light voltage drop sensor and bonnet/boot earth switch sensor. Entry/exit delays, auto-reset and adjustable alarm duration. 6-12V DC. PCB: 47mm x 55mm. **1019KT £11.95 Box £6.50**
- **LIGHT ALARM** Protect your valuables. Alarm sounds if circuit detects smallest amount of light. Place in cash box etc. **3008KT £4.50**
- **PIEZO SCREAMER** 110dB of ear piercing noise. Fits in box with 2 x 35mm piezo elements built into their own resonant cavity. Use as an alarm siren or just for fun! 6-9VDC. **3015KT £9.95**
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- **FUNCTION GENERATOR** Quad Op-Amp oscillator & wave shaper circuit generates audio range square waves (6Hz-6kHz), triangle & pseudo sine outputs. 9VDC. **3023KT £3.95**
- **LOGIC PROBE** tests CMOS & TTL circuits & detects fast pulses. Visual & audio indication of logic state. Full instructions supplied. **3024KT £6.95**
- **SQUARE WAVE OSCILLATOR** Generates square waves at 6 preset frequencies in factors of 10 from 1Hz-100kHz. Visual output indicator. 5-18VDC. Box provided. **3111KT £7.95**
- **PC DRIVEN POCKET SAMPLER/DATA LOGGER** Analogue voltage sampler records voltages up to 2V or 20V over periods from milli-seconds to months. Can also be used as a simple digital scope to examine audio & other signals up to about 5kHz. Software & D-shell case provided. **3112KT £19.95**
- **20 Mhz FUNCTION GENERATOR** Square, triangular and sine waveform up to 20MHz over 3 ranges using 'coarse' and 'fine' frequency adjustment controls. Adjustable output from 0-2V p-p. A TTL output is also provided for connection to a frequency meter. Uses MAX038 IC. Plastic case with printed front/rear panels & all components provided. 7-12VAC. **3101KT £49.95**

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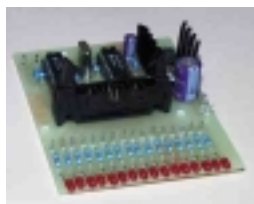
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# Editorial

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## **CHIPPER**

Every so often a new chip comes along that looks like it will be very popular for a wide range of applications. Just such a chip forms the basis of our main cover subject this month – the *Versatile Microphone/Audio Preamplifier*. The problem with specialized chips of this nature is that sometimes they don't stay in production for a long period. This can obviously cause headaches for hobbyists, who seem to like to build projects years after they have been published. This is why we advise readers to check that all components are still available before commencing any project in a back dated issue. Whilst it is sometimes possible to find old chips (particularly via the internet) they are often highly priced and obviously supplies do eventually get exhausted.

We do, however, have high hopes that this chip will be around for some time as it appears to have been designed to cover a very wide range of applications, including use for microphone inputs to PCs. This fact alone will ensure high demand and therefore longevity, should it be taken up by the computer manufacturers. Let's hope it is. However, that in itself does not entirely get us out of the woods – the PC makers will no doubt use a surface mount device which does not necessarily guarantee continuing availability of the DIL version. Once development has taken place, the industrial requirement for DIL versions often falls dramatically so they can sometimes be discontinued.

## **NO WAY**

We suppose the answer is to build it now and hope for the best. There seems to be no way of knowing which chips will hang around and also no way of knowing of all the chips that have been discontinued. We usually only find this out when readers ring us with buying problems. Thankfully we can often help them out, but we have an ever-increasing list of past projects that are no longer viable because of obsolete components. Unfortunately it is not a problem we expect will improve as time goes by.

*Clive Maxfield & Alvin Brown*

052000



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20 Pin DIL 0.3"	£0.12
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28 Pin DIL 0.6"	£0.13
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16 Pin DIL 0.3"	£0.23
18 Pin DIL 0.3"	£0.25
20 Pin DIL 0.3"	£0.28
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28 Pin DIL 0.6"	£0.39
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40 Way 0.3-0.6"	£8.93

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T018-4 Base Socket	£0.24
T05 Base Socket	£0.24

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14 Way Socket	£0.35
16 Way Socket	£0.37
20 Way Socket	£0.37
26 Way Socket	£0.38
34 Way Socket	£0.39
40 Way Socket	£0.55
50 Way Socket	£0.80

**IDC Cable Plugs**

10 Way Plug	£0.58
14 Way Plug	£0.64
16 Way Plug	£0.68
20 Way Plug	£0.72
26 Way Plug	£0.76
34 Way Plug	£0.78
40 Way Plug	£1.00
50 Way Plug	£1.22

**PCB Box Headers**

10 Way Straight	£0.23
14 Way Straight	£0.33
16 Way Straight	£0.36
20 Way Straight	£0.41
26 Way Straight	£0.55
34 Way Straight	£0.68
40 Way Straight	£0.75
50 Way Straight	£1.02
10 Way 90°	£0.33
14 Way 90°	£0.44
16 Way 90°	£0.42
20 Way 90°	£0.63
26 Way 90°	£0.81
34 Way 90°	£1.17
40 Way 90°	£1.17
50 Way 90°	£1.14

**PCB Latch Headers**

10 Way Straight	£0.41
14 Way Straight	£0.45
16 Way Straight	£0.51
20 Way Straight	£0.55
26 Way Straight	£0.73
34 Way Straight	£0.88
40 Way Straight	£0.92
50 Way Straight	£1.27
10 Way 90°	£0.46
14 Way 90°	£0.48
16 Way 90°	£0.54
20 Way 90°	£0.59
26 Way 90°	£0.81
34 Way 90°	£1.03
40 Way 90°	£1.23
50 Way 90°	£1.41

**PCB Latch Headers**

10 Way Straight	£0.41
14 Way Straight	£0.45
16 Way Straight	£0.51
20 Way Straight	£0.55
26 Way Straight	£0.73
34 Way Straight	£0.88
40 Way Straight	£0.92
50 Way Straight	£1.27
10 Way 90°	£0.46
14 Way 90°	£0.48
16 Way 90°	£0.54
20 Way 90°	£0.59
26 Way 90°	£0.81
34 Way 90°	£1.03
40 Way 90°	£1.23
50 Way 90°	£1.41

**DIL Headers**

14 Way DIL	£0.51
16 Way DIL	£0.53
20 Way DIL	£0.55
24 Way DIL	£0.90
40 Way DIL	£1.37

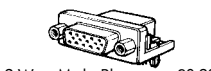
**Transition Headers**

10 Way Transition	£0.42
14 Way Transition	£0.42
16 Way Transition	£0.48
20 Way Transition	£0.48
26 Way Transition	£0.52
34 Way Transition	£0.56
40 Way Transition	£0.63
50 Way Transition	£0.84

**Large Range of Connectors available - contact our sales department for full details**

**D Type Connectors**

<b>Solder Bucket</b>	
9 Way Male Plug	£0.24
9 Way Female Socket	£0.24
15 Way Male Plug	£0.36
15 Way Female Socket	£0.36
15 Way H.D. Plug	£0.48
15 Way H.D. Socket	£0.48
23 Way Male Plug	£0.50
23 Way Female Socket	£0.50
25 Way Male Plug	£0.36
25 Way Female Skt	£0.37
<b>IDC Ribbon Mounting</b>	
9 Way Male Plug	£1.08
9 Way Female Socket	£0.93
15 Way Male Plug	£1.32
15 Way Female Socket	£1.32
25 Way Male Plug	£1.18
25 Way Female Socket	£1.13

**Right Angled PCB**

9 Way Male Plug	£0.33
9 Way Female Socket	£0.33
15 Way Male Plug	£0.39
15 Way Female Socket	£0.39
25 Way Male Plug	£0.52
25 Way Female Socket	£0.51

**Plastic D Covers**

9 Way Cover - Grey	£0.29
9 Way Cover - Black	£0.30
15 Way Cover - Grey	£0.32
15 Way Cover - Black	£0.32
25 Way Cover - Grey	£0.38
25 Way Cover - Black	£0.38
25 Way Cover - Grey	£0.34
25 Way Cover - Black	£0.37
9 to 9 Cover / Case	£0.80
25 to 25 Cover / Case	£0.84
9 to 25 Cover / Case	£0.80

**Audio Connectors**

2.5mm Jack Plug	£0.25
2.5mm Line Socket	£0.16
2.5mm Chassis Socket	£0.20
2.5mm Mono Plug	£0.24
3.5mm Mono Line Skt	£0.30
3.5mm Mono Chassis	£0.14
3.5mm Stereo Plug	£0.36
3.5mm Stereo Line Skt	£0.37
3.5mm Stereo Chassis	£0.34
1/4" Mono Plug	£0.34
1/4" Mono Line Socket	£0.35
1/4" Mono Chassis Sk	£0.35
1/4" Stereo Plug	£0.40
1/4" Stereo Line Socket	£0.40
1/4" Stereo Chassis Skt	£0.40
Neutrik Spekgon Plug	£2.81

**Phono Series**

Red Line Plug	£0.20
Black Line Plug	£0.20
Yellow Line Plug	£0.20
White Line Plug	£0.20
Red Line Socket	£0.20
Black Line Socket	£0.20
Yellow Line Socket	£0.20
White Line Socket	£0.20
Red Chassis Socket	£0.20
Black Chassis Socket	£0.20
Gold Plated Plug Red	£0.66
Gold Plated Plug Black	£0.66

**XLR Series - metal**

3 Pin Line Plug	£1.46
3 Pin Line Socket	£1.71
3 Pin Chassis Plug	£1.50
3 Pin Chassis Socket	£1.49
Neutrik Line Plug	£1.68
Neutrik Line Socket	£1.99
Neutrik Chassis Plug	£2.13
Neutrik Chassis Socket	£2.32

**RF Connectors**

BNC Plug 50Ω Solder	£0.99
BNC Plug 50Ω Crimp	£0.68
BNC Plug 75Ω Solder	£0.95
BNC Plug 75Ω Crimp	£0.68
BNC Chassis Socket	£0.81
F Plug - Twist	£0.24
F Plug - Crimp	£0.26
TNC Plug 50Ω Solder	£1.24
TNC Plug 50Ω Crimp	£0.85
TNC Plug 75Ω Solder	£1.40
TNC Plug 75Ω Crimp	£1.10
UHF Plug 5mm Cable	£0.63
UHF Plug 11mm Cable	£0.75
UHF Chassis Skt - Sqr	£0.50
UHF Chassis Skt - Rnd	£0.73

Extensive range of RF connectors in stock, inc. FME, SMA, Mini UHF & N Type.



<b>Terminals</b>	
Colours Red, Black, Green, Blue, White, Yellow	
2mm Solder Plugs	£0.18
2mm Chassis Sockets	£0.26
4mm Plugs - Solder	£0.38
4mm Plugs - Screw	£0.33
4mm Stackable Plugs	£0.40
4mm Shrouded Plugs	£0.74
4mm Chassis Sockets	£0.24
4mm Binding Posts	£0.46
33mm Crocodile Clips	£0.10

**Power Connectors**

<b>DC Low Voltage</b>	
DC Plug 0.7ID 2.35OD	£0.47
DC Plug 1.3ID 3.4OD	£0.32
DC Plug 1.7ID 4.0OD	£0.47
DC Plug 1.7ID 4.75OD	£0.47
DC Plug 2.1ID 5.0OD	£0.25
DC Plug 2.5ID 5.0OD	£0.24
DC Plug 3.1ID 6.3OD	£0.46
DC Line Socket 2.1mm	£0.57
DC Line Socket 2.5mm	£0.68
DC Chassis Skt 2.1mm	£0.40
DC Chassis Skt 2.5mm	£0.41

**IEC Mains 6A 250Vac**

3 Pin IEC Line Socket	£1.08
3 Pin IEC Line Plug	£1.78
3 Pin Chassis Socket	£0.75
3 Pin Chassis Plug	£0.72

**8 Way Builtin**

8 Pin Line Plug P551	£4.08
8 Pin Chassis Skt P552	£1.39

**Toggle Switches**

<b>Sub-Miniature</b>	
3A 125V 1A 250V	
5mm Ø Mounting Hole	
SPST 5 x 10mm	£0.58
SPDT 5 x 10mm	£0.60
SPDT c/Off 5 x 10mm	£0.81
DPDT 9.2 x 10mm	£0.66

**Miniature**

6A 125V 3A 250V	
6.2mm Ø Mounting Hole	
SPST 8 x 13mm	£0.65
SPDT 8 x 13mm	£0.54
SPDT c/Off 8 x 13mm	£0.60
SPDT c/o Biased 2 way	£0.97
SPDT c/o Biased 1 way	£1.04
DPDT 12 x 13mm	£0.72
DPDT c/Off 12 x 13mm	£0.80
DPDT c/o Biased 2 way	£1.28
DPDT c/o Biased 1 way	£1.28

**Standard**

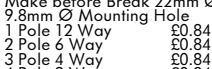
10A 250V Push on terminals	
12mm Ø Mounting Hole	
SPST 18 x 30mm	£1.28
SPDT 18 x 30mm	£1.31
SPDT c/Off 18 x 30mm	£1.43
DPDT 21 x 30mm	£1.65
DPDT c/Off 21 x 30mm	£1.68

**Slide Switches**

<b>Miniature</b>	
300mA 125V	
7 x 15mm Mounting Hole	
DPDT 7 x 23mm	£0.20

**Standard**

5.5 x 12mm Mounting Hole	
DPDT 12 x 35mm	£0.25
DPDT c/o 12 x 35mm	£0.27

**Rotary Switches**

150mA 250V	
Make before Break 22mm Ø	
9.8mm Ø Mounting Hole	
1 Pole 12 Way	£0.84
2 Pole 6 Way	£0.84
3 Pole 4 Way	£0.84
4 Pole 3 Way	£0.84

**Push Switches**

<b>Miniature Round</b>	
250mA 125V 28 x 10mm	
7mm Ø Mounting Hole	
Non Latching Push to Make	
Black PTM	£0.23
Red PTM	£0.23
Yellow PTM	£0.23
Green PTM	£0.23
Blue PTM	£0.23
White PTM	£0.23
Non Latching Push to Break	
Black PTB	£0.24

**Standard Square**

1A 250V	
39 x 15MM	
12mm Ø Mounting Hole	
Non Latching Push to Make	
Black PTM	£0.60
Red PTM	£0.60
Blue PTM	£0.60
White PTM	£0.60
Latching - push On push Off	
Black	£0.65
Red	£0.65
Blue	£0.65
White	£0.65

**Rocker Switches****Miniature**

6A 250V Solder Tags	
SPST 21 x 14 x 16mm	£0.69
DPDT 21 x 24 x 22mm	£1.02
SPST - Red Neon	£1.02
SPST - Green Neon	£1.02
SPST - Amber Neon	£1.02

**Standard**

15A 250V Push on Tags	
SPST 30 x 11 x 22mm	£0.58
DPDT 30 x 25 x 22mm	£1.12

**illuminated**

15A 250V Push on Tags	
SPST 30x14mm Red	£0.84
DPST 30x25mm Amber	£1.40
DPST 30x25mm Green	£1.40

**Relays**

PCB Mounting	
1A 24Vdc DPDT 5V	£1.38
1A 24Vdc DPDT 12V	£2.00
1A 110V SPDT 6V	£0.58
3A 110V SPDT 12V	£0.58
5A 110V SPDT 6V	£0.72
5A 110V SPDT 12V	£0.72
5A 110V DPDT 6V	£0.93
5A 110V DPDT 12V	£0.93
5A 240V DPDT 6V	£1.76
5A 240V DPDT 12V	£1.76
10A 240V SPDT 6V	£1.25
10A 240V SPDT 12V	£1.44
10A 240V SPDT 24V	£1.44

**Computer Accessories**

9M Gender Changer	£2.18
9F Gender Changer	£2.29
25M Gender Changer	£2.60
25F Gender Changer	£2.80
8 Male, 25 Female	£1.99

# Next Month

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## **CANUTE TIDE PREDICTOR**

For several years the author experimented with writing computer software intended to produce results that matched those given in published tide tables, and which could ultimately form the basis for a low-power micro-processor controlled tide predictor (long before PICs came along).

Eventually he became aware that official tide tables are compiled not just according to the geometries of the Earth-Moon-Sun system, but also in relation to local data compiled over generations. There was no hope, therefore, of developing a simple system that could match standard tide-table accuracy.

However, most people do not need the accuracy of official tide tables. All they might be interest in, for example, is whether it is better to go to the beach in the morning or afternoon in order to find the tide at the preferred state of rise or fall.

That is what the Canute Tide Predictor is aimed at achieving – to show on a liquid crystal display(LDC) a tide-state bar-graph and high-low tide times accurate to within about an hour. The use of a PIC16F876 micro-controller has allowed a very simple unit to be designed.

Anyone who loves the sea, sandy beaches, or rocky shore lines will find this design a useful guide when considering a quick trip to the coast.

## **TECHNOLOGY TIMELINES – THE FUTURE**

It's been interesting and fun looking back over the last 100 years or so to see how we got where we are – quite a staggered path, with all sorts of odd developments coming together to produce major forward steps in technology. Finally we get to peer into the future, it's not quite as exact an art as looking back, but Max and Alvin are taking a stab at it from their starting point at the forefront of technology in the USA. We may not need to wait long to see if what they predict actually happens with the rate of development of new technology.

## **ATMOSPHERIC ELECTRICITY**

The ionized layers of the atmosphere extend from about 40km to 200km (25 to 125 miles) above the Earth. This ionization is caused by the “Solar Wind” passing the Earth and leaves the upper atmosphere positively charged.

There is thus an electric field between the upper atmosphere and the Earth and, given suitable instruments, this field can be detected as it results in a miniscule current through the atmosphere.

A potential of around 100 volts is often present just one meter off the ground. In other words, there may be a potential of 200 volts or more between your nose and toes! Of course, nobody gets electrocuted because the resistance of the air is so high that only a very tiny current is present. And this is why the actual values are generally considered to be so difficult to measure. But in fact they can be measured quite easily and we will show you how.

## MAIL ORDER ONLY • CALLERS BY APPOINTMENT

### EPE MICROCONTROLLER P.I. TREASURE HUNTER

The latest MAGENTA DESIGN – highly stable & sensitive – with I.C. control of all timing functions and advanced pulse separation techniques.

- High stability drift cancelling
- Easy to build & use
- No ground effect, works in seawater



- Detects gold, silver, ferrous & non-ferrous metals
- Efficient quartz controlled microcontroller pulse generation.
- Full kit with headphones & all hardware

KIT 847.....£63.95

### PORTABLE ULTRASONIC PEST SCARER

A powerful 23kHz ultrasound generator in a compact hand-held case. MOSFET output drives a special sealed transducer with intense pulses via a special tuned transformer. Sweeping frequency output is designed to give maximum output without any special setting up.

KIT 842.....£22.56

ICEBREAKER  
□□□□□□□□

SEE ICEBREAK AD  
PAGE 367

### DC Motor/Gearboxes

Our Popular and Versatile DC motor/Gearbox sets.  
Ideal for Models, Robots, Buggies etc. 1-5 to 4-5V  
Multi ratio gearbox gives wide range of speeds.

LARGE TYPE – MGL £6.95  
SMALL – MGS – £4.77

### Stepping Motors

MD38...Mini 48 step...£8.65  
MD35...Std 48 step...£9.99  
MD200...200 step...£12.99  
MD24...Large 200 step...£22.95



### PIC PIPE DESCALER

- SIMPLE TO BUILD
- HIGH POWER OUTPUT
- AUDIO & VISUAL MONITORING
- SWEPT FREQUENCY

An affordable circuit which sweeps the incoming water supply with variable frequency electromagnetic signals. May reduce scale formation, dissolve existing scale and improve lathering ability by altering the way salts in the water behave.  
Kit includes case, P.C.B, coupling coil and all components.  
High coil current ensures maximum effect. L.E.D. monitor

KIT 868 .....£22.95 POWER UNIT.....£3.99



### MICRO PEST SCARER

Our latest design – The ultimate scarer for the garden. Uses special microchip to give random delay and pulse time. Easy to build reliable circuit. Keeps pests/pests away from newly sown areas, play areas, etc. Uses power source from 9 to 24 volts.

- RANDOM PULSES
- HIGH POWER
- DUAL OPTION

KIT 867.....£19.99

KIT+SLAVE UNIT.....£32.50

### WINDICATOR

A novel wind speed indicator with LED readout. Kit comes complete with sensor cups, and weatherproof sensing head. Mains power unit £5.99 extra.

KIT 856.....£28.00

Plug-in power supply £4.99



## ★ TENS UNIT ★

### DUAL OUTPUT TENS UNIT

As featured in March '97 issue.

Magenta have prepared a FULL KIT for this excellent new project. All components, PCB, hardware and electrodes are included. Designed for simple assembly and testing and providing high level dual output drive.

KIT 866.... Full kit including four electrodes £32.90

Set of  
4 spare  
electrodes  
£6.50



### 1000V & 500V INSULATION TESTER

Superb new design. Regulated output, efficient circuit. Dual-scale meter, compact case. Reads up to 200 Megohms. Kit includes wound coil, cut-out case, meter scale, PCB & ALL components.

KIT 848.....£32.95

## EPE TEACH-IN 2000

Full set of top quality NEW components for this educational series. All parts as specified by EPE. Kit includes breadboard, wire, croc clips, pins and all components for experiments, as listed in Introduction to Part 1.

\*Batteries and tools not included.

TEACH-IN 2000 –

KIT 879 **£44.95**

MULTIMETER **£14.45**

### SPACEWRITER

An innovative and exciting project. Wave the wand through the air and your message appears. Programmable to hold any message up to 16 digits long. Comes pre-loaded with "MERRY XMAS". Kit includes PCB, all components & tube plus instructions for message loading.

KIT 849.....£16.99

### 12V EPROM ERASER

A safe low cost eraser for up to 4 EPROMS at a time in less than 20 minutes. Operates from a 12V supply (400mA). Used extensively for mobile work – updating equipment in the field etc. Also in educational situations where mains supplies are not allowed. Safety interlock prevents contact with UV.

KIT 790.....£29.90

## SUPER BAT DETECTOR

1 WATT O/P, BUILT IN  
SPEAKER, COMPACT CASE  
20kHz-140kHz

NEW DESIGN WITH 40kHz MIC.

A new circuit using a 'full bridge' audio amplifier i.c., internal speaker, and head-phone/tape socket. The latest sensitive transducer, and 'double balanced mixer' give a stable, high performance superheterodyne design.

KIT 861.....£24.99

ALSO AVAILABLE Built & Tested ....£39.99



### MOSFET MkII VARIABLE BENCH POWER SUPPLY 0-25V 2-5A.

Based on our Mk1 design and preserving all the features, but now with switching pre-regulator for much higher efficiency. Panel meters indicate Volts and Amps. Fully variable down to zero. Toroidal mains transformer. Kit includes punched and printed case and all parts. As featured in April 1994 EPE. An essential piece of equipment.



Kit No. 845.....£64.95

## EPE PROJECT PICs

Programmed PICs for all\* EPE Projects  
16C84/16F84/16C71

All **£5.90 each**  
PIC16F877 now in stock

**£10** inc. VAT & postage  
(\*some projects are copyright)

### ULTRASONIC PEST SCARER

Keep pets/pests away from newly sown areas, fruit, vegetable and flower beds, children's play areas, patios etc. This project produces intense pulses of ultrasound which deter visiting animals.

- KIT INCLUDES ALL COMPONENTS, PCB & CASE

- EFFICIENT 100V TRANSDUCER OUTPUT
- COMPLETELY INAUDIBLE TO HUMANS

KIT 812.....£15.00





## SIMPLE PIC PROGRAMMER

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

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

Power Supply £3.99

EXTRA CHIPS:  
PIC 16F84 £4.84

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

## PIC16C84 LCD DISPLAY DRIVER

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

Kit 860 **£19.99**

Power Supply £3.99

FULL PROGRAM SOURCE  
CODE SUPPLIED – DEVELOP  
YOUR OWN APPLICATION!

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

## PIC16F84 MAINS POWER 4-CHANNEL CONTROLLER & LIGHT CHASER

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

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

Kit 855 **£39.95**

LOTS OF OTHER APPLICATIONS

## PIC TOOLKIT V1

- PROGRAMS PIC16C84 and 16F84 • ACCEPTS TASM AND MPASM CODE
- Full kit includes PIC16F84 chip, top quality p.c.b. printed with component layout, turned pin PIC socket, all components and software\*  
\*Needs QBASIC or QUICKBASIC

Kit 871 . . . **£13.99**. Built and tested **£21.99**

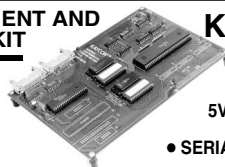
## PhizzyB

ALL PARTS FOR SERIES INCLUDING PCBs, PROGRAMMED CHIP, CD-ROM AND DISPLAYS

MAIN BOARD – FULL KIT	<b>£131.95</b>	BUILT .....	<b>£149.95</b>
I/O PORT KIT .....	<b>£16.99</b>	BUILT .....	<b>£24.99</b>
L.C.D. ....	<b>£12.49</b>	POWER SUPPLY ..	<b>£3.99</b>
8-BIT SWITCH/LATCH .....	<b>£7.95</b>	INT. MODULE ..	<b>£10.45</b>

## 68000 DEVELOPMENT AND TRAINING KIT

- NEW PCB DESIGN
- 8 MHz 68000 16-BIT BUS
- MANUAL AND SOFTWARE
- 2 SERIAL PORTS
- PIT AND I/O PORT OPTIONS
- I2C PORT OPTIONS



Kit 621

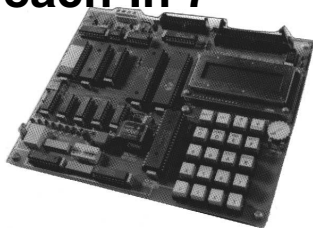
**£99.95**

- ON BOARD 5V REGULATOR
- PSU £6.99
- SERIAL LEAD £3.99

## 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  
Full Micro Lab Kit – £155.95  
Built Micro Lab – £189.95



## EPE PIC Tutorial

At Last! A Real, Practical, Hands-On Series

- Learn Programming from scratch using PIC16F84

- Start by lighting l.e.d.s and do 30 tutorials to Sound Generation, Data Display, and a Security System

- PIC TUTOR Board with Switches, l.e.d.s, and on board programmer

## PIC TUTOR BOARD KIT

Includes: PIC16F84 Chip, TOP Quality PCB printed with Component Layout and all components\* (\*not ZIF Socket or Displays). Included with the Magenta Kit is a disk with Test and Demonstration routines.

Kit 870 ..... **£27.95**, Built & Tested ..... **£42.95**

Optional: Power Supply – £3.99, ZIF Socket – £9.99

LCD Display ..... **£7.99** LED Display ..... **£6.99**

Reprints Mar/Apr/May 98 – £3.00 set 3

## PIC TOOLKIT V2

- SUPER UPGRADE FROM V1 • 18, 28 AND 40-PIN CHIPS
- READ, WRITE, ASSEMBLE & DISASSEMBLE PICS
- SIMPLE POWER SUPPLY OPTIONS 5-20V
- ALL SWITCHING UNDER SOFTWARE CONTROL
- MAGENTA DESIGNED PCB HAS TERMINAL PINS AND OSCILLATOR CONNECTIONS FOR ALL CHIPS
- INCLUDES SOFTWARE AND PIC CHIP

Kit 878 . . . **£22.99** with 16F84 . . . **£29.99** with 16F877

## SUPER PIC PROGRAMMER

- READS, PROGRAMS, AND VERIFIES
- WINDOWS<sup>TM</sup> SOFTWARE
- PIC16C6X, 7X, AND 8X
- USES ANY PC PARALLEL PORT
- USES STANDARD MICROCHIP • HEX FILES
- OPTIONAL DISASSEMBLER SOFTWARE (EXTRA)
- PCB, LEAD, ALL COMPONENTS, TURNED PIN SOCKETS FOR 18, 28, AND 40 PIN ICs.

- SEND FOR DETAILED INFORMATION – A SUPERB PRODUCT AT AN UNBEATABLE LOW PRICE.

Kit 862 **£29.99**

Power Supply £3.99

DISASSEMBLER  
SOFTWARE **£11.75**

## PIC STEPPING MOTOR DRIVER

INCLUDES: PCB,  
PIC16F84 WITH  
DEMO PROGRAM,  
SOFTWARE DISK,  
INSTRUCTIONS  
AND MOTOR.

Kit 863 **£18.99**

FULL SOURCE CODE SUPPLIED.  
ALSO USE FOR DRIVING OTHER  
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# Constructional Project

## VERSATILE MIC/AUDIO PREAMPLIFIER

by RAYMOND HAIGH

**Use one of the latest chips on the block to produce an audio pre-amp with AGC compression, limiting, and noise reduction.**

Intended primarily as a means of processing microphone inputs to computers, the SSM2166P integrated circuit (IC) – manufactured by Analog Devices – has a wider range of possible applications. Public address and surveillance systems immediately spring to mind, and the device will be of particular interest to radio enthusiasts, especially now that the popular Plessey 6270 IC mic/pre-amp, with voice gain, is no longer available.

This article describes how the new IC can be used for a variety of signal inputs, and additional circuitry is given for readers who

require a signal-strength meter.

### THE CHIP

The various amplifying and control stages built into the SSM2166 chip are shown in Fig.1.

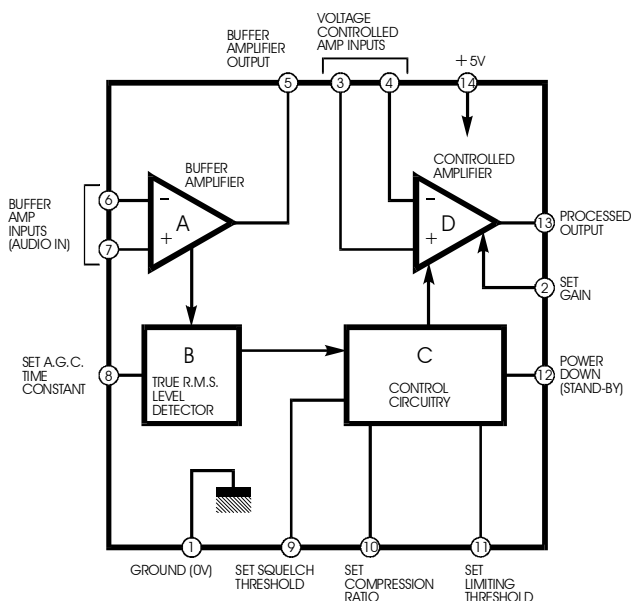
Signal inputs are buffered by opamp A, internally connected to a rectifier stage, B, which produces a DC voltage which varies in proportion to signal strength.

After processing by the control circuit, C, the DC voltage is used to fix the large and small signal gain of a second opamp, D.

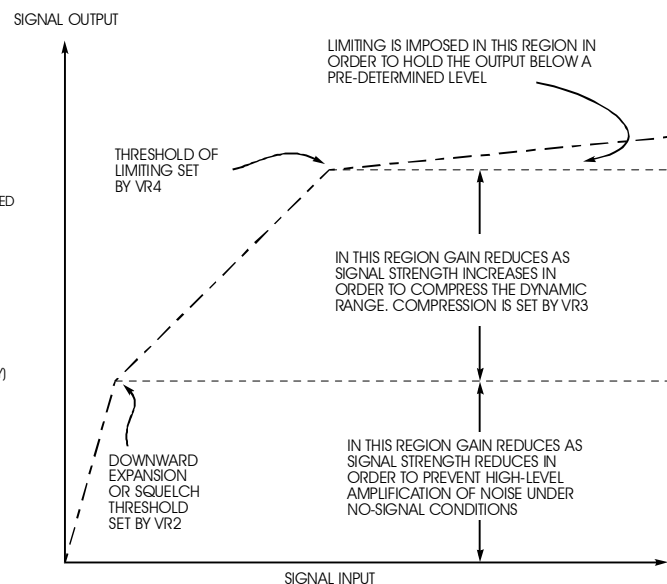
### AMPLIFIERS

The input impedance of buffer amplifier, A, is 180 kilohms (180k) and its gain can be set, by external feedback resistors, between 0dB and 20dB. There is a standing DC voltage on the input, and a blocking capacitor must be used.

The input and output impedances of the controlled amplifier, D, are 1k, and 75 ohms, respectively. A standing DC voltage necessitates the use of a blocking capacitor at the output.



**Fig.1. Internal block schematic for the SSM2166P microphone preamplifier, with variable compression and noise gating.**



**Fig.2. Relationship between limiting, compression, and downward expansion or "squelch".**

Provision is made for setting the nominal gain of the controlled stage between 0dB and 20dB, but AGC action will increase amplification, at the lowest signal levels, to as much as 60dB. The output can be muted.

Interestingly, the noise generated by the controlled stage is designed to be at a minimum when its gain is at a maximum, and this significantly improves the overall signal-to-noise ratio of the system.



### RECTIFIER

The circuit of the rectifier, or level-detector stage (B), has been specially developed for this application. It produces a DC control voltage, which is proportional to the log of the true RMS value of the input signal.

The speed at which the control voltage responds to changes in signal level, or the "attack time", can be controlled by the user. Response to high-level changes is automatically

speeded up by the IC in order to minimize the duration of any overload.

### CONTROL CIRCUIT

The control circuit (C) enables the user to program the performance of the IC in a very comprehensive way, and the amount of signal compression can be set between zero and 60dB.

Signal limiting can also be applied to prevent the occasional transient exceeding

the desired maximum output. It can be set at outputs ranging from 30mV to 1V. Above this threshold, the maximum compression ratio of 15:1 is applied.

The response of the system to very low level inputs can be reduced in order to prevent the amplification of noise under no-signal conditions. The threshold of this downward expansion (the lower the signal the less it is amplified), can be set at inputs of between 250uV and 20mV.

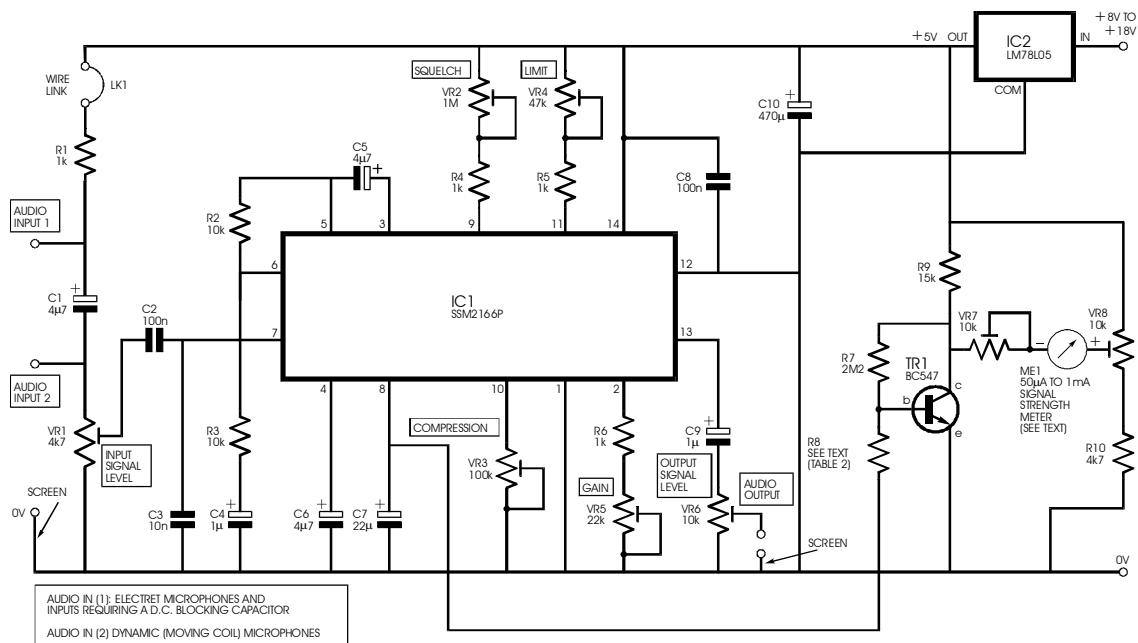


Fig.3. Complete circuit diagram for the Versatile Mic/Audio Preamplifier.

Provision is made for the device to be placed in a "power-down" or stand-by mode, and this feature will be of particular interest when it is used in sophisticated surveillance systems. In this state, current consumption is reduced to around 10mA and the input and output ports assume a high impedance.

User programmable control circuitry, coupled with the complex rectifier or level-detector, contributes significantly to the chip's performance. The relationship between the noise reduction, compression and limiting functions is displayed in Fig.2.

### RATINGS

No doubt with computer circuit compatibility in mind, the SSM2166 is designed for a 5V supply. The absolute maximum supply voltage is 10V. Current consumption is approximately 10mA.

The maximum input to the buffer is 1V, and the maximum output from the controlled amplifier is 14V RMS for 1 per cent total harmonic distortion. Frequency response extends well into the RF spectrum.

Static discharges can damage the IC, and the usual precautions (discharging the body) should be taken when handling and connecting it into circuit.

The SSM2166P is embedded in a 14-pin, dual-in-line package, and the suffix "P" refers to the standard-size version. This is the type most likely to be stocked by suppliers. However, surface-mount types are also manufactured: these carry the suffix "S".

### CIRCUIT DETAILS

The full circuit diagram for the Versatile Mic/Audio Preamplifier, incorporating a signal strength meter, is given in Fig.3. Provision for controlling so many functions results in a plethora of preset potentiometer controls. However, they do enable the signal processing to be tailored to individual requirements, and their adjustment is not critical or difficult. A summary of their various functions is set out in Table 1.

Preset VR1 permits adjustment of the input signal level to prevent overload and to optimize the performance of the

circuit. Its value is appropriate for moving coil and electret microphones, and for audio signals derived from most transistor circuits. Keeping the

## COMPONENTS

### Resistors

R1, R4, R5, R6 1k (4 off)  
R2, R3 10k (2 off)  
R7 2M2  
R8 (see Table 2)  
R9 15k  
R10 4k7

All 0.25W 5% carbon film

### Potentiometers

VR1 4k7 enclosed carbon preset, horizontal  
VR2 1M enclosed carbon preset, horizontal  
VR3 100k enclosed carbon preset, horizontal  
VR4 47k enclosed carbon preset, horizontal  
VR5 22k enclosed carbon preset, horizontal  
VR6, VR7, VR8 10k enclosed carbon preset, horizontal (3 off)

### Capacitors

C1, C5, C6 4u7 radial electrolytic, 10V (3 off)  
C2, C8 100n ceramic (2 off)  
C3 10n ceramic  
C4, C9 1u radial electrolytic 10V (2 off)  
C7 22u radial electrolytic  
C10 470u radial electrolytic

### Semiconductors

TR1 BC547 (or similar, e.g. BC239, BC548) *npn* low-power transistor  
IC1 SSM2166 microphone preamp (Analog Devices)  
IC2 LM78L05ACZ +5V 100mA voltage regulator

### Miscellaneous

ME1 50uA to 1mA FSD moving coil meter (see text)

Printed circuit board available from the *EPE Online Store*, code 7000260 ([www.epemag.com](http://www.epemag.com)); 14-pin DIL socket; screened cable, solder pins, solder, multistrand connecting wire, etc.

**See also the  
SHOP TALK Page!**

**Approx. Cost  
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**Table 1: Preset Control Functions**

Preset	Value	Function
VR1	4k7	Set input signal level: clockwise to increase.
VR2	1M	Set threshold of downward expansion (squelch): clockwise to lower.
VR3	100k	Set compression: clockwise to increase.
VR4	47k	Set threshold of signal limiting: clockwise to lower.
VR5	22k	Set gain of controlled amplifier: clockwise to increase.
VR6	10k	Set output signal level: clockwise to increase.
VR7	10k	Set signal strength meter pointer at full scale (when strongest signal being processed): clockwise gives clockwise pointer movement.
VR8	10k	Set signal strength meter pointer at zero (under no-signal conditions): clockwise gives clockwise pointer movement.

value below 5 kilohms increases the stability margin of IC1.

Power can be supplied to an electret microphone's integral FET (field-effect-transistor) buffer via resistor R1, and C1 acts as a DC blocking capacitor. The input arrangements for alternative microphones and other signal sources are discussed at greater length later.

The input signal to IC1 is applied to the non-inverting (+) input of the buffer amplifier stage (Pin 7 – see Fig.1) via blocking capacitor C2. This IC has an extended frequency response and C3 introduces a measure of roll-off above 20kHz or so, again in the interests of stability.

### **BUFFER GAIN**

The gain of the buffer amplifier is set at 6dB by resistors R2 and R3, and this is likely to be sufficient for most purposes. Gain can be increased to a maximum of 20dB by decreasing R3 to about 1.2 kilohms. Adding this to the gain of the controlled amplifier results in an overall system gain, when signals are too small to initiate compression, of 80dB.

This is a great deal of amplification in a small package, and particular care must be taken with the screening and routing of input and output leads, and the connections to a shared power supply, if instability is to be avoided. Separate ground, or 0V leads, from signal source circuitry, the preamplifier, and the power amplifier, should be run to a common point at the power supply. The screening braid of signal cables should be connected to ground at the preamplifier end only.

If desired, the gain of the buffer can be set at unity by deleting R3 and inserting a wire link in place of resistor R2 (to connect pin 5 and pin 6). Blocking capacitor C4 maintains the correct DC conditions.

### **CONTROLLED AMPLIFIER**

The output from the buffer stage (pin 5) is connected, via DC blocking capacitor C5 to the non-inverting (+) input (pin 3) of the controlled amplifier stage. A capacitor of identical value, C6, at pin 4 connects the inverting (–) input to ground (0V). (This connection makes any electrical noise on the ground rail appear as a common mode signal to the controlled amplifier and the differential input circuitry rejects it).

The nominal gain of the controlled amplifier can be set, by preset VR5, between unity and 20dB. Resistor R6 ensures that the gain does not fall below unity.

Switched muting can be achieved by grounding pin 2 via a 330 ohm resistor (the switch should be located at the ground or 0V rail end). Switch clicks can be suppressed by connecting a 10nF capacitor between pin 2 and ground.

The IC can be put in standby mode by disconnecting pin 12 from ground and connecting it, via a 100 kilohms resistor, to the +5V rail. (Provision has not been made for muting or powering-down on the PCB.)

The processed output is taken from pin 13 and connected, via DC blocking capacitor C9, to preset VR6. This enables the output signal level to be adjusted to suit the input sensitivity of the power

amplifier.

### **ATTACK TIME**

The response or “attack” time of the AGC system can be controlled by adjusting the value of the rectifier reservoir capacitor C7. The IC manufacturer suggests a value within the range 2.2uF to 47uF, with smaller capacitors being suitable for music and the larger for speech.

Too low a value will result in “pumping” effects, with background noise “rushing up” between bursts of speech. This will become increasingly apparent as the compression ratio is raised.

Conversely, too high a value will excessively slow the response of the system to changes in signal level. The 22uF component specified for C7 has been found to work well with both speech and music inputs.

The attack time is controlled mainly by the value of C7, but the much longer “decay” time is dependant upon this capacitor and the internal control circuit. Fast attack and slow decay help to reduce the pumping effect, which seems far less pronounced with this IC than with simpler audio AGC systems.

### **COMPRESSION**

The amount of compression is determined by preset VR3, which connects pin 10 to ground. There is no compression with the potentiometer set to zero. When its resistance is at maximum, a 60dB change in input level (above the downward expansion or squelch threshold) changes



the output by less than 6dB.

The onset of limiting is controlled by preset VR4. Setting this potentiometer to maximum resistance fixes it at 30mV. With VR4 at minimum resistance, it is around 1V RMS. Above the threshold of limiting, a 15:1 compression ratio is imposed, irrespective of the setting of compression control VR3.

### NOISE REDUCTION

Preset potentiometer VR2 sets the threshold below which downward expansion (gain reduces as the signals become weaker) is applied. With maximum resistance, downward expansion starts at signal levels in the region of 250mV. Turned to zero resistance, the threshold is raised to around 20mV.

Gain rises to a maximum under no-signal conditions with all conventional AGC systems, and the amplification of external and internally generated noise produces a loud and tiresome hiss in the speaker or 'phones. The IC's noise reduction facility, which operates as a "squench" control, is very effective in overcoming this. It can reduce output noise below the level of audibility when signal levels fall to zero.

With any squench system, a need to resolve very weak signals overlaid by noise compromises the usefulness of the feature. Radio enthusiasts with a particular interest in it could mount VR2 as a panel control so that the threshold could be adjusted to suit reception conditions.

### POWER SUPPLY

The maximum safe supply voltage is 10V, and it should be

noted that, under a light load, a fresh 9V alkaline battery will usually deliver a higher voltage than this.

However, in order to ensure the correct operation of the device, and provide a high degree of isolation from other equipment sharing the same power supply, a 5V 100mA voltage regulator, IC2, is included in the circuit. This enables supplies with outputs ranging from 8V to 18V (or more, depending on IC2 rating) to be used.

Bypass capacitors C8 and C10 shunt the noise in the regulator output to ground. Note that C8 is essential to the stability of IC1 and it must be located as close as possible to pin 14, even when the unit is battery powered.

### SIGNAL STRENGTH METER

Some readers, especially those wishing to incorporate the unit into a radio receiver, may welcome the provision of a signal strength meter. This is included in the circuit diagram of Fig.1 and consists of transistor TR1, meter ME1 and associated components.

The AGC control voltage appears on pin 8 of IC1. It ranges from 290mV under no-signal conditions to approximately 720mV with high level inputs.

**Table 2: Signal Strength Meter ( Values of R8 for different meter sensitivities)**

Meter FSD	R8
50uA	1M
100uA	470k
500uA	100k
1mA	47k

Transistor TR1, configured as a DC amplifier, ensures that IC1's AGC line is only lightly loaded, even when a 1mA meter is used. It forms one arm of a bridge circuit, the other three being its collector load, R9, and the potential divider chain comprising preset VR8 and resistor R10. The bridge is balanced, and the meter set at zero under no-signal conditions, by preset potentiometer VR8.

When a signal is being processed, the rising AGC voltage on the base (b) of TR1 increases its collector current and, hence, the voltage drop across resistor R9. This unbalances the bridge and drives the meter pointer over. Preset VR7 adjusts the sensitivity of the meter so that the pointer can be set just short of full-scale deflection (FSD) when registering a strong signal.

The circuit can be made to accommodate meters with full-scale deflections ranging from 50mA to 1mA by adjusting the value of resistor R8. This resistor controls the flow of current through the base-emitter junction of transistor TR1, and values to suit a range of meter FSDs are given in Table 2. Bias resistor R7 provides a measure of negative feedback which helps to stabilize the operation of the circuit.

Almost any small-signal *npn* transistor should prove suitable for TR1, and a 2N5827 or 2N5828 could be used in addition to the types listed in the Components list. These devices have different case styles and the base connections must be checked.

### CONSTRUCTION

All the components, with the exception of the meter ME1, are

assembled on a small, single-sided, printed circuit board (PCB). The topside component layout, together with an (approximately) full-size underside copper foil master pattern, is shown in Fig.4. This board is available from the EPE Online Store (code 7000260) at [www.epemag.com](http://www.epemag.com)

Commence construction in the usual way by mounting the smallest components first working up to the largest, but fit IC1, IC2, and TR1 last (see earlier comments about the static sensitive nature of IC1). A holder for IC1 will facilitate substitution checking. Solder pins, inserted at the lead-out points, will ease the task of off-board wiring.

## SPOT-CHECKS

When all the components have been soldered in position on the PCB, double-check the orientation of electrolytic capacitors, the ICs, and the transistor. Also, check the PCB for bridged tracks and poor solder joints.

Next, with IC1 "out of circuit", connect a supply voltage of between 7V and 9V and check that the output from regulator IC2 is producing 5V. A fault in this device, or its wrong connection, could result in the destruction of IC1 when higher voltages are applied.

Once all is well, place IC1 in its socket (checking orientation), connect, via screened cable, a signal source and a power amplifier. Adjust the various preset potentiometers until the processing meets your requirements. All preset functions are summarized in Table 1 for ease of reference.

## MICROPHONES

The unit works well with

dynamic (moving coil), electret, crystal, and ceramic microphones. Screened cable

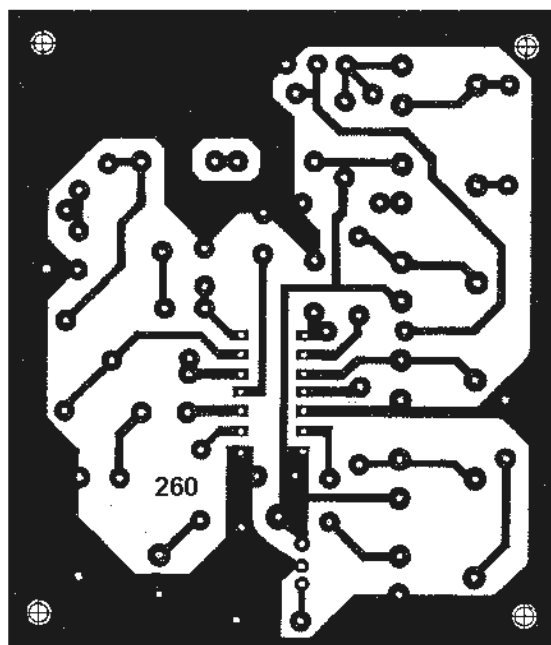
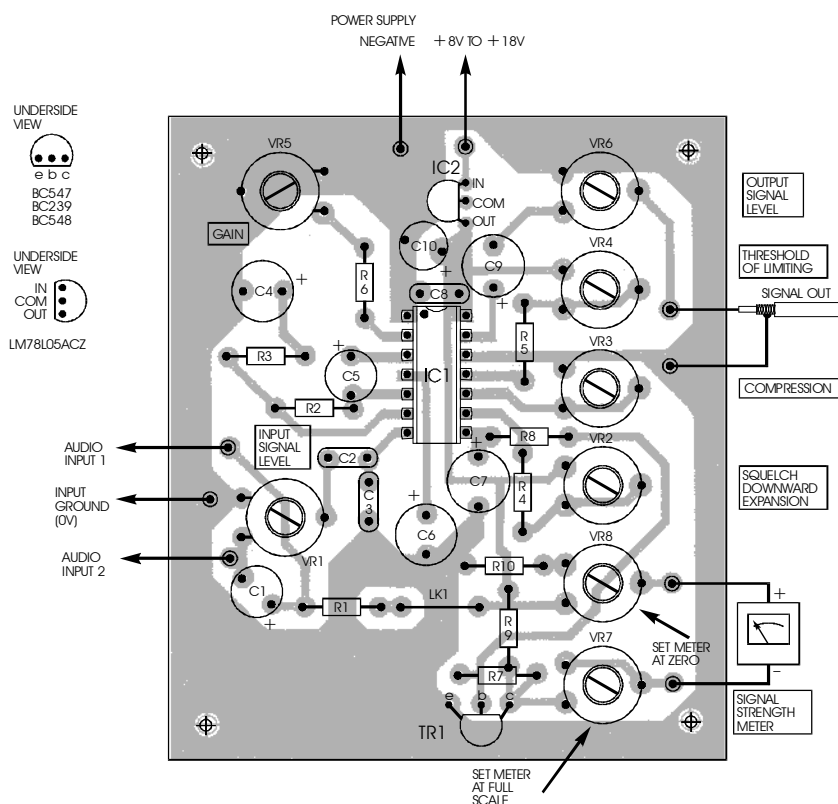
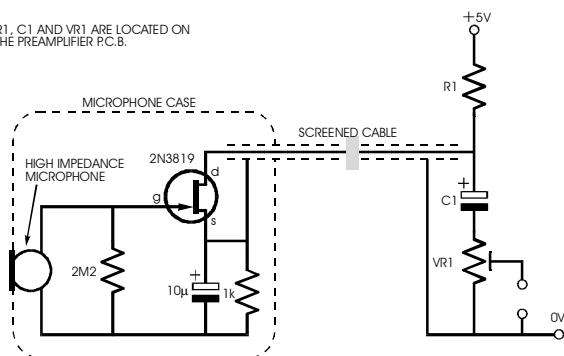


Fig.4. Printed circuit board component layout, inter-wiring details and (approximately) full-size underside copper foil master.

R1, C1 AND VR1 ARE LOCATED ON THE PREAMPLIFIER P.C.B.



**Fig.5.** The line-powered buffer stage built into electret microphones can also be used for ceramic and crystal types. (Most FETs will function in this circuit with the source grounded, eliminating the need for the source resistor and bypass capacitor.)

must, of course, be used to connect any type of microphone to the preamplifier.

Very high quality studio microphones can be insensitive and require balanced feeders to minimize hum pick-up. The pre-amplifier described here is configured for unbalanced inputs, and is not likely to be suitable, as it stands, for microphones of this kind.

A few words about the various types of signal input may prove helpful.

**Dynamic Microphones** are manufactured with impedances ranging from 50 ohms to 600 ohms. Output tends to be greatest with the higher impedance units.

This type of microphone should be connected to Input 2 (i.e., directly across preset VR1), and the wire link must be removed to isolate resistor R1 from the 5V rail.

**Electret Microphones** are a modern development of the capacitor microphone (a permanently charged diaphragm, the electret,

eliminates the need for an external charging voltage). The output from the actual unit is low and at a high impedance, so these microphones have an integral FET buffer. The drain load for the internal FET is provided at the amplifier end of the cable (resistor R1 in Fig.3), to facilitate line powering.

Electret microphones must be connected to Input 1, and the wire link must be in place to connect resistor R1 to the supply rail. The 1 kilohm drain load (R1), fed from the 5V supply, should ensure the optimum performance of most microphones of this kind.

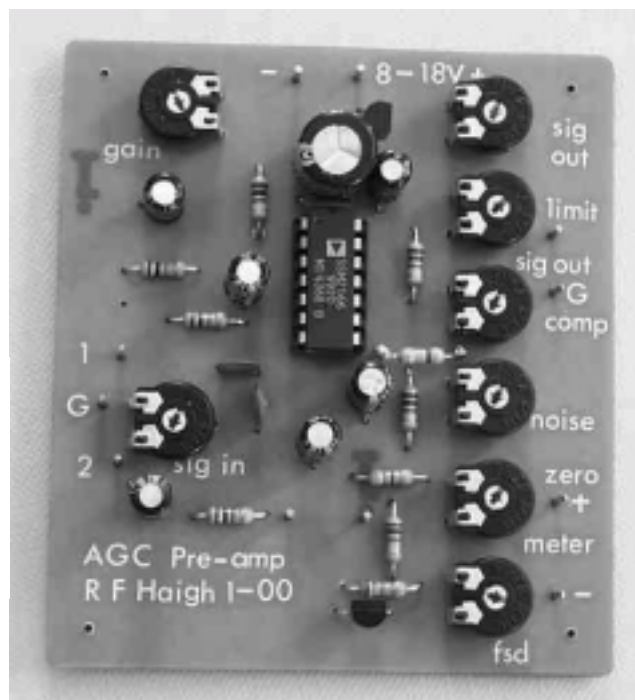
**Crystal and Ceramic Microphones** rely upon the piezo-electric effect to produce a signal voltage. The vibrating diaphragm induces stresses in a wafer of crystal, often Rochelle salt, or in a barium titanate

element in the case of ceramic units.

These microphones should be connected to Input 2. They have a high impedance, and feeding them into preset VR1 will reduce their response to low audio frequencies. Low frequency roll-off is, however, desirable for communications work, and more is said about this later.

The use of long connecting cables will attenuate the signal but have little effect on frequency response (cable capacitance is modest compared to the self-capacitance of these microphones, which can be as high as 30nF).

If an extended frequency response is required from microphones of this type, the use of an external, line-powered, FET buffer, as built into electret microphones, is



*Layout of components on the completed circuit board. The "Signal Strength Meter" components, except the meter, have been included on the board (bottom right).*

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recommended. This will also prevent signal losses when long cables are used.

A suitable circuit diagram is given in Fig.5 and the circuit can be built inside the microphone case. When this arrangement is adopted, resistor R1 must, of course, be connected to the supply rail, and the signal must be fed to Input 1.

### RADIO RECEIVERS

Audio derived AGC is often incorporated into direct conversion radio receivers. Even simple superhets can benefit from this form of control (sometimes a conventional RF derived system is not very effective when amateur single-side-band signals are being processed).

Direct conversion and regenerative receivers will require a single transistor audio amplifier, after the product detector or regenerative detector, in order to

ensure sufficient signal voltage for the SSM2166P. The output from the detector stage in most superhets will be more than adequate.

Radio receivers should be connected to Input 1, and the wire link removed. The orientation of electrolytic capacitor C1 will usually be correct when the receiver has a negative ground or 0V rail.

However, some diode detectors in superhets are configured to provide an output which is negative going with respect to ground (to suit the receiver's AGC circuit). The polarity of C1 will need to be reversed when equipment of this kind is connected.

### SIGNAL PROCESSING

The preamplifier's frequency response is reasonably flat from below 100Hz to more than 20kHz. Speech clarity, especially under noisy conditions, can be improved by "rolling off" frequencies below 300Hz and above 3000Hz, and active or passive band-pass filters are often used for this purpose.

A big improvement can, however, be made by modifying some of the coupling and bypass components in the preamplifier. Constructors wishing to limit the frequency response in this way should reduce the value of capacitor C9, to 47nF (a Mylar or ceramic capacitor is then suitable). This will attenuate the lower frequencies.

Wiring a 220nF ceramic capacitor across preset VR1 will attenuate the higher frequencies. Although extremely simple, these measures are quite effective.

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### DIGITAL TEST METER

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DC volts 200mV to 1000V.  
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# Ingenuity Unlimited

## ROLL-UP, ROLL-UP!

Ingenuity is our regular round-up of readers' own circuits. We pay between \$16 and \$80 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 must not have been submitted for publication elsewhere**. The circuits shown have NOT been proven by us. *Ingenuity Unlimited* is open to ALL abilities, but items for consideration in this column should 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!](#)

## Sensitive Hall Effect Switch – Feel the Field

Using the UGN3503U linear Hall Effect sensor with a dual opamp allows the construction of a simple but extremely sensitive Hall Effect switch that could prove useful in many applications. A circuit diagram for just such a switch is shown in Fig. 1. The Hall Effect device is IC1, which has just three terminals, for positive and negative supplies and the output. A regulated 5V supply is suggested for most applications.

With a 5V supply and in the absence of a magnetic field, the output from IC1 is about 2.5V. On the approach of a magnet, the output will rise or fall, depending on the magnetic field's polarity. With a 5V supply, the AD8532 is an excellent choice for the dual opamp IC2 as it is designed for this supply voltage, has rail-to-rail inputs and outputs and, being a CMOS component, has very high input

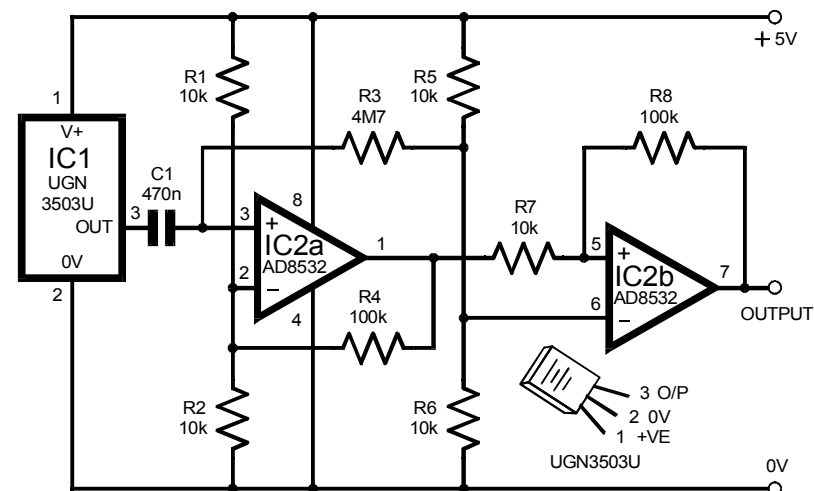


Fig.1. Sensitive Hall Effect Switch circuit diagram.

In addition it can supply up to 250mA of output current.

The first opamp, IC2a, is used as a non-inverting amplifier with a voltage gain of about 20 to amplify the output of IC1 to more useful levels. Because AC coupling via capacitor C1 is used for the input, resistor R3 sets the working point to half the

supply. This is necessary to avoid drift in the Hall Effect sensor IC1. The high value of R3 allows the circuit to operate at very low frequencies, down to less than 1Hz. The second opamp IC2b is connected as a comparator with hysteresis set by resistors R7 and R8 to about 500mV to ensure a rapid,

## Win a Pico PC-Based Oscilloscope

- 50MSPS Dual Channel Storage Oscilloscope
- 25MHz Spectrum Analyzer
- Multimeter
- Frequency Meter
- 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.





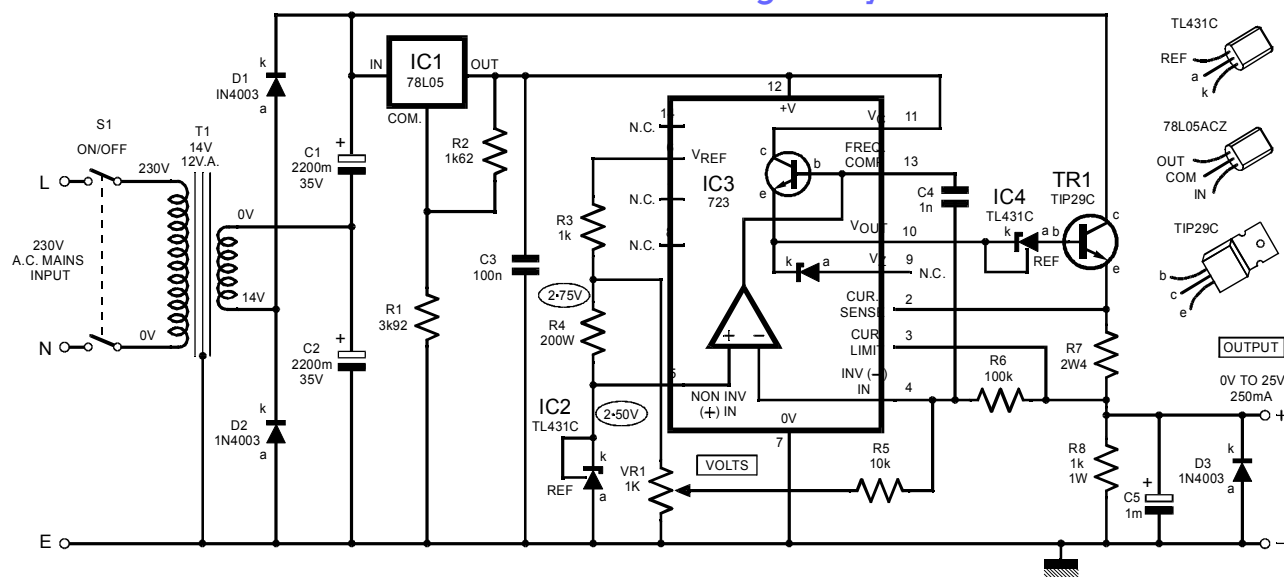


Fig.4. Experimenter's Power Supply circuit using the 723 variable voltage regulator.

ference plus two  $V_{BE}$  drops gives sufficient headroom at pin 13 for the amplifier stage when  $V_{out} = 0$ .

The 723's internal Zener diode at pin 9 was not used, as

the 6.2V requires a larger source from the transformer at maximum output, 25V. Even with this precaution it is possible to exceed the 723's absolute maximum voltage at pins 11

therefore, a three terminal regulator, 78L05ACZ (IC1) was added to maintain 30V.

As constructed, a single mains transformer with two, isolated 12VA windings allowed dual, floating DC sources of 0V to 25V magnitude, a convenience if both positive and negative voltages or their sum is desired.

John A. Haas

# Constructional Project

## LOW-COST CAPACITANCE METER

by **ROBERT PENFOLD**

***A simple starter project that will let you get the measure of most capacitors.  
Five switched ranges: 1nF to 10uF.***

A typical multimeter can measure voltage, current and resistance over a wide range of values, and usually has a few "tricks up its sleeve" such as continuity tester and transistor checker facilities. Some multimeters have capacitance measuring ranges, but this feature remains something of a rarity. This is a pity, because anyone undertaking electronic faultfinding will soon need to check suspect capacitors and a ready-made capacitance meter is an expensive item of equipment.

The unit featured here offers a low-cost solution to the problem of testing capacitors. It is an analog capacitance meter that has five switched ranges with full-scale values of **1nF**; **10nF**; **100nF**; **1uF**; and **10uF**. It cannot measure very high or low value components, but it is suitable for

testing the vast majority of capacitors used in everyday electronics.

### SYSTEM OPERATION

The block diagram for the *Low-Cost Capacitance Meter* is shown in Fig.1. Like most simple capacitance meter designs, this unit is based on a monostable circuit. When triggered by an input pulse a monostable produces an output pulse having a duration that is controlled by a *CR* network. In this case the monostable is triggered manually using a pushbutton switch each time a reading is required.

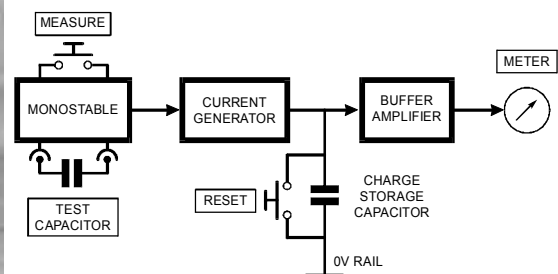
The resistor in the timing network is one of five resistors selected via a switch, and these resistors provide the unit with its five ranges. The capacitor in the *CR* network is the capacitor

under test.

The duration of the output pulse is proportional to the values of both components in the *CR* network. If a 1nF capacitor produces an output pulse of one millisecond in duration, components having values of 2.2nF and 4.7nF would respectively produce pulse lengths of 2.2ms and 4.7ms.

Each output pulse must be converted into a voltage that is proportional to the pulse duration. A moving coil panel meter can then read this voltage, and with everything set up correctly it will provide accurate capacitance readings.

If we extend the example given previously, with a potential of one volt per millisecond being produced, a meter having a full-scale value of 10V would actually read 0 to 10nF. This time-to-voltage conversion is actually quite simple to achieve, and is provided by a constant current generator and a charge storage capacitor.



**Fig.1. Schematic block diagram for the Low-Cost Capacitance Meter.**

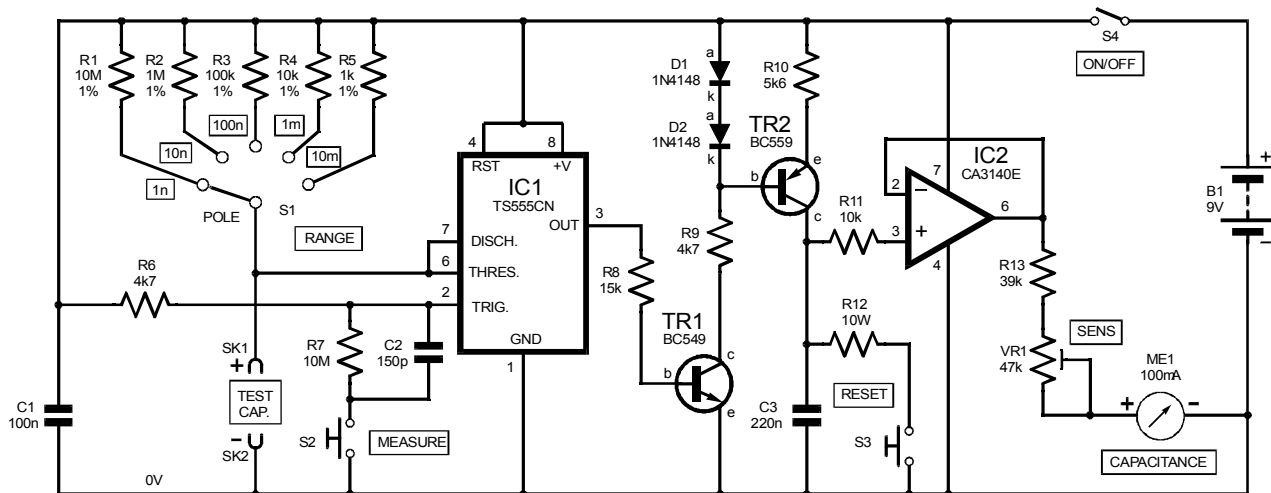


Fig.2. Complete circuit diagram for the Low-Cost Capacitance Meter.

capacitor.

When charged via a resistor the potential across the capacitor does not rise in a linear fashion. As the charge potential increases, the voltage across the resistor falls, giving a steadily reducing charge current. The voltage therefore increases at an ever-decreasing rate (inverse exponentially).

A current regulator avoids this problem by ensuring that the charge current does not vary with time, giving a linear rise in the charge voltage. The circuit therefore provides the required conversion from capacitance to voltage, but it is important that loading on the storage capacitor is kept to a minimum.

Tapping off a significant current could adversely affect the linearity of the circuit and would also result in readings rapidly decaying to zero. The meter is, therefore, driven via a buffer amplifier that has a very high input impedance. Once a reading has been taken and noted, operating the Reset switch discharges the storage capacitor and returns the reading to zero so that a new reading can be taken.

## CIRCUIT OPERATION

The complete circuit diagram for the *Low-Cost Capacitance Meter* project appears in Fig.2. The monostable is based on a low-power 555 timer (IC1) used in

the standard monostable configuration.

Apart from the fact it gives much longer battery life, a low-power 555 is a better choice for this type of circuit due its lower self-capacitance. This produces much better accuracy on the 1nF range, and a standard 555 is

## COMPONENTS

### Resistors

R1 10M 1% metal film  
R2 1M 1% metal film  
R3 100k 1% metal film  
R4 10k 1% metal film  
R5 1k 1% metal film  
R6, R9 4k7 (2 off)  
R7 10M  
R8 15k  
R10 5k6  
R11 10k  
R12 10 ohms  
R13 39k

All 0.25W 5% carbon film, except where otherwise specified

### Potentiometer

VR1 47k miniature enclosed or skeleton preset, horizontal

### Capacitors

C1 100n ceramic  
C2 150p ceramic plate  
C3 220n polyester

### Semiconductors

D1, D2 1N4148 signal diode (2 off)  
TR1 BC549 *nnp* transistor  
TR2 BC559 *npn* transistor  
IC1 TS555CN low power timer  
IC2 CA3140E PMOS opamp

### Miscellaneous

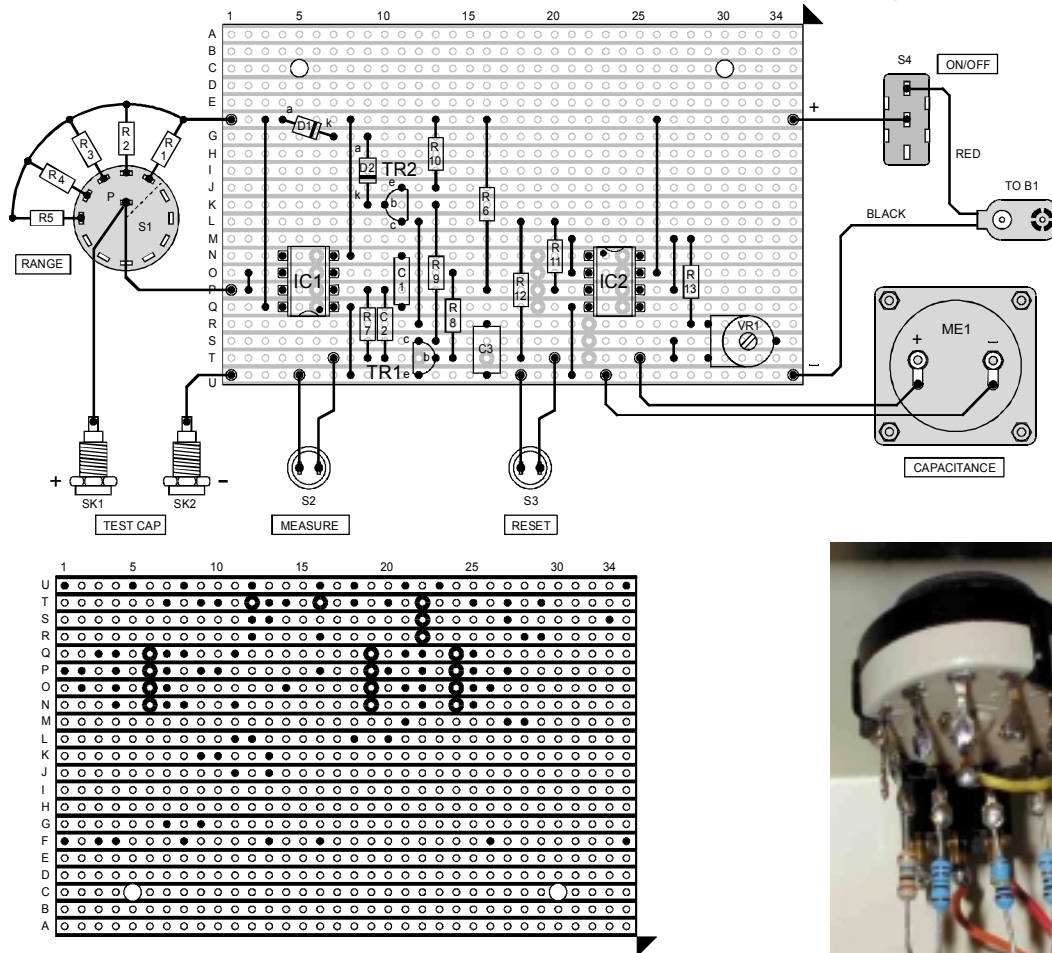
ME1 100uA moving coil panel meter  
SK1 2mm socket, red  
SK2 2mm socket, black  
S1 12-way single-pole rotary switch (set for 5-way operation) (see text)  
S2, S3 pushbutton switch, push-to-make (2 off)  
S4 s.p.s.t. miniature toggle switch  
B1 battery (PP3 size), with connector leads

Metal instrument case (or type to choice), size 150mm x 100mm x 75mm; stripboard 0.1-inch matrix, size 34 holes by 21 copper strips; 8-pin DIL socket (2 off); control knob; calibration capacitor (see text); test leads (see text); solder pins; multistrand connecting wire; solder, etc.

See also the  
SHOP TALK Page!

Approx. Cost  
Guidance Only (Excluding batteries, case, & meter)

**\$19**



**Fig.3. Stripboard component layout, interwiring, and details of breaks required in underside copper tracks.**

therefore not recommended for use in this circuit.

Switch S1 sets the Range and R1 to R5 are the five timing resistors. Resistors R1 to R5 respectively provide the 1nF, 10nF, 100nF, 1uF, and 10uF ranges.

One slight flaw in the 555 for this application is that it will only act as a pulse stretcher and not as a pulse shortener. In other words, the output pulse will not end at the appropriate time if the input pulse is still present.

If it were used to directly trigger IC1, the input pulse from pushbutton switch S2 would invariably be far too long. A simple CR circuit is therefore

used to ensure that IC1 will always receive a very short trigger pulse, regardless of how long Measure switch S2 is pressed.

Resistor R6 holds the trigger input of IC1 (pin 2) high under standby conditions, but it is briefly pulsed low when S2 is operated and capacitor C2 charges via R6. When S2 is released, resistor R7 discharges C2 so that the unit is ready to trigger again the next time S2 is operated. Resistor R7 has been given a very high value so that the discharge time of C2 is long enough to prevent spurious triggering if S2 does not operate "cleanly". Most mechanical switches suffer from contact bounce, and without this debouncing it is likely that re-

*Mount the Range resistors directly on the switch tags before the switch is fitted in the case.*

triggering would occur practically every time S2 was released.

Under standby conditions the output at pin 3 of IC1 is low, and both transistor TR1 and TR2 are switched off. Consequently, only insignificant leakage currents flow into the charge storage capacitor C3. An output pulse from IC1 switches on TR1, which in turn activates TR2.

Transistor TR2 is connected as a conventional constant current generator, and the value of resistor R10 controls the



output current. This is around 115uA with the specified value. Transistors TR1 and TR2 switch off again at the end of the pulse from IC1, and the charge voltage on C3 is then read by the voltmeter circuit based on panel meter ME1.

### METER CIRCUIT

Operational amplifier (opamp) IC2 is used as the buffer amplifier, and the PMOS input stage of this device ensures that there is no significant loading on the "charge" capacitor C3. The input resistance of IC2 is actually over one million megohms.

However, the voltage on C3 will gradually leak away through various paths, including C3's own leakage resistance. The reading should remain accurate for at least a minute or two, and in most cases it will not change noticeably for several minutes. There will certainly be plenty of time for a reading to be taken before any significant drift occurs.

Briefly operating Reset switch S3 discharges C3 and zeros the meter so that another reading can be taken. Resistor R12 limits the discharge current to a level that ensures the contacts of S3 have a long operating life. The rate of discharge is still so high that it appears to be instant.

Preset VR1 enables the sensitivity of the voltmeter ME1 to be adjusted, and in practice this is adjusted so that the required full-scale values are obtained. In order to ensure good accuracy on all five ranges it is essential for range resistors R1 to R5 to be close tolerance (one or two percent) components.

There is no overload

protection circuit for the meter, but this protection is effectively built into the design. The circuit driving the meter is only capable of producing minor overloads, and is incapable of inflicting any damage. The current consumption of the circuit is only about 3mA, and a PP3 size battery is adequate to power the unit.

### CONSTRUCTION

The *Low-Cost Capacitance Meter* is built up on a small piece of stripboard having 34 holes by 21 copper strips. The topside component layout, underside details and interwiring to off-board components is shown in Fig.3.

As this board is not of a standard size, a piece will have to be cut from a large board using a small hacksaw. Cut along rows of holes rather than between them, and smooth any rough edges produced using a file. Then drill the two 3mm diameter mounting holes in the board and make the 17 breaks in the copper strips. There is a special tool for making the breaks in the copper strips, but a handheld twist drill bit of around 5mm diameter does the job very well.

The circuit board is now ready for the components, link wires, and solder pins to be added. The CA3140E used for IC2 has a PMOS input stage that is vulnerable to damage from static charges, and the appropriate handling precautions must therefore be taken when dealing with this IC.

It should be fitted to the board via a holder, but it should not be plugged into place until the unit is otherwise finished, and the board and wiring double-checked for any errors.

It should be left in its anti-static packing until then. Try to handle the device as little as possible when fitting it in its IC socket, and keep well away from any likely sources of static electricity such as television sets and computer monitors.

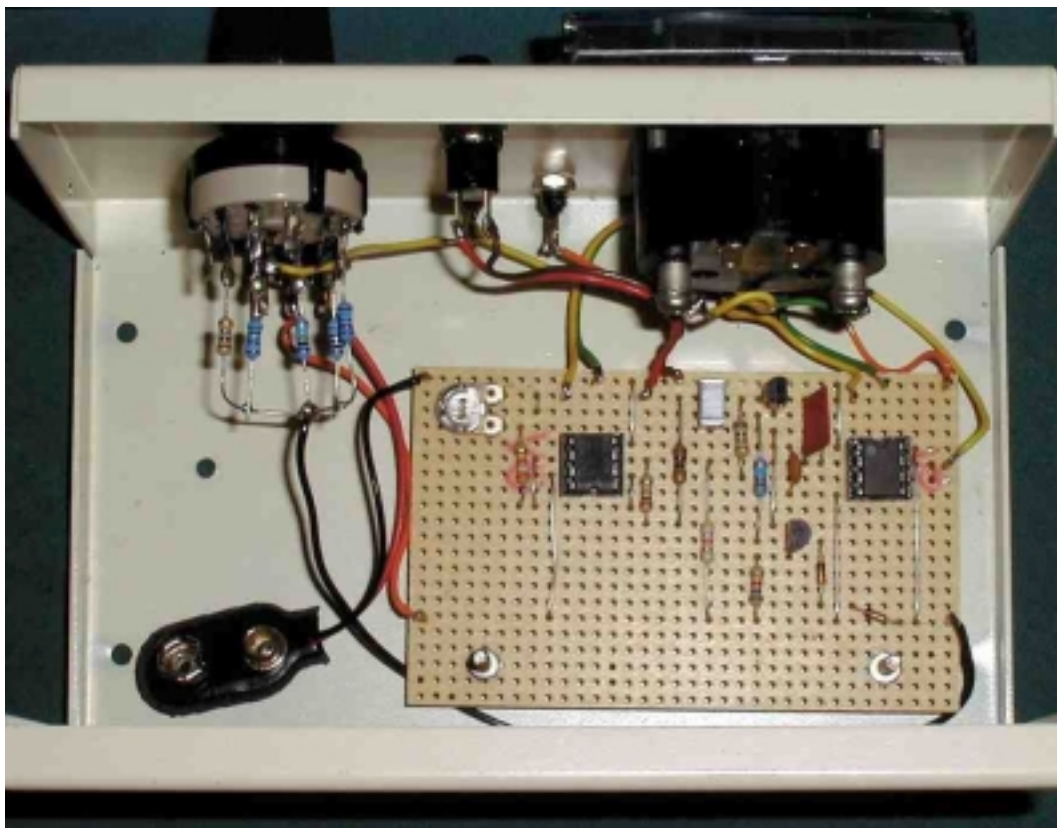
Although the TS555CN timer used for IC1 is not static-sensitive it is still a good idea to fit it in an IC socket. Be careful to fit IC1 the right way around because it has the opposite orientation to normal, with pin one at the bottom. This chip could easily be destroyed if it is fitted the wrong way around.

In all other respects construction of the board is fairly straightforward. The link wires can be made from the trimmings from resistor leadouts or 22 s.w.g. tinned copper wire. In order to fit into this layout properly capacitor C3 should be a printed circuit mounting component having 7.5mm (0.3-inch) lead spacing. Be careful to fit the diodes and transistors with the correct orientation. Note that transistors TR1 and TR2 have opposite orientations.

### RANGE RESISTORS

The five range resistors (R1 to R5) are mounted directly on the Range rotary switch S1, which helps to minimize stray capacitance and pick up of electrical noise. This aids good accuracy, especially on the 1nF range. It is best to mount the resistors on S1 before this switch is fitted in the case.

Fitting the resistors is made much easier if the switch is stuck to the workbench using Plasticine, or Bostik Blu-Tack. Provided the tags and the ends of the leadouts are tinned with solder it should then be quite easy to build this sub-assembly.



*Layout of components inside the metal case of the completed Low-Cost Capacitance Meter.  
The circuit board is mounted to one side to leave space for the battery*

Try to complete the soldered joints reasonably swiftly so that the resistors do not overheat. It takes quite a lot of heat to destroy resistors, but relatively small amounts can impair their accuracy.

### **CASING UP**

A medium size metal instrument case is probably the best choice for a project of this type, but a plastic box is also suitable. The exact layout is not critical, but mount SK1 and SK2 close together.

Many capacitors will then connect directly into the sockets without too much difficulty, but a set of test leads will also be needed to accommodate some capacitors. All that is required are two insulated leads about

100mm long. Each lead is fitted with a 2mm plug at one end and a small crocodile clip at the other.

Fitting the meter on the front panel is potentially awkward because a large round cutout is required. For most meters a cutout of 38mm diameter is required, but it is advisable to check this point by actually measuring the diameter of the meter's rear section. DIY superstores sell adjustable hole cutters that will do the job quickly and easily, or the cutout can be made using a coping saw, Abrafile, etc.

Four 3mm diameter holes are required for the meter's threaded mounting rods. Marking the positions of these is quite easy as they are usually at the corners of a square having

32mm sides, and the same center as the main cutout. Once again though, it would be prudent to check this by making measurements on the meter prior to drilling the holes.

The circuit board is mounted on the base panel of the case towards the left-hand side of the unit, leaving sufficient space for the battery to the right of the board. The component panel is mounted using either 6BA or metric M2.5 bolts, and spacers or nuts are used to ensure that the underside of the board is held well clear of the case bottom. To complete the unit the hard wiring is added. This offers nothing out of the ordinary, but be careful to connect the battery clip and meter ME1 with the correct polarity.

### **CALIBRATION**

Preset potentiometer (wired as a "variable resistor") VR1 must be given the correct setting in order to obtain good accuracy from the unit, and a close tolerance capacitor is needed for calibration. For optimum accuracy this capacitor should have a value equal to the full-scale value of the range used during calibration.

In theory it does not matter which range is used when calibrating the unit, but in practice either the 1nF or 10nF range has to be used. Suitable capacitors for the other ranges are either unavailable or extremely expensive.

The 10nF range is the better choice as the small self-capacitance of IC1 is less

significant on this range, although this factor seems to have very little affect on accuracy. Probably the best option is to calibrate the unit on the 10nF range using a 10nF polystyrene capacitor having a tolerance of one percent.

It is possible that a large reading will be produced on the meter when the unit is first switched on, but pressing Reset switch S3 should reset the meter to zero. If it is not possible to zero the meter properly, switch off at once and recheck the entire wiring, etc.

If all is well, set preset VR1 at maximum resistance (adjusted full clockwise). Then with the unit set to the correct range and the calibration capacitor connected to SK1 and SK2, operate pushswitch S2. This should produce a strong

deflection of the meter, and VR1 is then adjusted for precisely full-scale reading on meter ME1. The unit should then provide accurate readings on all five ranges.

### **IN USE**

The Meter is suitable for use with polarized capacitors such as electrolytic and tantalum types. However, it is essential that they are connected to SK1 and SK2 with the correct polarity. The positive (+) lead connects to SK1 and the negative lead connects to SK2.

Especially when using the 1nF and 10nF ranges, avoid touching the lead that connects to SK1 when a reading is being taken. Otherwise electrical noise might be introduced into the system producing inaccurate results.

Avoid connecting a charged capacitor to this or any other capacitance meter, since doing so could result in damage to the semiconductors in the meter circuit. If in doubt always discharge a capacitor before testing it.

# Constructional Project

## **MULTI-CHANNEL TRANSMISSION SYSTEM** by **ANDY FLIND**

***A PIC-based 8 to 16-Channel 2-wire on-off signaling communication link. An add-on Interface (next month) will extend possible options to internal private telephone and intercom systems.***

This project provides up to sixteen channels of on-off signaling communication through just a single pair of wires, in one direction or in both directions simultaneously. In a one-way system the Transmitter may be powered through the same pair of wires, which allows the monitoring of up to sixteen inputs from locations having no local power supplies. An interfacing option (next month) enables operation through audio circuits, such as private internal telephone and intercom systems.

Although ideal for remote signaling and alarm system monitoring, other possible applications could include such things as environmental monitoring, model railway controls and switching for advanced lighting or display systems. The versatility of using circuit modules, and the ways in which they can be connected together, means that possible applications are limited only by the constructor's own imagination.

### **HOSPITAL CALL**

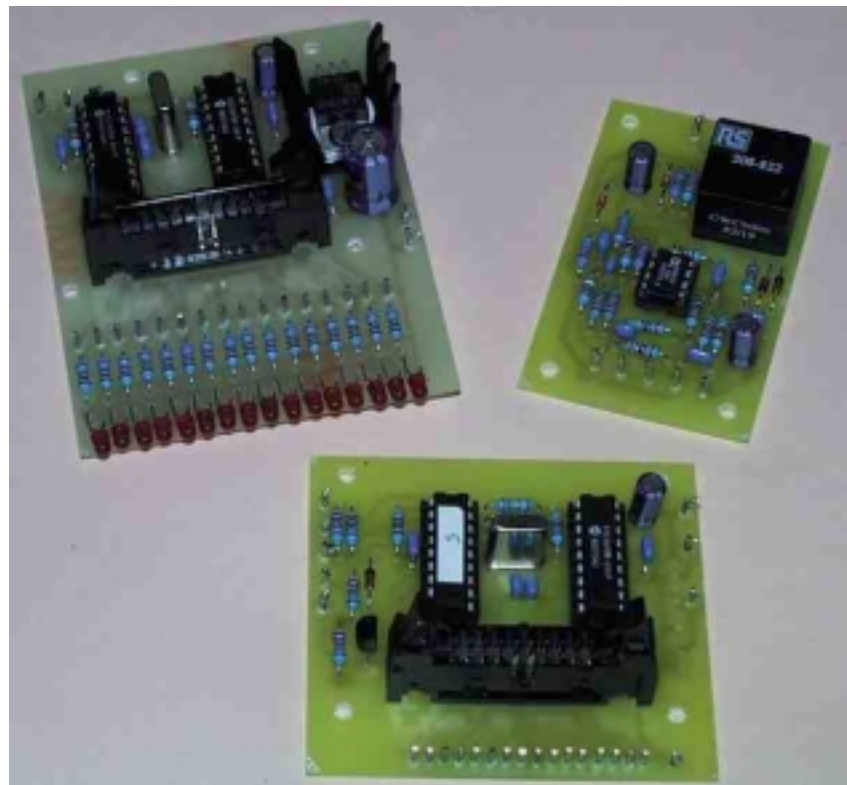
Like many designs, this one began with a request from a friend, who on this occasion is the volunteer engineer for the local "Hospital Radio". Although operated by amateurs, this service manages to maintain

impressively high operating standards.

At present a new studio is being constructed at some distance from their existing one and for a while they will be operating these simultaneously, often with a disk jockey. working in both. To make this possible, a number of signaling channels are required for functions such as indicating when a

microphone is in use. Security monitoring channels are also needed since the original studio is housed in a "Portacabin" and has suffered from attempted break-ins.

The request, then, was for the provision of sixteen "on-off" signaling channels to operate through a single circuit from the hospital's internal telephone system. Plus, the icing on the



*The three modules: Receiver board; Interface (next month) and, foreground, Transmitter board.*



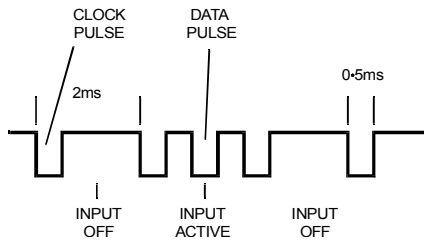


Fig.1. Transmission method

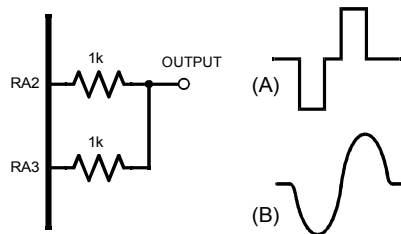


Fig.2. Waveform generation.

designer's cake, it was required to operate simultaneously in both directions.

## TAKE YOUR PIC

Initial thoughts were that the task could be carried out easily with a suitably programmed PIC. Whilst the programming proved far from easy, it eventually resulted in the extremely versatile system described here.

It can operate to the original specification with sixteen channels in each direction through a circuit capable only of handling low-level audio signals, but, as described, it can also be used in several other ways to suit less demanding applications. It can have either eight or sixteen channels, in one or both directions, and in some cases the Transmitter may be powered through the signaling wires which can sometimes be very useful.

Later upgrading of a system is also simple, as the second eight channels can be added by simply plugging in extra PICs. This is a project offering lots of possible options for tailoring the configuration to suit the

individual constructor's needs.

## SENDING A SIGNAL

The method of signal transmission used is relatively simple. A total of sixteen "clock" pulses are sent and for each there is a following "signal" pulse if the associated input is active. Part of the resulting waveform is shown in Fig.1.

It can be seen that the pulses are negative-going, with a positive quiescent state which allows the signaling line to serve as the transmitter power supply if required. The basic timing of each pulse is 0.5ms low, 0.5ms high, so that if all the switches are active the sequence becomes a burst of 1kHz tone, a suitable frequency for transmission through an audio circuit.

Squarewaves with a peak-to-peak amplitude of 5V are not suitable for telephone circuits however, as stray coupling into adjacent circuits in the cables is likely to cause interference to other users. The original intention was to "smooth" and attenuate the waveform with passive low-pass filtering and restore it at the far end with a comparator, but this idea failed since telephone circuits usually carry only AC signals due to coupling transformers and capacitors.

The average DC content of the waveform produced by this project varies with the number of active inputs and the resulting variation of the average level at the far end of an AC coupled circuit made it impossible to adjust the comparator for reliable operation. A solution was eventually found for this problem, the principle of which is shown in Fig.2.

Two outputs from the PIC (RA2 and RA3) are connected

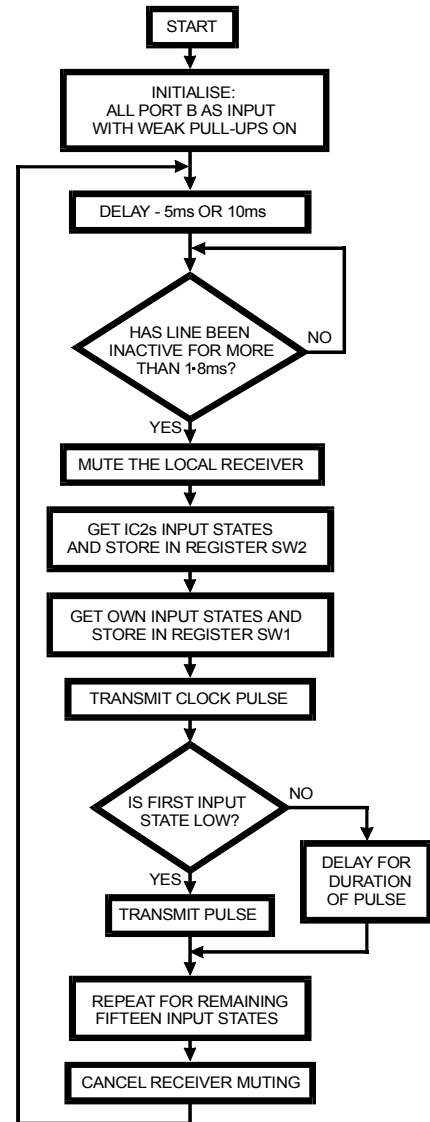
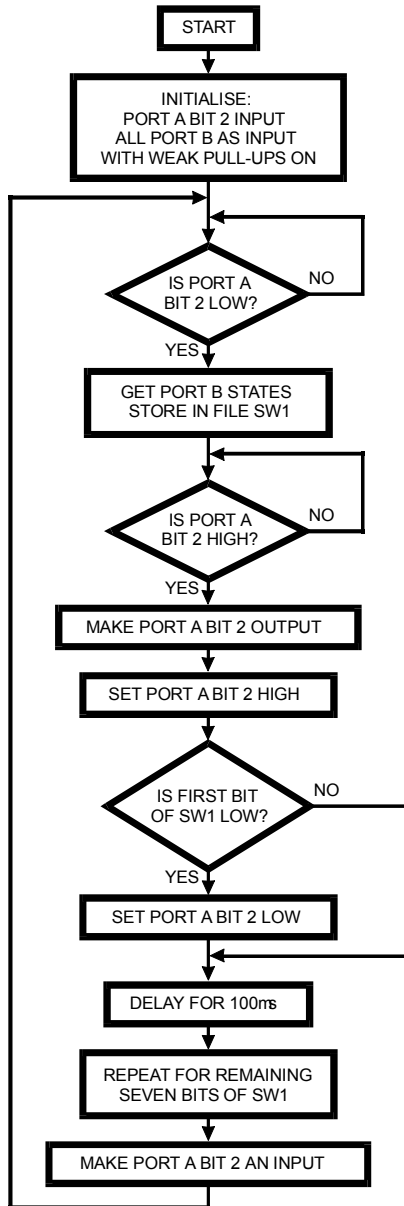


Fig.3. Flow diagram for the first Transmitter PIC, IC1.

through a pair of 1 kilohm (1k) resistors and the output is taken from their junction. The quiescent state consists of one output high (positive) and one low (negative) so that the output is half the supply voltage. A "signal pulse" consists of making both outputs low, followed by a return to the quiescent state, then both outputs high, then back to one high, one low.

This results in the waveform shown at Fig.2a, which is much better for transmission through an





**Fig.4. Flow diagram for the second Transmitter PIC, IC2.**

AC circuit. Furthermore, if the “low” and “high” states occupy around 61 per cent of the total period the energy content will be similar to that of a cycle of sine wave. When passed through a suitable low-pass filter this produces a very good approximation of a sine wave as shown in Fig.2b, far more suited to telephone circuits.

In passing, it's worth mentioning that with a 5V supply

the current “wasted” by the two resistors in the quiescent state is only 2.5mA as they present a series resistance of 2 kilohms, whilst the output impedance is only 500 ohms as for this they are effectively in parallel.

### BI-DIRECTIONAL OPERATION

Achieving bi-directional operation was more difficult. In telephony there are “two-to-four-wire” converter circuits which split the conventional two wires into separate transmit and receive pairs. They work by coupling the circuit to the receiver through an impedance of some kind, often just a resistor, and injecting an inverted form of the locally transmitted signal into the receiver to cancel the bit of it that comes through this impedance.

Success with this type of circuit assumes that the transmission path will have a known and constant impedance, both resistive and reactive, and attempts to use it with the proposed telephone circuit failed miserably. Eventually a software solution was found in which each transmitter checks the line for silence before transmitting and mutes the local receiver before doing so. Two such transmitters can be made to synchronize to each other and take turns to transmit.

The PIC16F84 can have internal “weak pull-up” resistors applied to the eight bits of port B when these are configured as inputs, removing the necessity to provide them externally. Each input can then be as simple as just a switch pulling it to ground if required.

A single PIC can only provide eight such inputs however, and this project required sixteen. Since these ICs are now available at a cost of less than 2 UK

pounds from some suppliers, the quickest and cheapest way to obtain a further eight inputs is from a second PIC which transmits its inputs serially to the first upon request.

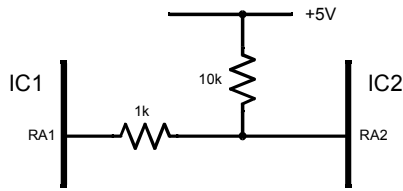
### SOFTWARE OPERATION

An outline of the software operation for the first PIC, IC1, in the Transmitter circuit is shown in the flow diagram Fig.3. The initial setting up includes configuring all of port B as inputs with active weak pull-ups.

This is followed by a brief delay. It is unlikely but quite possible that both transmitters in a bi-directional system might check the line, find it inactive and transmit together in perfect synchronization. The use of a slightly different delay in each transmitter will quickly break such a pattern to ensure correct operation. Five and ten milliseconds are the values used for this.

Following the delay the PIC monitors the line for a period of inactivity greater than 1.8ms, after which it mutes the input to the local receiver, collects the input states from the second PIC, IC2, and stores them in a register named SW2, and then stores its own input states in register SW1. It then transmits the first clock “pulse” as described earlier and checks the first bit of SW1. If this is clear, corresponding to an active input, a second pulse is transmitted. If it is set, the input was inactive so a delay lasting the period of a pulse is called.

This action is repeated for the remaining seven bits of SW1 followed by the eight bits of SW2, the whole process taking precisely 32ms. After this the program returns to the start and the entire sequence is repeated.



**Fig.5. Communication between two PICs**

A flow diagram of the Transmitter software for IC2 is shown in Fig.4.

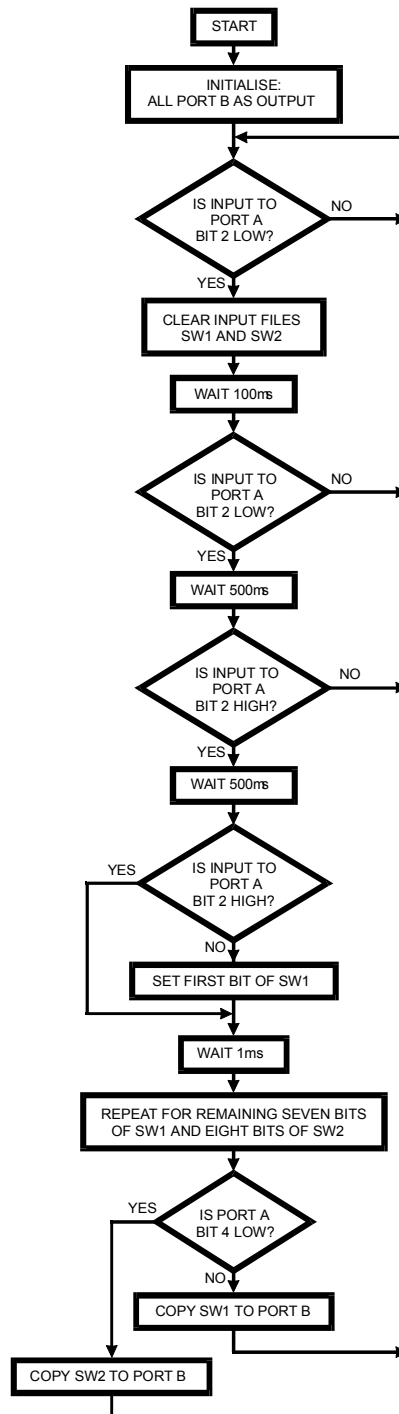
## PIC-TO-PIC

From time to time readers have asked how communication between PICs can be achieved so a detailed description of the method used may be helpful. In this circuit two PIC connections (RA1 and RA2) are linked as shown in Fig.5. A 1k resistor is used in case both pins become outputs simultaneously, although this should never be the case.

Initially, both connections are configured as inputs and the 10k resistor pulls them both high. When IC1 requires data from IC2, it's pin becomes an output and is pulsed low for about 400us before returning to the input state.

Meanwhile, IC2 has been waiting for the low pulse. On seeing this it stores its input states in a register and waits for the input to return to the high state. When this happens it makes its pin an output and sends the eight input states serially at intervals of 100us. Following this the pin returns to the input state and the program returns to the start to wait for the next pulse from IC1.

In the meantime, 50us after restoring its connection to input, IC1 commences taking eight readings from it at 100us intervals and storing the results in register SW2. The whole



**Fig.6. Flow diagram for the Receiver.**

process takes just over a millisecond and is easy to implement, both in hardware and software. This is serial communication at its simplest

and more sophisticated methods are obviously possible but it provides a starting point for anyone wanting to connect two or more PICs together.

One advantage of this method is that for eight-channel operation IC2 can be omitted. IC1 will still request the information but will "see" eight inactive inputs as each time it reads the pin it will see a high state set by the 10k resistor.

## RECEIVER SOFTWARE

Continuing with the Receiver, the flow diagram for this is shown in Fig.6. The program begins by looking for a falling edge in the input signal from the line. When it locates one it clears the two input registers named SW1 and SW2 which will contain the sixteen switch states.

It then waits for 100us, which should take it into the low portion of a pulse if this was the origin of the edge. It checks the input is still low, if not it returns to the program start. Otherwise, it waits for 500us and checks that the input is now high, as it will be if a pulse is present. Again, if it isn't the program returns to the start.

After another 500us, which takes it to the point where the input will be low or high depending on the input state being transmitted, it samples the state of the line and stores it in the first bit of register SW1. A further delay of 1ms takes it to the next clock pulse, where the process is repeated until all sixteen pulses have been checked and their associated data bits read.

Both low and high states of all sixteen clock pulses are checked and if any are missing

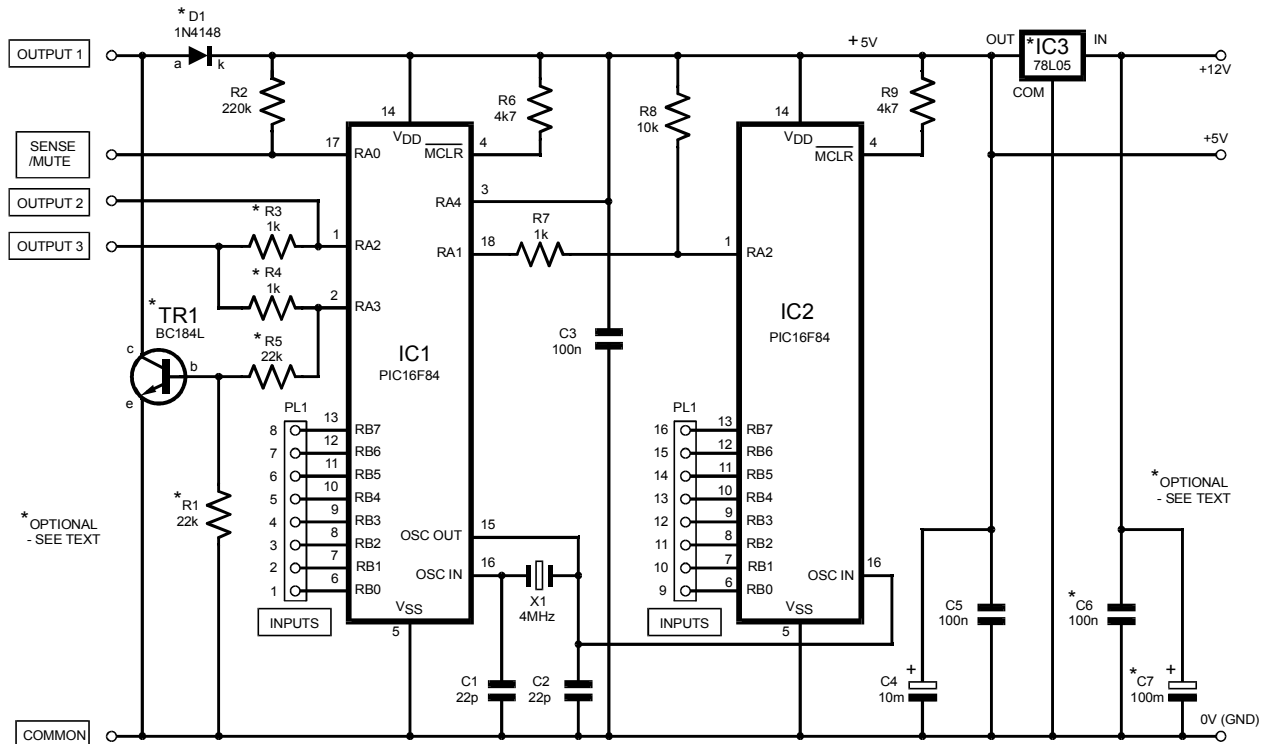


Fig. 7. Full circuit diagram for the Transmitter section. Note the items marked with an asterisk are optional – see text.

the program immediately returns to the start. This provides rapid synchronization to the transmitter and good protection against data corruption as a complete valid sequence must

be received before output takes place.

Assuming a complete sequence is received, the program now checks the input to

port A bit 4. This is wired “high” for IC1 and “low” for IC2, so the PIC knows which socket it is in and sends the appropriate eight bits of data to port B, SW1 in the case of IC1 and SW2 for IC2.

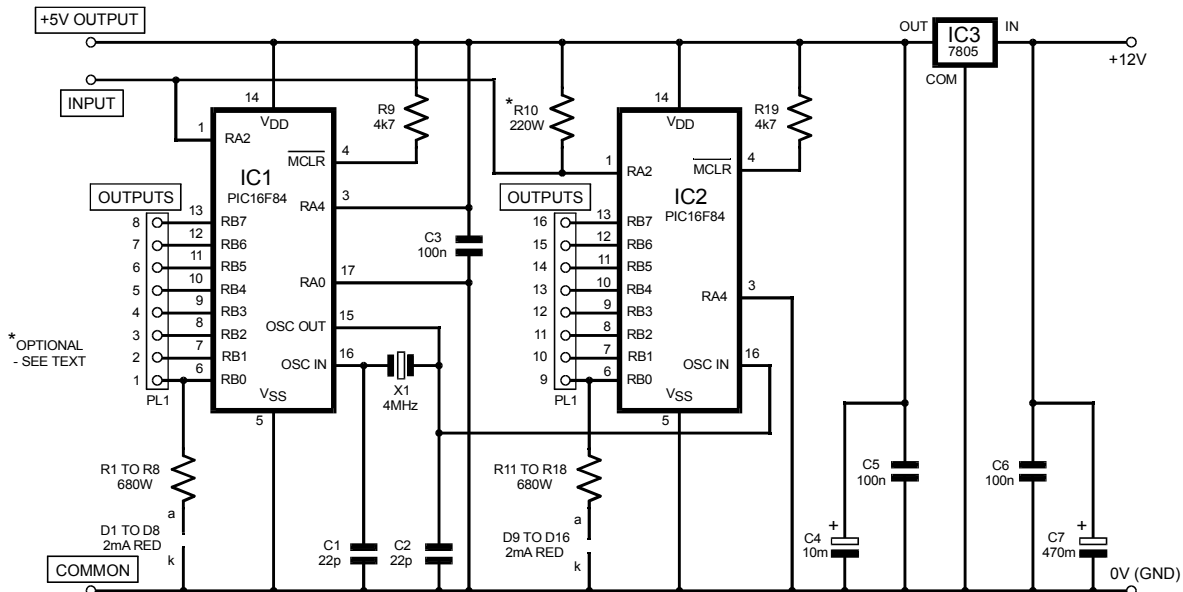


Fig. 8. Complete circuit diagram for the Receiver section of the Multi-Channel Transmission System.

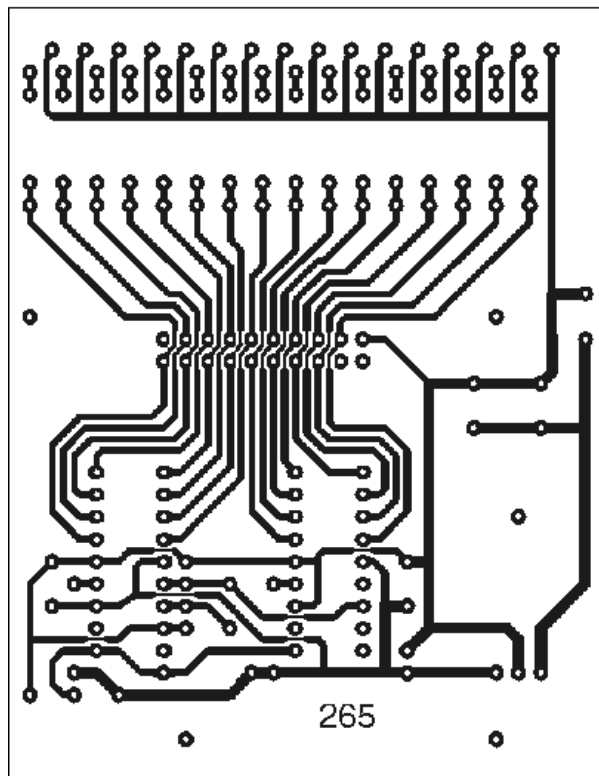
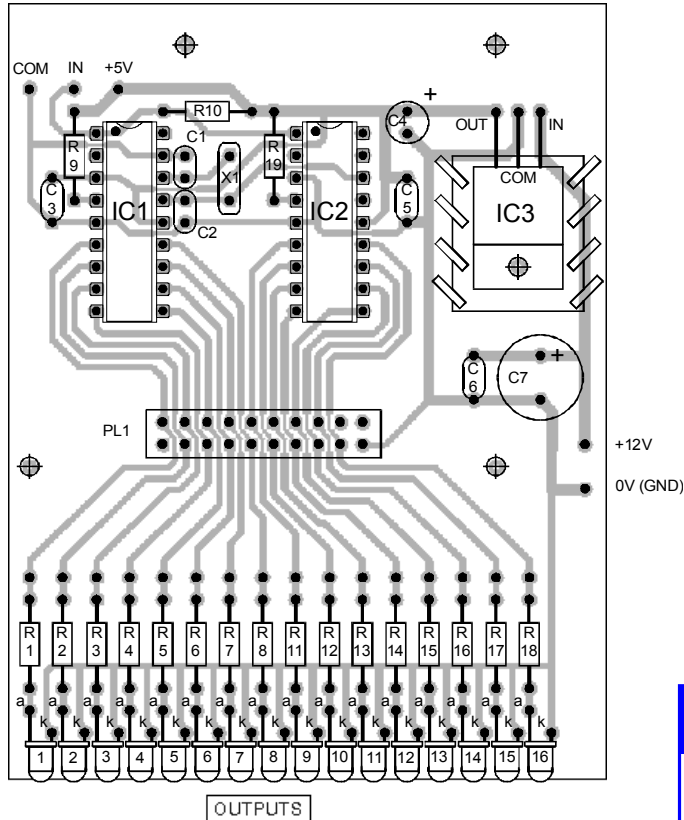
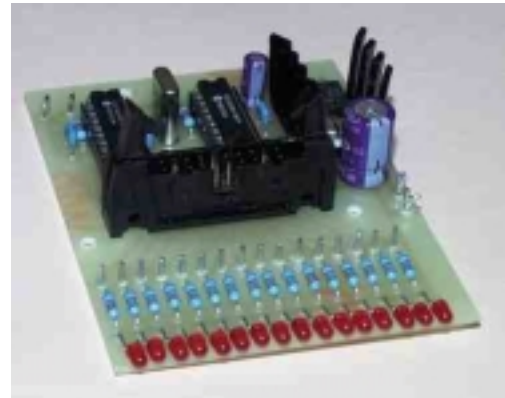


Fig.9. Receiver printed circuit board component layout and (approximately) full-size copper foil master pattern.



Complete Receiver module, including the LEDs. The LEDs, together with their associated resistors, can be omitted if you wish – see text.

## COMPONENTS

### RECEIVER

#### Resistors

R1 to R8, R11 to R18 680 ohms (16 off)  
R9, R19 4k7 (2 off)  
\*R10 220 ohms

All 0.6W 1% metal film

#### Capacitors

C1, C2 22p resin-dipped ceramic (2 off)  
C3, C5, C6 100n resin-dipped ceramic (3 off)  
C4 10u radial electrolytic, 63V  
C7 470u radial electrolytic, 25V

#### Semiconductors

D1 to D16 red LEDs, 2mA type (16 off)  
IC1, IC2 PIC16F84 pre-programmed microcontroller (2 off)  
IC3 7805 5V 1A voltage regulator

#### Miscellaneous

X1 4MHz crystal  
PL1 20-way IDC header plug

Printed circuit board available from the *EPE Online Store*, code 7000265 (Receiver) at [www.epemag.com](http://www.epemag.com); 18-pin DIL socket (2 off); small heatsink for IC3; multistrand connecting wire; solder pins, solder, etc.

\*Note: Resistor R10 is optional (see text).

See also the  
SHOP TALK Page!

Approx. Cost  
Guidance Only

**\$32**

## COMPONENTS

### TRANSMITTER

#### Resistors

- \*R1, R5 22k (2 off)
- R2 220k
- \*R3, \*R4, R7 1k (3 off)
- R6, R9 4k7 (2 off)
- R8 10k

All 0.6W 1% metal film

#### Capacitors

- C1, C2 22p resin-dipped ceramic (2 off)
- C3, C5, \*C6 100n resin-dipped ceramic (3 off)
- C4 10u radial electrolytic, 63V
- \*C7 100u radial electrolytic, 25V

#### Semiconductors

- \*D1 1N4148 signal diode
- \*TR1 BC184L *n*pn transistor
- IC1, IC2 PIC16F84 pre-programmed microcontroller (2 off)
- IC3 78L05 5V 100mA voltage regulator

#### Miscellaneous

- X1 4MHz crystal
- PL1 20-way IDC header plug

PCB available from the *EPE Online*

Store, code 7000264 (Transmitter)

[www.epemag.com](http://www.epemag.com); 18-pin DIL socket (2 off); solder pins, solder, multistrand connecting wire, etc.

Note, All components marked with an asterisk are optional (see text).

See also the

**SHOP TALK Page!**

Approx. Cost  
Guidance Only

**\$26**

In contrast to the Transmitter there is no communication between the two ICs which both simply check and store all sixteen bits and output the appropriate set. This allows them to use identical software and, as with the Transmitter, if just eight channels are required the second IC can be simply omitted.

An examination of the software of this project will reveal that it is written in straightforward "top-down" style with most repetitive operations

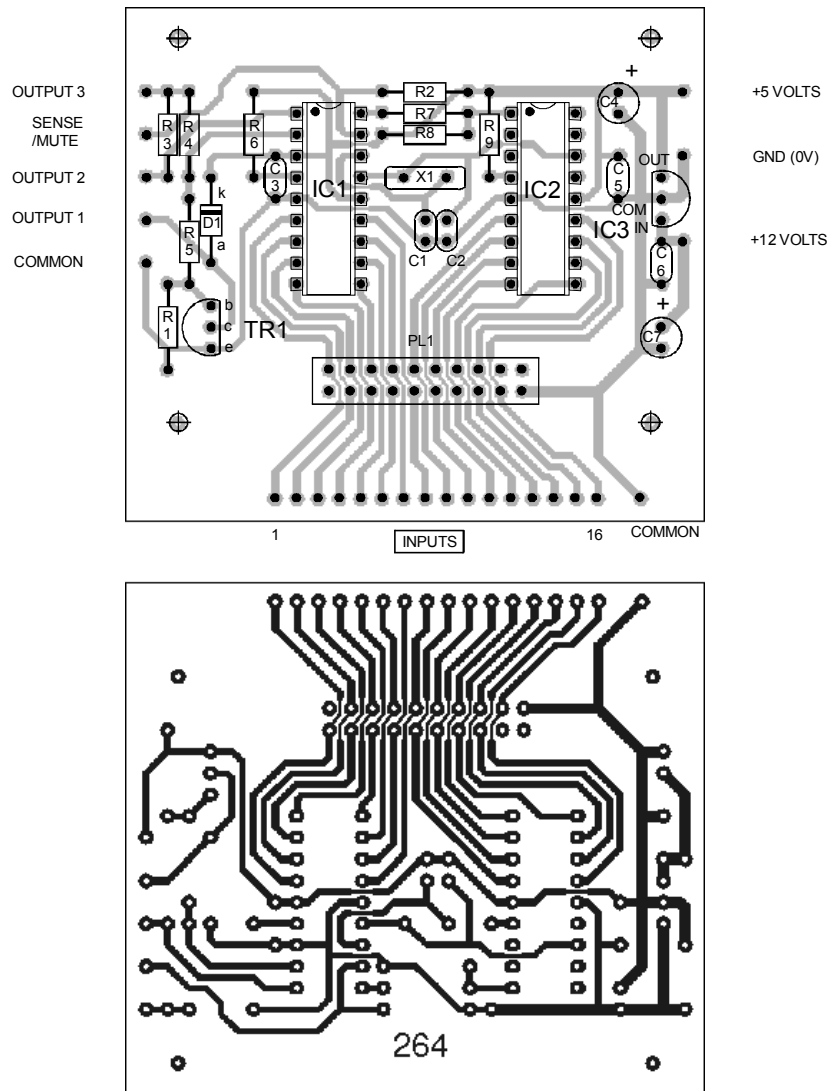


Fig.10. Printed circuit board topside component layout and (approximately) full-size under-side copper foil master pattern for the Transmitter.

simply repeated the appropriate number of times in preference to using loop techniques. This tends to improve reliability and is easy to follow, even though it is more tedious to write.

## TRANSMITTER CIRCUIT

As with many PIC projects, the circuits are relatively simple as so much of the work is done by the software. The only complexity is in the Transmitter

where the various methods of use make some of the components optional.

These options will be explained in more detail next month. For now the simplest method will be described so that construction and testing can be carried out.

The full circuit diagram of the Transmitter is shown in Fig.7. The two 16F84 PICs, IC1 and IC2, share a common clock using the oscillator of IC1 with a



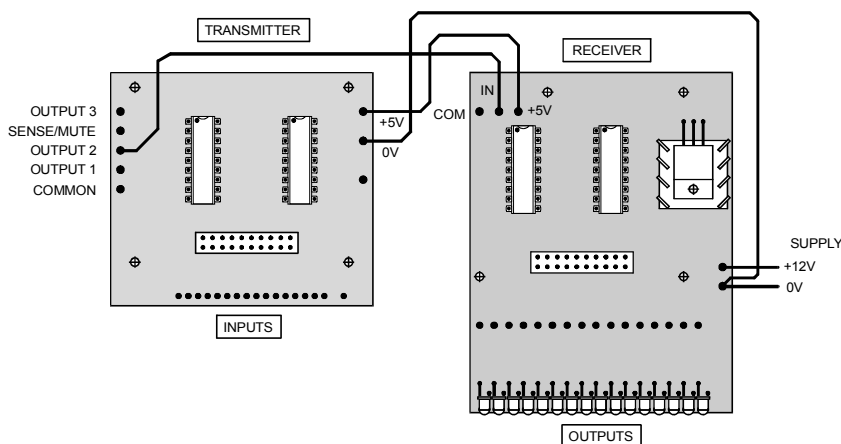


Fig.11. Test set-up for checking out the two PCBs.

4MHz crystal X1 and capacitors C1 and C2.

Both IC1 and IC2 have all eight inputs of port B pulled high internally so these are simply brought out to pins to which external connections can be made. The communication between them is through resistor R7 with pull-up resistor R8. A digital output is taken from IC1 port A bit 2 (at pin 1), which is normally high and goes low for clock and data pulses.

The sensing and muting function, only required for synchronized bi-directional use, is performed with port A bit 1 (at pin 18) and operates as follows. When used in this way the signal is coupled to the local receiver through a 10k resistor, and the sense/mute pin is also connected to the receiver side of this resistor.

Initially it is an input, and listens for a continuous "high" signal to confirm that the other transmitter is not sending. Once this is detected it is converted to an output and set high for the duration of transmission, so the local receiver effectively sees a continuous inactive line. Where this facility is not required, resistor R2 holds this pin high so that transmission will take place anyway.

Other optional bits are resistors R3 and R4 which are only required if the unit is used with the Interface circuit to be described next month, and resistors R1, R5, transistor TR1 and diode D1, are needed if it is to be powered through a 2-wire connection from the distant Receiver. The principle here is that one of the two wires is a common ground (0V), or negative, whilst the other is energized from +5V through a 220 ohm resistor (an option in the Receiver) and charges capacitor C4 via diode D1 whilst the line is high. Then C4 supplies the circuit whilst the line is pulled low for pulses by transistor TR1.

Finally, there is an optional on-board 5V supply regulator, IC3. In most cases the Transmitter will be supplied with +5V from a Receiver, either local for a bi-directional system or remote. However, if an application requires that it should be self-powered for any reason, regulator IC3 can be fitted together with input decoupling capacitors C6 and C7. In most cases these three components will not be needed. Also, of course, where only eight channels are needed IC2 may be omitted.

## RECEIVER CIRCUIT

The Receiver circuit diagram shown in Fig.8 is even simpler. As with the Transmitter, the two PIC16F84s, IC1 and IC2, share a common 4MHz crystal clock. However, there is no communication between them. Instead the input signal is connected to RA2 (at pin 1) of both PICs. Each of the sixteen outputs is provided with a resistor supplying a LED (light-emitting diode). These can be omitted if not required although they are useful when testing. For clarity only one resistor and one LED are shown for each IC in Fig.8, since the others are identical. The supply regulator IC3 is a robust 1A type mounted on a small heatsink as it has to supply the LEDs and probably also some output circuits and a Transmitter. The only optional component is resistor R10 which is needed if 2-wire operation with the Transmitter powered from the line is intended.

## CONSTRUCTION

Construction of this project is straightforward. The Transmitter and Receiver circuits, that make up the Multi-channel Transmission System, are both built up on single-sided printed circuit boards (PCBs). These boards are available from the *EPE Online Store* (codes 7000264 (Transmitter) and 7000265 (Receiver)). The Interface PCB (next month) is also available (code 7000266), all from the *EPE Online Store* at [www.epemag.com](http://www.epemag.com)

Starting with the Receiver, all the components except resistor R10, just above IC1, should be fitted as shown in Fig.9. The use of DIL sockets is recommended for the two PICs, IC1 and IC2.

Solder pins are suggested for the external connections, as these will then be more robust and can be made from the component side of the board. A degree of force is sometimes required to insert such pins so it may be best to fit them first.

The LEDs, which should be 2mA types, and their associated resistors are optional. Where fitted it is not too difficult to bend their leads in the required manner, and a little "Blu-Tack" or "Play-Do" may be helpful for holding them in position during soldering.

Not mentioned so far is the plug PL1. A requirement for the original application was a means of rapid connection and removal for testing and service purposes so 20-way IDC header plugs were included in the design. These are retained in this project but can be omitted if not required.

The two PICs should not be inserted yet. An initial test is to supply the completed Receiver board with +9V to +12V which should result in a supply current of about 4.8mA whilst the regulated output of +5V should be available from the solder pin, marked +5V, just above IC1.

### TRANSMITTER

If the above test is satisfactory construction can continue with the Transmitter PCB, the component layout, together with an approximately full-size copper foil master, is shown in Fig.10. All the optional components should be omitted at this stage and the two PICs should not be inserted.

Once the board has been completed, it is worth checking initially by powering it with a 5V supply taken from the Receiver. It should draw virtually no

current at all since the only components bridging the supply are the three decoupling capacitors. However, short circuits do occasionally occur in construction and electrolytic capacitors have been known to be fitted the wrong way round!

### TESTING

If all seems well IC1, programmed with TXIC1\_5 (5ms delay) or TXIC1\_10 (10ms delay) software, can be inserted. This should raise the supply current to about 2mA and the average voltage measured with a meter at Output 2 should be about 4V, indicating that IC1 is operating and transmitting an appropriate pulse sequence.

Next, a PIC programmed with receiver RX software should be inserted into the Receiver board at IC1 position and a connection made from Output 2 of the Transmitter to "IN" of the Receiver as shown in Fig.11. Connecting any of the first eight inputs (1 to 8) to ground (0V) should now illuminate the corresponding output LEDs on the Receiver or take the appropriate outputs high if the LEDs are not fitted.

Finally, if all sixteen channels are required, a second PIC with RX software can be fitted to the Receiver and one with TXIC2 software to the transmitter, after which the remaining eight channels (9 to 16) can be tested. The two boards are now operational and ready for use.

### RESOURCES

Software for the *Multi-Channel Transmission System Transmitter* and *Receiver* modules is available for free download from the *EPE Online Library* at [www.epemag.com](http://www.epemag.com)

Ready-programmed PICs are also available and full details, including the above options, can be found in the **Shoptalk** page in this issue.

**Next Month:** Details of the various ways in which these units can be used will be given, together with the construction of an Interface board for use with internal telephone circuits or similar long lines. This is effective in reducing or eliminating the radiated interference sometimes caused by high-level digital signals in transmission circuits.

# Constructional Project

## **PIR LIGHT CHECKER**

by **TERRY DE VAUX-BALBIRNIE**

### ***Be trigger happy with your outdoor security light system***

Passive infrared (PIR) lamps, of the type that may be bought in any DIY store, are now very popular with householders. Mounted on an outside wall, they may be used to improve security or simply to illuminate dark areas when a member of the family passes by.

### **JUST PASSING THROUGH**

These lamps are designed to switch on for a certain time when someone walks in the detection field. This extends fan-shaped from a "window" in the front of the detector. In simple units, the operating time is fixed at manufacture. However, it is more usual to provide a control, which may be used to adjust it over a

certain range.

Normally, the lamps operate only when the ambient light falls below a certain level so that they will not switch on during daylight hours. Again, the point at which this happens is often adjustable using a control on the unit.

The working part of a PIR lamp is a sensor, which detects the infrared radiation that is naturally emitted by a warm body. The detector may be contained in a separate unit connected remotely to the lamp. In most DIY units, however, it is attached to the lamp itself because this makes for simpler installation.

When a warm object moves in the sensitive zone, a signal is given which, after processing, operates a relay and switches

on a filament bulb. In the larger security-type lamp, the bulb will be a halogen unit of some 150W to 500W rating. Smaller PIR lamps use an ordinary 60W household bulb.

### **BLOWING IN THE WIND**

When the PIR unit is properly installed, the lamp does its job well and rarely causes problems. However, when it is not properly set up it may be activated by animals such as dogs and cats passing by.

Any warm object moving in (and especially across) the detection field is likely to cause the unit to trigger – even warm air from a nearby central heating flue. Tree branches and other objects moving in the wind sometimes activate it – presumably because they reflect infrared from somewhere else.

Any cause of false triggering may be difficult to track down. It can occur even when the user has taken every precaution detailed in the installation guide. After supposedly "correct" setting-up, there is often a tendency towards occasional false triggering. This will require further adjustment on a "trial and error" basis to eliminate it completely.

Most PIR lamps have a "test" facility, which enables them to operate in daylight and this helps with the initial adjustment process. However, it will miss any false triggering



which happens only occasionally. There could be considerable difficulty when the lamp is mounted in a position that cannot be seen from the house.

Normally, the only way to check for correct operation would be to stand outside and watch it for a long period of time! Unnecessary operation of the lamp can be a nuisance to neighbors as well as wasting electricity and reducing the life of the bulb. With this *PIR Light Checker*, however, you can leave the monitoring to automatic electronics!

## CLOCKED

This self-contained battery-operated unit will automatically monitor

a PIR lamp over a period of several hours overnight. A LED (light-emitting diode) display registers the number of times it has been triggered, up to nine. If the count exceeds this, the display will return to zero but the decimal point will light up. This shows the "overflow" – that is, a number greater than nine. When the unit is switched off then on again, the count is reset to zero, ready for a further test.

By adjusting the aim and sensitivity control on the lamp (if one exists), re-siting and cutting away foliage as necessary, any improvement can be easily monitored. Multiple causes of false triggering may then be eliminated one by one over a period of a few days. Note that if the unit is used to monitor the lamp overnight, it will record an extra count at dawn and this will need to be subtracted from the total.

This circuit is only suitable for use at

## COMPONENTS

### Resistors

R1	56k
R2	sub-miniature light-dependent resistor (LDR), dark resistance 5M ohms approximately (see text)
R3, R4	470k (2 off)
R5	3M3
R6, R7, R9 to R11	1M (5 off)
R8, R19	2M2 (2 off)
R12 to R18, R20	270 ohms (8 off)

All 0.25W 5% carbon film

### Potentiometer

VR1	2M2 miniature enclosed carbon preset, horizontal
-----	--------------------------------------------------

### Capacitors

C1	47nF metallised polyester, 2.5mm pitch
C2	100nF metallised polyester, 2.5mm pitch
C3, C4, C6, C7	100nF metallised polyester, 5mm pitch (4 off)
C5	1uF radial electrolytic, 63V
C8	220uF radial electrolytic, 10V

### Semiconductors

D1	1N4001 1A 50V rectifier diode
TR1	2N3903 npn transistor
IC1	ICL7611 micropower opamp
IC2	ICM75561PD dual CMOS timer
IC3	40110B decade up/down counter

### Miscellaneous

X1	7-segment, common cathode LED display, 12.7mm
S1	miniature s.p.s.t. push-to-make or biased toggle switch
S2	miniature s.p.s.t. toggle switch

PCB available from the *EPE Online Store*, code 7000263 ([www.epemag.com](http://www.epemag.com)); 8-pin DIL socket; 14-pin DIL socket; 16-pin DIL socket; 1.5V AA-size alkaline cell (4 off) and holder; plastic case, size 138mm x 76mm x 38mm internal; PCB supports (2 off); connecting wire; solder, etc.

See also the  
SHOP TALK Page!

Approx. Cost

Guidance Only (excl. battery pack)

\$32

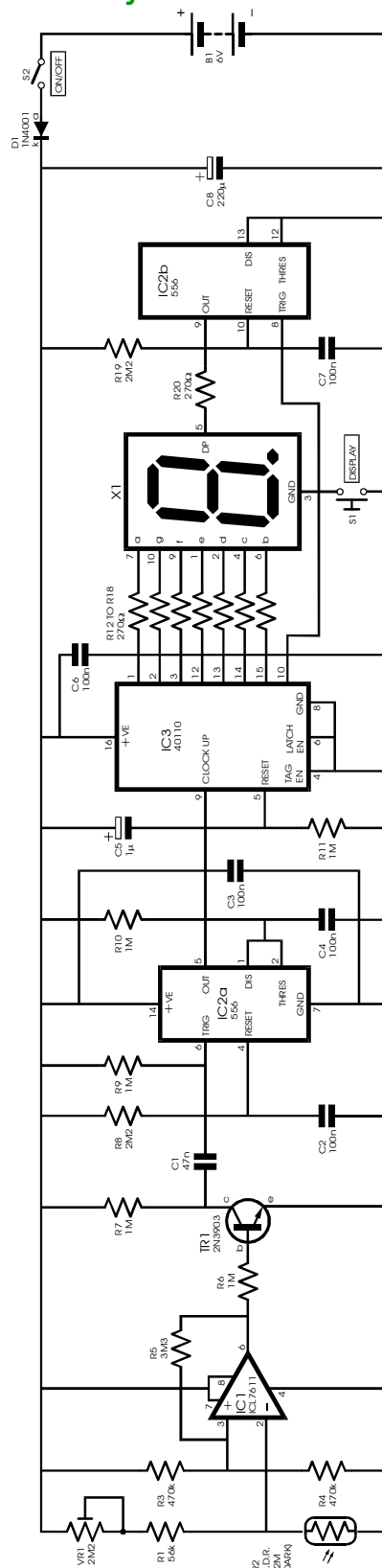


Fig.1. Complete circuit diagram for the PIR Light



night with the PIR lamp in "normal" mode. There must be no other bright sources of light nearby which could result in false counts.

## BATTERY SAVING

The circuit is housed in a small plastic box. This has a seven-segment LED display showing through a hole in the lid. There are also two switches (see photograph). One of these is simply an on-off switch while the other activates the display. This latter switch is operated only when a reading needs to be taken and so saves battery power. A hole in the side of the box allows light from the lamp being monitored to reach a sensor on the printed circuit board (PCB) inside.

The unit draws power from a 6V battery pack consisting of four AA-size alkaline cells. Under standby conditions, the current requirement of the prototype unit is some 400uA.

When the display is operated, the current rises to a value that depends on the number being displayed. This is because each digit is formed by lighting up the appropriate segments in the display. The most current-hungry case is when the number "8" is involved (since this uses all seven segments) together with the "over-flow" decimal point.

Since each segment and the decimal point require 12mA approximately, the total current will be about 100mA. However, this will only be needed for a few seconds during each test and, as stated earlier, it is the "worst" case. In practice, the battery pack should last for at least a year under normal conditions.

## HOW IT WORKS

The full circuit diagram for the *PIR Light Checker* is shown in Fig.1. Power is derived from a 6V battery pack (4 x 1.5V cell) B1 via on-off switch S2 and diode D1. The diode prevents possible damage if the supply were to be connected in the opposite sense. If this were done, the diode would be reverse-biased so no current would flow.

It will be found that the actual nominal supply voltage is 5.3V taking into account the forward voltage drop of the diode (0.7V approximately). Capacitor C8 charges up almost instantly and helps to provide a smooth and stable supply.

The light-sensing section of the circuit is centered on IC1 and associated components. The light detector itself is a light-dependent resistor (LDR), R2. The resistance of this device rises as the illumination of its sensitive surface falls.

The LDR works in conjunction with fixed resistor R1 and preset potentiometer VR1 to form a potential divider connected across the supply. Thus, as the resistance of the LDR increases, the voltage across it will rise. This voltage will therefore be greater when the LDR is dark than when it is illuminated. The actual "dark" and "light" voltages can be varied within certain limits by adjusting VR1. The voltage appearing across the LDR is applied to the inverting input (pin 2) of operational amplifier (opamp) IC1. The non-inverting input (pin 3) is connected to the mid-point of a further potential divider consisting of fixed resistors R3 and R4. Since these have the same value, the voltage here will be equal to one-half that of the supply – that is, 2.6V approximately.

## A BIT DIM

With preset VR1 suitably adjusted, under dim conditions the voltage at the opamp inverting input will exceed that at the non-inverting one, so the device will be off with the output (pin 6) low. When the LDR is sufficiently illuminated, the conditions will reverse with the inverting input voltage falling below the non-inverting one. The opamp will then switch on and output pin 6 will go high. Resistor R5 applies some positive feedback to the system, which sharpens the switching action at the critical light level.

Transistor TR1 inverts the output state of the opamp. When the output is high, current flows into TR1 base (b) through current-limiting resistor R6. This switches the transistor on and its collector (c) goes low. When the opamp output is low, no current will enter the base and the transistor will remain off. The collector will then take on a high logic state via load resistor R7. The state of the collector is therefore in the opposite sense to that of the opamp output.

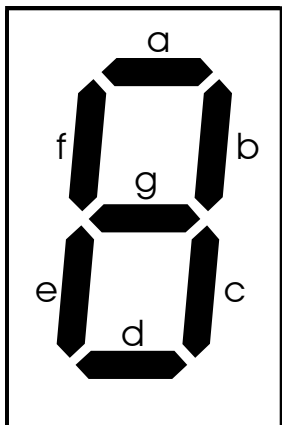
## MONOSTABLE

Transistor TR1's collector is connected to the trigger input (pin 6) of a monostable based on IC2a, which is one half of dual integrated circuit timer, IC2.

When TR1 collector goes from high to low (that is, the LDR is illuminated), the trigger input receives a low pulse through capacitor C1. The monostable output (pin 5) then goes high for a time dependent on the values of resistor R10 and capacitor C4. With the values specified, the timed period is 0.1s, approximately.

While the opamp output





*Fig.2. The seven segments of the display are identified by letters (a to g)*

remains low (the LDR dimly illuminated), the high state of TR1's collector has no effect. In fact, in the absence of a low pulse, IC2a trigger input is kept high through resistor R9 and this prevents possible false triggering. Capacitor C3 decouples this section of the circuit.

At the instant of powering-up, capacitor C2 keeps IC2a reset input (pin 4) low and this disables the monostable. The capacitor soon charges up through resistor R8, pin 4 goes high and the monostable then functions normally. The purpose of this is to allow time for the power supply to settle down to a steady state since, otherwise, the monostable could self-trigger and a false count would be registered.

### COUNTING PULSES

When the monostable outputs a pulse, this is transferred to the "clock up" input (pin 9) of counter and 7-segment driver IC3. This registers the number of pulses received and decodes the result into a form which will directly drive the 7-segment LED display X1.

The seven segments of the LED display are identified by letters **a** to **g** as shown in Fig.2. Note that the unit used in this circuit is a common cathode type. In this, all the LED cathodes (including that of the decimal point) are connected together and taken to pin 3 (GND).

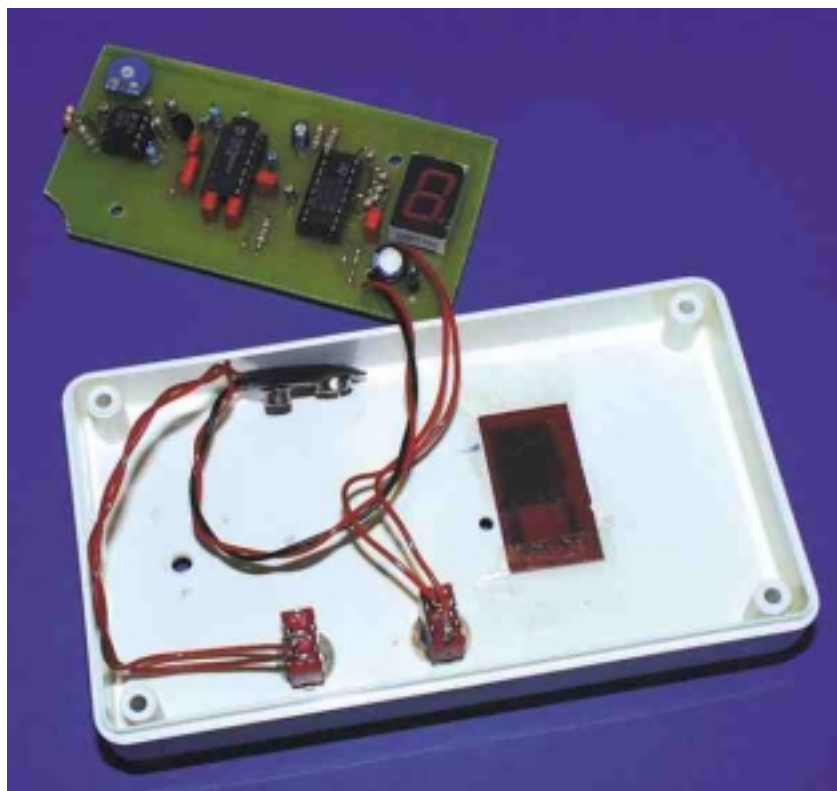
Each segment requires a current-limiting resistor (R12 to R18) as with a conventional LED. With the value specified, each one will draw 12mA approximately when using a new battery.

The display, however, will do nothing until push-to-make "Display" switch S1 is operated. This allows current to flow through any active segments and complete the circuit via pin 3 to the 0V line. With S1 in the

off state, no current is drawn by the display.

At the instant of switching on, IC3's reset input (pin 5) is maintained in a high state while capacitor C5 charges up through R11. During this time, the counter is reset so the display will always begin at zero. After a short time, C5 will charge sufficiently, pin 5 will go low and the counter will function normally. Capacitor C6 decouples this section of the circuit.

When the count passes from 9 to 0, IC3's carry output, pin 10, goes low momentarily. This would normally be used to feed the clock input of a second counter/driver IC and a further display would provide a readout up to 99.

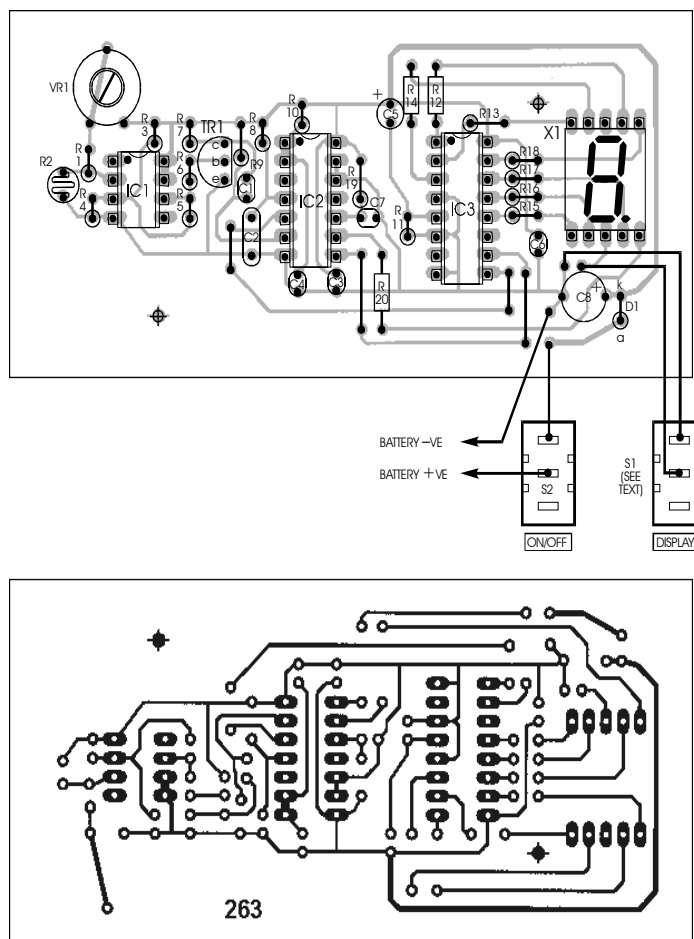


*The PCB removed from the case lid to show wiring to the display and on/off toggle switches. The display switch needs to be a "biased" off type. Note the 7-segment display chip must be the highest component on the PCB.*



*Close-up of circuit board showing the leads of the LDR carefully bent at right-angles to the PCB to align with "light window" in side of case.*

To save costs only one counter and display are used in this circuit. However, the low pulse provides the "overflow" indication by operating the decimal point. This uses IC2b (the second section of dual timer IC2). It is configured as a form of latch by making the threshold and discharge inputs (pin 12 and pin 13) low. Thus, once triggered by making pin 8 low for an instant, the output (pin 9) will go high and remain high until the supply is interrupted. The output feeds the decimal point via current-limiting resistor R20.



*Fig.3. Printed circuit board component layout, (approximately) full-size underside copper foil master pattern, and wiring to the two off-board switches.*

## CONSTRUCTION

The *PIR Light Checker* circuit is built on a single-sided printed circuit board (PCB). The topside component layout and (approximately) full-size underside copper foil master pattern are shown in Fig.3. This board is available from the *EPE Online Store* (code 7000263) [www.epemag.com](http://www.epemag.com)

In the prototype, one corner of the PCB had to be cut off to avoid a bush in the box, see photograph. Begin construction by drilling the two fixing holes and soldering the three IC sockets and four link wires into place.

Omit display X1 for the moment. Note that it must end up as the highest component on the PCB. Checks should be made at intervals during the other assembly by inserting it into its holes in the PCB (but do not solder it yet).

Follow with all resistors (including preset VR1 but not LDR R2). Note that many of the resistors are mounted vertically (see photo).

Solder electrolytic capacitors C5 and C8 in position taking care over their polarity. If they are not of the sub-miniature type, it may be necessary to

mount them flat on the PCB so that they will not be higher than the display.

Cut the LDR leads to a length of about 10mm and solder them to the R2 position on the PCB. Bend them through right-angles so that the "window" points to the left. Note that the specified LDR is a sub-miniature type having a body diameter of 5mm approximately. If one of these is not readily available, it would be possible to use a standard ORP12 device, but some adjustment may be needed to the end leads to prevent the body getting in the



*Layout of components on the completed circuit board.  
Note, one corner of the board has been trimmed off so it will fit  
in the case.*

way of anything else.

Add the diode and transistor to the PCB, taking care over their orientation. The flat face of transistor TR1 should face to the right as viewed in Fig.3.

Solder the display to the PCB (with the decimal point at bottom right, as shown in the photo) using minimum heat from the soldering iron to prevent possible damage.

Solder 10cm pieces of light-duty stranded connecting wire to the points labeled +6V and S1. Solder the negative (black) battery connector lead to the 0V point. Adjust VR1 to approximately mid-track position.

### TESTING

Immediately before handling the pins of IC1, IC2 and IC3, touch something which is "earthed" (such as a metal water tap). This will remove any static charge, which may be present on the body. Insert the ICs in their sockets with the correct orientation.

Before mounting the PCB in its case, perform a basic check so that any minor problems may

be resolved more easily.

To do this, bare the end few millimeters of the wires for display switch S1 and connect them together. Similarly, bare the end of the +6V wire. Insert the cells for battery B1 into their holder and apply the connector. Twist the battery connector positive (red) wire to the +6V wire from the PCB.

The display should light up and read zero. The decimal

point should also be off. If it shows some other number, or the decimal point is on, the connection was probably not done "cleanly", so disconnect the battery, wait for 30 seconds and try again!

Cover the LDR with the hand then remove it to allow light to reach its window. The display should advance to a count of 1. If this does not work, it is likely that the LDR has not been properly covered. Try working in a dark cupboard and open the door slightly to give the flash of light. If this still does not work, re-adjust preset VR1 and try again.

By allowing repeated flashes of light to reach the LDR, the counter should increment to 9 and the next flash should return it to zero. However, the decimal point should now be seen to be lit up. If you wish to reset the display, you will need to wait for up to thirty seconds between disconnecting the battery and re-connecting it again.



*Completed PIR Light Checker front panel layout.  
The display cutout has been backed with a piece of translucent  
filter material.*



### ENCLOSURE

If all is well, the PCB may now be mounted in the box. Note that when using the specified unit, everything may be attached to the lid section. This method places least strain on the battery connecting wires.

First, disconnect the positive supply wire and detach the battery connector. Decide on positions for the PCB, battery pack and switches, checking that there is sufficient space for everything to fit. Arrange for the LDR to lie between 5mm and 10mm from the side of the box.

In the prototype, a miniature toggle switch with “make” contacts was used for the on-off switch and a matching biased toggle switch was used for the display. A biased switch is one that springs back to the off position when pressure is removed from the actuating lever. It is best to use either a biased toggle switch or a push-to-make switch to activate the display so that it cannot be left on accidentally.

Mark through the PCB fixing holes. Measure the position of the display and mark around its outline. Mark also the position directly in line with the LDR

window and VR1 on the top. Mark the position of the switches. Remove the PCB and drill all these holes.

The hole for the LDR should have a diameter of approximately 4mm (about twice as large if the ORP12 type LDR is used). The hole above the preset VR1 position should be large enough to allow it to be adjusted using a thin screwdriver or trimming tool.

The easiest way to make the hole for the display is to drill small holes within its outline then remove the plastic using a small hacksaw blade, or sharp chisel. Finally, smooth the edges up to the line using a small file.

Attach the PCB temporarily using nylon fixings and with short plastic stand-off insulators on the bolt shanks. Adjust the length of the stand-off insulators so that the display will end up 1mm approximately below the inside face of the box. When satisfied, re-attach the PCB.

Check that the LDR window lies directly in line with the hole drilled for it. If not, adjust the position of its end leads so that it is. Attach the switches. Secure the battery pack using a small bracket or adhesive pads. Refer to Fig.3 and complete the

internal wiring.

In the prototype, a piece of red plastic filter was glued over the display hole on the inside of the box. This gives a professional appearance and also improves the contrast of the display. If a piece of real filter is not available, perhaps suitable material could be obtained from a sweet wrapper or something similar.

### INTO SERVICE

With switch S2 off, connect the battery and attach the lid. Find a suitable place for the unit so that light from the PIR lamp will reach the LDR directly through the hole in the side of the box. The fact that the LDR is some distance behind the hole makes the response directional. This is useful because it tends to discriminate against other sources of light, which could result in false counting.

Make some tests at night. For initial trials, you may find it helpful to use an elastic band or PVC tape to hold the display switch (S1) on, so that the count may be observed over a period of time. Remember that this wastes the batteries so don't do it for too long.

Adjust preset VR1 for best effect. Remember to protect the unit against rain entering if this is a possibility.

No more disturbed neighbors with this “Trigger Happy” circuit!

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By Alan Winstanley

### GOOGLE BOX

Eagle-eyed readers will have noticed that I recently placed a Google search engine in the 100 percent revalidated **Net Work A-Z** page on our web site, which contains many of the existing links I have highlighted in the past. Google is hugely fast and easy to use. Instead of trying to index every known web site, Google actually indexes on the basis of all the other links made to those same web sites. The search engine makes the reasonable assumption that the better a web site is, the greater the number of links pointing to that site. More importantly, Google keeps a cache of stored web pages, so that even if a web site is taken down there is still a possibility that you can retrieve the content from Google's cache. Give it a try.

In March 2000 Net Work I outlined the evolution of Alta Vista, Digital Equipment's leading search engine and portal site which was acquired by computer manufacturer Compaq in early 1998. There is no doubt that Alta Vista is a first-rate search engine, offering further options to non-English users courtesy of its Babel Fish language translator. Alta Vista continues to roll out across Europe, starting out in Germany almost a year ago, followed by Sweden and more recently the UK in December 1999. The Californian-based company then launched into France and the Netherlands last month.

### FREE FOR ALL

In early March Alta Vista UK took the wind out of the sails of cable operator NTL ([www.askntl.com](http://www.askntl.com)) as well as British Telecom, by announcing its new free Internet access service for UK users. In fact it isn't entirely free – there will be a one-off set-up charge of anything up to 50 UK pounds being reported, and an annual cost of say 20 UK pounds. The new service, to be called AltaVista0800, will be rolled out at a rate of 90,000 users per month starting in June 2000.

In the USA and Canada, a service called AltaVista Free Access has been available since August 1999 (see [www.microav.com](http://www.microav.com)), offering completely free Internet access to its users. There are no set-up or subscription charges at all. Instead, AltaVista Free Access employs a "Micro Portal" – a window on the user's computer screen which contains rotating adverts and other customizable content. The technology behind this is provided by **1stUp.com**, a US developer specializing in advert-supported dial-up accounts. The advertising window must always remain open to enjoy free Internet access, which is a powerful incentive for many consumers already conditioned to banner adverts to remain loyal.

In the UK, by using an 0800 access number, subscribers are relieved of the worry of the cost

of the phone call, though obviously they still have to pay line rental charges. Alta Vista UK's new service will not allow a permanent 24 x 7 connection to the Internet, because it will time out after five minutes of inactivity. Furthermore, any attempt to "ping" an open connection with a keep-alive utility such as WakeUp will be treated as an abuse, presumably leading to withdrawal of the service.

### UNDER THE SURF

The new service announced by Alta Vista UK wrong-footed British Telecom into declaring its own revised plan for un-metered access. BT previously suggested its SurfTime package (see Net Work Feb '00) could cost anything up to 35 UK pounds a month for always-on access. I showed how this was five times more than a user in Dallas, Texas who pays just \$12 (7 UK pounds a month) after loyalty discounts, with local Internet and voice calls thrown in for free.

In light of Alta Vista UK's new 0800 package, BT was forced into firming up its own position. They make much of the fact that their SurfTime option will be available to businesses as well as home users, and they are attempting to cater for users' differing habits, given that many users are obviously at work during the day and only access the Internet during evenings and weekends. The cheapest option



that BT now proposes is for occasional users, paying 1 pence per minute daytimes, 0.6 pence evenings and 0.5 pence weekends, on top of line rental at 9.26 UK pounds per month.

As usual, BT's press release is not entirely straightforward, partly because they hint at an all-inclusive cost for Internet access by bundling in rental figures plus an estimate of monthly ISP charges. For a service fee of 5.99 UK pounds a month excluding rental, BT customers can choose the evening and weekend package which allows for un-metered access plus up to 80 minutes' voice calls. BT's always-on package is likely to cost 19.99 UK pounds per month plus rental for home users and 29.74 UK pounds excluding VAT (including rental) for business users.

Realizing that the rates will be scrutinized by an increasingly impatient audience, BT has gone to extraordinary lengths to emphasize how competitive they say their dial-up Internet packages are in comparison with similar ones in the USA.

The rates won't be available to end-users until June 2000, and there is a further complication: BT SurfTime will require users to access their preferred ISP by using an 0844 04 number. If your preferred ISP doesn't offer one, then you can't use the SurfTime package. More problems in store include the fact that no wholesale pricing had been offered, therefore no other service provider (e.g. Freeserve)

would be able to compete by reselling BT SurfTime.

As if BT's convoluted phone tariffs aren't enough, don't forget the offerings over at BT Internet ([www.btinternet.com](http://www.btinternet.com)), the telco's Internet Service Provider arm. Un-metered 0800 evening and weekend access is now available at a new lower rate of 9.99 UK pounds a month or 109.98 UK pounds a year, and as a sign of their eagerness to help novices getting to grips with the Internet, BT have actually **increased** the cost of support calls to 50 pence a minute up from local rate.

## LOOKING AHEAD

The UK Internet market remains as volatile as ever, and further sweeping changes are probable over the next 12 to 18 months before the market finally settles down. For Freeserve, the 18-month old pioneer of the free ISP model, interesting times are ahead. As with all free ISPs, Freeserve makes its revenue from that all-important slice of the cost of the BT 0845 phone call, plus advertising and the cost of providing technical support.

Consumers tend not to have much loyalty towards their ISP and if they suddenly decide to jump ship from the free ISPs and move to a service such as AltaVista0800, preferring to pay an annual fee for free unlimited calls, this is bound to have a profound impact on Freeserve which charges nothing as an

ISP but makes you pay for the calls instead. It is hard to know what will happen to those free ISPs that also bundle your domain name and technical support in with the deal.

It is not as though any of these free ISPs can levy even a small monthly fee, as they don't have any billing mechanism in place. Freeserve's latest move involves offering free Internet access, provided customers make 10 UK pounds of calls per month routed through Energis, its parent telco. However, BT is now spending the intervening months rolling out the interconnect components, and ISPs which adopt the 0844 SurfTime tariff are expected to be able to charge their subscription fees to their customer using the user's BT phone bill. When there are new offers springing up all the time, it makes sense not to commit to a long-term agreement until all the players have made their moves.

You can E-mail me at [alan@epemag.demon.co.uk](mailto:alan@epemag.demon.co.uk). My web site is at <http://home-pages.tcp.co.uk/~alanwin>

# Special Feature

## Part 4 – COMPUTERS 1900-1999

by Clive “Max” Maxfield and Alvin Brown

***Boldly going behind the beyond, behind which no one has boldly gone behind, beyond, before!***

The purpose of this series is to review how we came to be where we are today (technology-wise), and where we look like ending up tomorrow. In Part 1 we cast our gaze into the depths of time to consider the state-of-the-art in electronics, communications, and computing leading up to 11:59pm on 31 December 1899, as the world was poised to enter the 20th Century.

Parts 2 and 3 covered fundamental electronics and communications in the 20th Century, respectively. Now, in Part 4 we consider some of the key discoveries in computing that occurred during the 20th Century. These developments have set the scene for what is to come as we plunge forth into the third millennium. But before we start, let's first consider logic diagrams and logic machines, which usually receive little mention ...

### LOGIC AND LOGIC DIAGRAMS

With the exception of Charles Babbage's proposal for a mechanical computer called the *Analytical Engine* in 1832, very little thought was given to computing prior to 1900. Instead, effort was focused on simple mechanical calculators, and also on variations of another mechanism put forward in 1882

by Babbage called a *Difference Engine*, which could be used to generate certain mathematical tables.

However, this is not to say that nothing of interest (computing-wise) was taking place, because there were a number of developments that would prove to be extremely interesting to computer scientists in the 20th Century.

First of all, the self-taught British mathematician George Boole published two key papers in 1847 and 1854. These papers described how logical expressions could be represented in a mathematical form that is now known as Boolean Algebra. What Boole was trying to do was to create a mathematical technique that could be used to represent and rigorously test logical and philosophical arguments.

We can only imagine what Boole would have thought had he realized that his new mathematics would find application in designing digital computers 100 years in his future. But we digress ...

### LOGIC WONDERLAND

In 1881, a lecturer in logic and ethics at John Hopkins

University called Allan Marquand invented a graphical technique of representing logical problems using squares and rectangles. Marquand's efforts set a number of people to pondering, including the Reverend Charles Lutwidge Dodgson, who published his own diagrammatic technique in a book called *The Game of Logic* in 1886. (The Reverend is better known to most of us as Lewis Carroll, the author of *Alice's Adventures in Wonderland*.)

In the early 1890s, yet another approach was put forward by the English logician John Venn, who was extremely impressed by Boole's work. Unlike earlier graphical techniques, Venn's diagrams were based on the use of circles and ellipses, which could be employed to represent Boolean equations.

The rectangles and squares of Marquand and Carroll eventually led to Maurice Karnaugh inventing a graphical technique for both representing and minimizing Boolean expressions in the 1950s. These techniques were to become tremendously useful to designers of digital logic, and Karnaugh maps and Venn Diagrams are both still taught and used to this day.

### LOGIC MACHINES

In addition to speculating about logic, it should come as



*Stanhope Square Demonstrator, late 18th century. Courtesy Science Museum/ Science and Society Picture Library.*

no surprise to learn that people have been experimenting with so-called “logic machines” for quite some time. Perhaps the earliest example is a set of concentric, nested discs revolving around a central axis as proposed by the Spanish theologian Ramon Lull in 1274. Each disc contained a number of different words or symbols, which could be combined in different ways by rotating the disks.

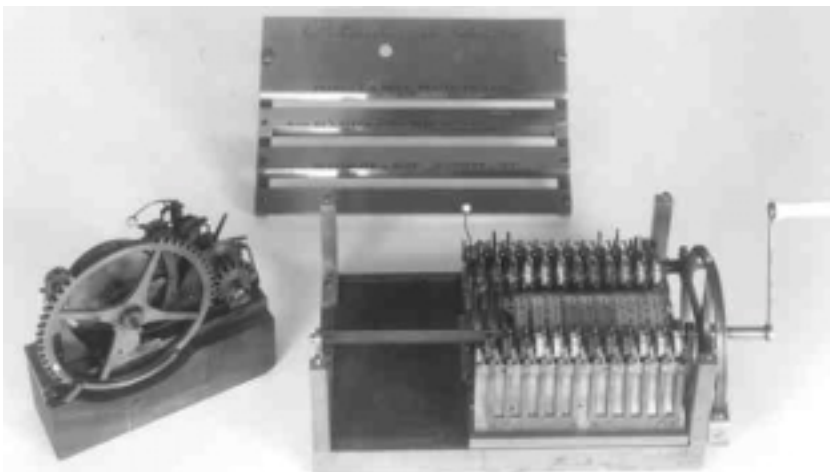
Lull’s disks were followed by a variety of other techniques over the centuries, most of which we would now consider to

be “half-baked” on a good day.

The world’s first real logic machine (that is, one that could actually be used to solve simple logic problems, as opposed to Lull’s which tended to create more problems than it solved) was invented in the late 1700s by the British scientist and statesman Charles Stanhope (third Earl of Stanhope).

This device, the *Stanhope Demonstrator*, was a small box with a window in the top, along with two different colored slides that the user pushed into slots in the sides. Although this doesn’t sound like much it was a start, but Stanhope wouldn’t publish any details and instructed his friends not to say anything about what he was doing.

In fact, it wasn’t until around sixty years after his death that the Earl’s notes and one of his devices fell into the hands of the Reverend Robert Harley, who subsequently published an



*Stanhope’s calculating machine, 1777. Courtesy Science Museum/Science and Society Picture Library.*

## TIMELINES

- 1274:** Spain. Theologian Ramon Lull proposes a “logic machine” consisting of a set of concentric, nested disks.
- 1777:** Charles Stanhope invents a mechanical calculating machine.
- Late 1700s:** Charles Stanhope invents the Stanhope Demonstrator.
- 1822:** England. Charles Babbage starts to build a mechanical calculating machine – the Difference Engine.
- 1832:** England. Charles Babbage conceives the first mechanical computer – the Analytical Engine.
- 1847:** England. George Boole publishes his first ideas on symbolic logic.
- 1869:** William Stanley Jevons invents the Logic Piano.
- 1881:** Alan Marquand invents a graphical technique of representing logic problems.
- 1886:** Reverend Charles Lutwidge Dodgson (Lewis Carroll) publishes a diagrammatic technique for logic representation in *The Game of Logic*.
- 1890s:** John Venn proposes logic representations using circles and ellipses.
- 1925:** America. Scientist, engineer, and politician Vannevar Bush designs an analog computer called the Product Intergraph.
- 1930:** America. Vannevar Bush designs an analog computer called a Differential Analyzer.
- 1936:** America. Efficiency expert August Dvorak patents his layout for

article on the Stanhope Demonstrator in 1879.

Stanhope also invented a circular demonstrator and a mechanical calculating machine.

### LOGIC PIANOS

Working on a somewhat different approach was the British logician and economist William Stanley Jevons, who, in 1869, produced the earliest model of his famous *Jevons' Logic Machine*. This device is notable because it was the first machine that could solve a logical problem faster than that problem could be solved without using the machine!

Jevons was an aficionado of Boolean logic, and his solution was something of a cross between a logical abacus and a piano (in fact it was sometimes referred to as a "Logic Piano"). This device, which was about a meter (three feet) tall, consisted of keys, levers and pulleys, along with letters that could be either visible or hidden. When the operator pressed keys representing logical operations,

the appropriate letters appeared to reveal the result.

The next real advance in logic machines was made by Allan Marquand, whom we previously met in connection with his work on logic diagrams. In 1881, by means of the ingenious use of rods, levers, and springs, Marquand extended Jevons' work to produce the *Marquand Logic Machine*. Like Jevons' device, Marquand's machine could only handle four variables, but it was smaller and significantly more intuitive to use.

### ROCKET-POWERED FRISBEES

Things continued to develop apace. In 1936, the American psychologist Benjamin Burack from Chicago constructed what was probably the world's first electrical logic machine. Burack's device used light bulbs to display the logical relationships between a collection of switches, but for some reason he didn't publish anything about his work until 1949.

In fact, the connection between Boolean algebra and circuits based on switches had been recognized as early as 1886 by an educator called Charles Pierce. However, nothing substantial happened in this area until 1938, at which time the American engineer Claude E. Shannon

keys on a typewriter called the Dvorak Keyboard.

- 1936:** America. Psychologist Benjamin Burack constructs the first electrical logic machine (but he didn't publish anything about it until 1949).
- 1937:** America. George Robert Stibitz, a scientist at Bell Labs, builds a simple digital calculator machine based on relays called the Model K.
- 1937:** England. Graduate student Alan Turing (of Colossus fame) writes his ground-breaking paper: *On Computable Numbers with an Application to the Entscheidungsproblem*.
- 1937:** England. Alan Turing invents a theoretical (thought experiment) computer called the Turing Machine.
- 1938:** America. Claude E. Shannon publishes an article (based on his master's thesis at MIT) that showed how Boolean algebra could be used to design digital circuits.
- 1938:** Germany. Konrad Zuse finishes the construction of the first working mechanical digital computer (the Z1).
- 1939:** America. George Robert Stibitz builds a digital calculator called the Complex Number Calculator.
- 1939:** America. John Vincent Atanasoff (and Clifford Berry) may or may not have constructed the first truly electronic special-purpose digital computer called the ABC (but it did not work until 1942).



*Monroe's "Full Automatic" calculating machine, 1922, the first machine to offer fully automatic multiplication and division. Courtesy Science Museum/Science and Society Picture Library.*





*Hartree Differential Analyzer, 1935, based on that invented by Vannevar Bush. Courtesy Science Museum/Science and Society Picture Library.*

published an article based on his master's thesis at MIT.

Shannon's thesis has been described as: "*Possibly the most important Master's thesis of the twentieth century.*" In his paper, which was widely circulated, Shannon showed how Boole's concepts of TRUE and FALSE could be used to represent the functions of switches in electronic circuits. (Shannon is also credited with the invention of the rocket-powered Frisbee, and is famous for riding down the corridors at Bell Laboratories on a unicycle while simultaneously juggling four balls.)

Following Shannon's paper, a substantial amount of attention was focused on developing electronic logic machines. Unfortunately, interest in special-purpose logic machines waned in the 1940s with the advent of general-purpose computers, which proved to be much more powerful and for which programs could be written to handle formal logic.

## ELECTROMECHANICAL COMPUTERS

In 1927, with the assistance of two colleagues at MIT, the American scientist, engineer and politician Vannevar Bush designed an analog computer that could solve simple equations. This device, which Bush dubbed a *Product Intergraph*, was subsequently built by one of his students.

Bush continued to develop his ideas and, in 1930, built a bigger version, which he called a *Differential Analyzer*. The Differential Analyzer was based on the use of mechanical integrators that could be interconnected in any desired manner. To provide amplification, Bush employed torque amplifiers, which were based on the same principle as a ship's capstan. The final device used its integrators, torque amplifiers, drive belts, shafts, and gears to measure movements and distances (not dissimilar in concept to an automatic slide rule).

**1940:** America. George Robert Stibitz performs first example of remote computing between New York and New Hampshire.

**1941:** Germany. Konrad Zuse finishes the first true relay-based general-purpose digital computer (the Z3).

**1942:** Germany. Between 1942 and 1943 Konrad Zuse builds the Z1 and Z2 computers for the Henschel aircraft company.

**1942:** Germany. Between 1942 and 1945/6 Konrad Zuse develops the ideas for a high-level computer programming language called Plankalkul.

**1943:** England. Alan Turing and team build a special-purpose electronic (vacuum tube) computer called Colossus.

**1944:** America. Howard Aiken and team finish building an electromechanical computer called the Harvard Mark I (also known as the IBM ASCC).

**1945:** America. Hungarian/American mathematician Johann (John) Von Neumann publishes a paper entitled First Draft of a report on the EDVAC.

**1946:** America. John William Mauchly, J. Presper Eckert and team finish building a general-purpose electronic computer called ENIAC.

**1948:** America. Work starts on the first commercial computer, UNIVAC 1.

**1948:** America. First commercial computer, UNIVAC 1, is completed.

**1949:** England, Cambridge University. Small experimen-



*Harvard Mark I, the first large-scale automatic digital computer.  
Courtesy of IBM.*

Although Bush's first Differential Analyzer was driven by electric motors, its internal operations were purely mechanical. In 1935 Bush developed a second version, in which the gears were shifted electro-mechanically and which employed paper tapes to carry instructions and to set up the gears.

In our age, when computers can be constructed the size of postage stamps, it is difficult to visualize the scale of the problems that these early pioneers faced. To provide some sense of perspective, Bush's second Differential Analyzer weighed in at a whopping 100 tons! In addition to all of the mechanical elements, it contained 2000 vacuum tubes, thousands of relays, 150 motors, and approximately 200 miles of wire.

As well as being a major achievement in its own right, the Differential Analyzer was also significant because it focused attention on analogue computing techniques, and therefore detracted from the investigation and development of digital solutions for quite some time.

## FLASHLIGHT BULBS AND TIN CANS

However, not everyone was enamoured by analog computing. In 1937, George Robert Stibitz, a scientist at Bell Laboratories built a digital machine based on relays, flashlight bulbs and metal strips cut from tin-cans, which he called the *Model K* (because most of it was constructed on his kitchen table).

Stibitz's machine worked on the principle that if two relays were activated they caused a third relay to become active, where this third relay represented the sum of the operation. For example, if the two relays representing the numbers 3 and 6 were activated, this would activate another relay representing the number 9. (A replica of the Model K is on display at the Smithsonian.)

Stibitz went on to create a machine called the *Complex Number Calculator*, which, although not tremendously sophisticated by today's standards, was an important step along the way. In 1940, Stibitz performed a spectacular

tal computer called ED-SAC performs its first calculation.

**1949:** England. EDSAC computer uses first assembler called Initial Orders.

**1949:** America. MIT's first real-time computer, Whirlwind.

**1950:** America. Jay Forrester at MIT invents magnetic core store.

**1951:** America. Computers are sold commercially.

**1952:** America. John William Mauchly, J. Presper Eckert and team finish building a general-purpose (stored program) electronic computer called EDVAC.

**1956:** America. John Backus and team at IBM introduce the first widely used high-level computer language, FORTRAN.

**1956:** America. John McCarthy develops a computer language called LISP for artificial intelligence applications.

**1956:** America. MANIAC 1 is the first computer program to beat a human in a game (a simplified version of chess).

**1957:** America. IBM 610 Auto-Point computer is introduced.

**1958:** America. Computer data is transmitted over regular telephone circuits.

**1959:** America. COBOL computer language is introduced for business applications.

**1961:** Time-sharing computing is developed.

**1963:** In America, the LINC computer was designed at MIT.

demonstration at a meeting in New Hampshire.

Leaving his computer in New York City, he took a teleprinter to the meeting and proceeded to connect it to his computer via telephone. In the first example of remote computing, Stibitz astounded the attendees by allowing them to pose problems, which were entered on the teleprinter; within a short time the teleprinter presented the answers generated by the computer.

### HARVARD MARK I

Many consider that the modern computer era commenced with the first large-scale automatic digital computer, which was developed between 1939 and 1944. This device, the brainchild of a Harvard graduate, Howard H. Aiken, was officially known as the IBM automatic sequence controlled calculator (ASCC), but is more commonly referred to as the *Harvard Mark I*.

The Mark I was constructed out of switches, relays, rotating shafts, and clutches, and was described as sounding like a *"roomful of ladies knitting."* The machine contained more than 750,000 components, was 50 feet long, 8 feet tall (15.2m x 2.4m), and weighed approximately five tons (5080kg)!

Although the Mark I is considered to be the first digital computer, its architecture was significantly different from modern machines. The device consisted of many calculators, which worked on parts of the same problem under the guidance of a single control unit.

Instructions were read in on paper tape, data was provided separately on punched cards,

and the device could only perform operations in the sequence in which they were received. This machine was based on numbers that were 23 digits wide – it could add or subtract two of these numbers in three-tenths of a second, multiply them in four seconds, and divide them in ten seconds.

### KONRAD ZUSE

In the aftermath of World War II, it was discovered that a program controlled calculator called the Z3 had been completed in Germany in 1941, which means that the Z3 predated the Harvard Mark I. The Z3's architect was a German engineer called Konrad Zuse, who developed his first machine, the Z1, in his parents' living room in Berlin in 1938.

Although based on relays, the Z3 was very sophisticated for its time; for example, it utilized the binary number system and could handle floating-point arithmetic. (Zuse had considered employing vacuum tubes, but he decided to use relays because they were more readily available and also because he feared that tubes were unreliable).

In 1943, Zuse started work on a general-purpose relay computer called the Z4. Sadly, the original Z3 was destroyed by bombing in 1944 and therefore didn't survive the war (although a new Z3 was reconstructed in the 1960s). However, the Z4 did survive – in a cave in the Bavarian Alps – and by 1950 it was up and running in a Zurich bank.

It is interesting to note that paper was in short supply in Germany during the war, so instead of using paper tape, Zuse was obliged to punch holes in old movie film to store

**1965:** John Kemeny and Thomas Kurtz develop the BASIC computer programming language.

**1968:** First Static RAM IC reaches the market.

**1970:** First floppy disk (8.5 inch) is used for storing computer data.

**1970:** America. Ethernet developed at Palo Alto Research center by Bob Metcalfe and David Boggs.

**1971:** America. Datapoint 2200 computer introduced by CTC.

**1971:** CTC's Kenbak-1 Computer is introduced.

**1971:** America. Ted Hoff designs (and Intel releases) the first computer-on-a-chip, the 4004 microprocessor.

**1971:** Niklaus Wirth develops PASCAL computer language (named after Blaise Pascal).

**1972:** November, America. Intel introduce the 8008 microprocessor.

**1973:** America. Xerox Alto Computer is introduced.

**1973:** May, France. 8008-based Micral microcomputer is introduced.

**1973:** June, the term microcomputer first appears in print in reference to the 8008-based Micral microcomputer.

**1973:** America. Scelbi Computer Consulting Company introduce the Scelbi-8H microcomputer-based do-it-yourself computer kit.

**1973:** PDP-8 becomes the first popular microcomputer.

**1974:** America. Intel introduce





*Rebuilt version of Konrad Zuse's Z1 computer. The original was built in his parent's living room in Berlin in 1938. Courtesy of Horst Zuse.*

his programs and data. We may only speculate as to the films Zuse used for his hole-punching activities; for example, were any first-edition Marlene Dietrich classics on the list? (Marlene Dietrich fell out of favor with the Hitler regime when she emigrated to America in the early 1930s, but copies of her films would still have been around during the war.)

Zuse was an amazing man who was well ahead of his time. In fact there isn't enough space to do him justice in this article, but you can find a "world-exclusive" feature article on Zuse at the *EPE Online* web site at [www.epemag.com](http://www.epemag.com). This article, which was written by Konrad's eldest son, Horst Zuse, contains over 100 photographs from Horst's private collection, many of which have never been published before!

### FIRST ELECTRONIC COMPUTERS

We now turn our attention to an American mathematician and physicist, John Vincent Atanasoff, who has the dubious honor of being known as the man who either did or did not construct the first truly electronic special-purpose digital computer.

A lecturer at Iowa State College (now Iowa State University), Atanasoff was disgruntled with the cumbersome and time-consuming process of solving complex equations by hand. Working alongside one of his graduate students (the brilliant Clifford Berry), Atanasoff commenced work on an electronic computer in early 1939, and had a prototype machine by the autumn of that year.

In the process of creating the device, Atanasoff and Berry evolved a number of ingenious and unique features. For example, one of the biggest problems for computer designers of the time was to be able to store numbers for use in the machine's calculations.

Atanasoff's design utilized capacitors to store electrical charge that could represent numbers in the form of logic 0s and logic 1s. The capacitors were mounted in rotating Bakelite cylinders, which had metal bands on their outer surface. These cylinders, each approximately 12 inches tall and 8 inches in diameter (30cm x 20cm), could store thirty binary numbers, which could be read off the metal bands as the cylinders rotated.

Input data was presented to

the 8080 microprocessor.

**1974:** August, America. Motorola introduce the 6800 microprocessor.

**1974:** June, America. Radio Electronics magazine publishes an article by Jonathan (Jon) Titus on building an 8008-based microcomputer called the Mark-8.

**1975:** America. MOS Technology introduce the 6502 microprocessor.

**1975:** January, America, Ed Roberts and his MITs company introduce the 8080-based Altair 8800 microcomputer.

**1975:** April, America. Bill Gates and Paul Allen found Microsoft.

**1975:** July, America. Microsoft release BASIC 2.0 for the Altair 8800 microcomputer.

**1975:** America. MOS Technology introduce the 6502-based KIM-1 microcomputer.

**1975:** America. Sphere Corporation introduce the 6800-based Sphere 1 microcomputer.

**1975:** America. Microcomputer in kit form reaches US home market.

**1976:** America. Zilog introduce the Z80 microprocessor.

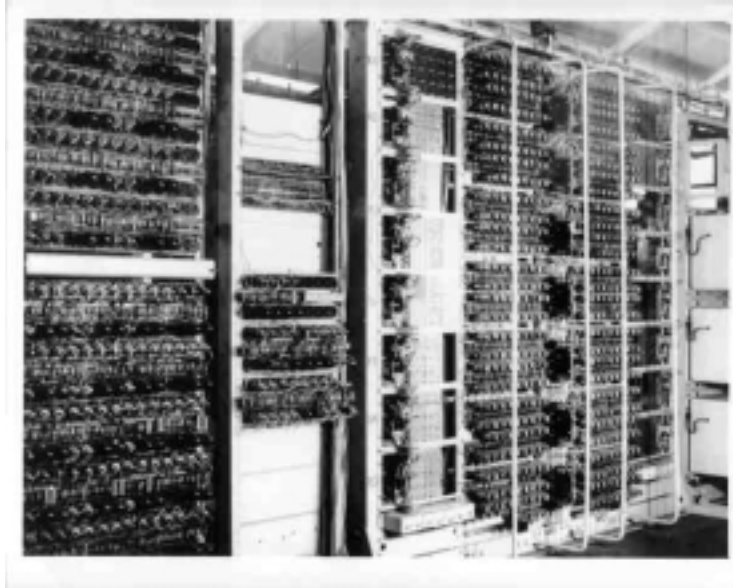
**1976:** March, America. Steve Wozniak and Steve Jobs introduce the 6502-based Apple 1: microcomputer.

**1976:** April 1st, America. Steve Wozniak and Steve Jobs form the Apple computer company.

**1977:** April, America. Apple introduces the Apple II microcomputer.

**1977:** April, America. Com-





*The Colossus computer, Bletchley Park, 1943. Used to de-cypher the German "ENIGMA" codes during WWII. Courtesy Science Museum/Science and Society Picture library.*

the machine in the form of punched cards, while intermediate results could be stored on other cards. Once again, Atanasoff's solution to storing intermediate results was quite interesting – he used sparks to burn small spots onto the cards. The presence or absence of these spots could be automatically determined by the machine later, because the electrical resistance of a carbonized spot varied from that of the blank card.

Some references report that Atanasoff and Berry had a fully working model of their machine by 1942. However, while some observers agreed that the machine was completed and did work, others reported that it was almost completed and would have worked, while still others stated that it was just a collection of parts that never worked. So unless more definitive evidence comes to light, it's a case of: *"You pays your money and you takes your choice"*.

## GENIUSES AND ECCENTRICS

Many of the people who designed the early computers were both geniuses and eccentrics of the first order, and the English mathematician Alan Turing was "first amongst equals." In 1937, while a graduate student, Turing wrote his ground-breaking paper *On Computable Numbers with an Application to the Entscheidungsproblem*.

Since Turing did not have access to a real computer (not unreasonably, because they didn't exist at the time), he invented his own as an abstract "paper exercise". This theoretical model, which became known as a *Turing Machine*, was both simple and elegant, and subsequently inspired many "thought experiments".

During World War II, Turing worked as a cryptographer, decoding codes and ciphers at

modore Business Machines present their 6502-based Commodore PET microcomputer.

**1977:** August, America. Tandy/Radio Shack announce their Z80-based TRS-80 microcomputer.

**1978:** America. Apple introduce the first hard disk drive for use with personal computers.

**1979:** America, the first true commercial microcomputer program, the VisiCalc spreadsheet, is available for the Apple II.

**1979:** ADA programming language is named after Augusta Ada Lovelace (now credited as being the first computer programmer).

**1981:** America. First IBM PC is launched.

**1981:** America. First mouse pointing device is introduced.

**1981:** First laptop computer is introduced.

**1983:** Apple's Lisa is the first personal computer to use a mouse and pull-down menus.

**1983:** Time magazine names the computer as Man of the year.

**1984:** 1 MB memory chips introduced.

**1985:** CD-ROMs are used to store computer data for the first time.

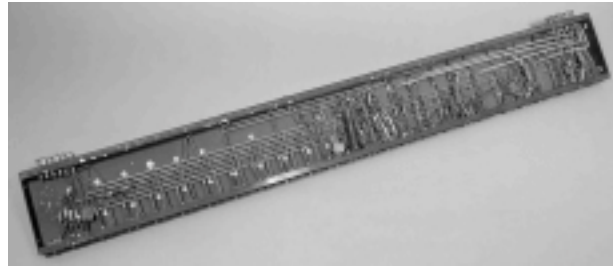
one of the British government's top-secret establishments located at Bletchley Park. During this time Turing was a key player in the breaking of the German's now-famous code generated by their ENIGMA machine. However, in addition to ENIGMA, the Germans had another cipher that was employed for their ultra-top-secret communications. This cipher, which was vastly more complicated than ENIGMA, was generated by a machine called a *Geheimfenschreiber* (secret telegraph), which the allies referred to as the "Fish".

In January 1943, along with a number of colleagues, Turing began to construct an electronic machine to decode the *Geheimfenschreiber* cipher. This machine, which they dubbed *Colossus*, comprised 1,800 vacuum tubes and was completed and working by December of the same year!

By any standards *Colossus* was one of the world's earliest working programmable electronic digital computers. But it was a special-purpose machine that was really only suited to a narrow range of tasks (for example, it was not capable of performing decimal multiplications). Having said this, although *Colossus* was built as a special-purpose computer, it did prove flexible enough to be programmed to execute a variety of different routines.

### **ENIAC AND EDVAC**

By the mid-1940s, the majority of computers were being built using vacuum tubes rather than switches and relays. Although vacuum tubes were fragile, expensive and used a lot of power, they were much faster than relays (and much quieter). If we ignore Atanasoff's machine and *Colossus*, then the first true



*One small section of the receiver unit for ENIAC. Another photo of ENIAC was shown in Part 2. Courtesy*

*Science Museum/Science and Society Picture Library.*

general-purpose electronic computer was the electronic numerical integrator and computer (*ENIAC*), which was constructed at the University of Pennsylvania between 1943 and 1946.

ENIAC, which was the brainchild of John William Mauchly and J. Presper Eckert Jr., was a monster – it was 10 feet (3m) tall, occupied 1,000 square feet (300m<sup>2</sup>) of floor-space, weighed in at approximately 30 tons (30480kg), and used more than 70,000 resistors, 10,000 capacitors, 6,000 switches, and 18,000 vacuum tubes. The final machine required 150 kilowatts of power, which was enough to light a small town.

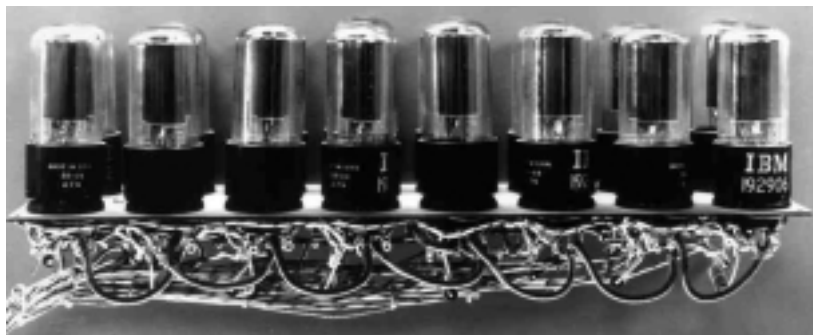
One of the greatest problems with computers built from vacuum tubes was reliability; 90 percent of ENIAC's down-time was attributed to locating and replacing burnt-out tubes. Records from 1952 show

that approximately 19,000 vacuum tubes had to be replaced in that year alone, which averages out to about 50 tubes a day!

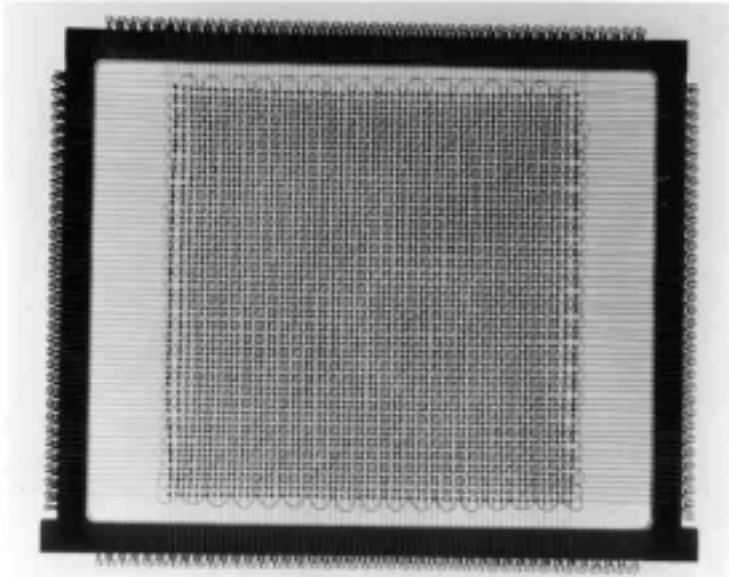
In August 1944, Mauchly and Eckert proposed the building of another machine called the electronic discrete variable automatic computer (*EDVAC*). This new machine was intended to feature many improvements over ENIAC, including a new form of memory based on pulses of sound racing through mercury delay lines.

### **FIRST DRAFT**

In June 1944, the Hungarian-American mathematician Johann (John) von Neumann first became aware of ENIAC. Von Neumann, who was a consultant on the Manhattan Project, immediately recognized the role that could be played by a computer like ENIAC in solving the vast arrays of complex equations involved in designing atomic weapons.



*Electronic vacuum tubes, 1946, which replaced electric relays and made operational programs that could multiply two 10-digit numbers 40 times per second. Courtesy of IBM.*



*Magnetic core memory store. Logic 0 and 1 depended on the polarity of the magnetized field for each bead.  
Courtesy of IBM.*

Von Neumann was tremendously excited by ENIAC and quickly became a consultant to both the ENIAC and EDVAC projects. In June 1945, he published a paper entitled *First Draft of a report on the EDVAC*, in which he presented all of the basic elements of a stored-program computer:

- o) A memory containing both data and instructions. Also to allow both data and instruction memory locations to be read from, and written to, in any desired order.
- o) A calculating unit capable of performing both arithmetic and logical operations on the data.
- o) A control unit, which could interpret an instruction retrieved from the memory and select alternative courses of action based on the results of previous operations.

The key point made by the paper was that the computer could modify its own programs, in much the same way as was originally suggested by Charles Babbage in the 1830s. The computer structure resulting from the criteria presented in this paper is popularly known as a *von Neumann Machine*, and virtually all digital computers from that time forward have been based on this architecture.

Unfortunately, although the conceptual design for EDVAC was completed by 1946, several key members left the project to pursue their own careers, and the machine did not become fully operational until 1952. When it was finally completed, EDVAC contained approximately 4,000 vacuum tubes and 10,000 crystal diodes. A 1956 report shows that EDVAC's average error-free up-time was approximately eight hours.

## EDSAC TO UNIVAC

In light of its late completion, some would dispute EDVAC's claim-to-fame as the first stored-program computer. A small experimental machine based on the EDVAC concept consisting of 32 words of memory and a 5-instruction command set was operating at Manchester University, England, by June 1948.

Another machine called EDSAC (Electronic Delay Storage Automatic Calculator) performed its first calculation at Cambridge University, England, in May 1949. EDSAC contained 3,000 vacuum tubes and used mercury delay lines for memory. Programs were input using paper tape and output results were passed to a teleprinter.

Additionally, EDSAC is credited as using one of the first assemblers called *Initial Orders*, which allowed it to be programmed symbolically instead of using machine code. Last but not least, the first commercially available computer, UNIVAC I (Universal Automatic Computer), was also based on the EDVAC design. Work started on UNIVAC I in 1948, and the first unit was delivered in 1951, which therefore predates EDVAC's becoming fully operational.

## MAGNETIC CORE STORES

One of the biggest problems faced by early computer designers was the lack of small, efficient memories. In Germany Konrad Zuse experimented with purely mechanical memories (which were surprisingly reliable), whilst other engineers worked with a variety of esoteric techniques, including the phosphorescent effect in



storage oscilloscopes, and mercury delay lines as discussed earlier.

Around 1950, Jay Forrester at MIT came up with the idea of using ferromagnetic beads ("cores") threaded onto wires to store logic 0s and 1s (depending on which way they were magnetized). Although unwieldy by today's standards, these core stores were incredibly useful at that time, and they paved the way for bigger and better computers.

Of course, the advent of the transistor was revolutionary in computing circles, because each transistor could replace a vacuum tube that was 100s of times larger, consumed 100s of times more power, and was 100s of times less reliable.

However, transistors by themselves did not oust core stores. This was due to the fact that storing one bit of data required a single core only 1mm or less in diameter, but storing the same bit would require between four and six transistors. Thus, it was not until the invention of the integrated circuit that useful semiconductor memory devices started to appear in the early 1970s. (The development of vacuum tubes, transistors, and integrated circuits were discussed in Part 2.)

### **FIRST MICROPROCESSORS**

In 1970, the Japanese calculator company Busicom approached Intel with a request to design a set of twelve integrated circuits for use in a new calculator. The task was presented to one Marcian "Ted" Hoff, a man who could foresee a somewhat bleak and never-ending role for himself designing sets of special-purpose

integrated circuits for one-of-a-kind tasks.

However, during his early ruminations on the project, Hoff realized that rather than design the special-purpose devices requested by Busicom, he could create a single integrated circuit with the attributes of a simple-minded, stripped-down, general-purpose computer processor.

The result of Hoff's inspiration was the world's first microprocessor, the 4004, where the '4's were used to indicate that the device had a 4-bit data path (there is a photo in Part 2). The 4004 was part of a four-chip system which also consisted of a 256-byte ROM, a 32-bit RAM, and a 10-bit shift register.

The 4004 itself contained approximately 2,300 transistors and could execute 60,000 operations per second. The advantage (as far as Hoff was concerned) was that by simply changing the external program, the same device could be used for a multitude of future projects.

In November 1972, Intel introduced the 8008, which was essentially an 8-bit version of the 4004. The 8008 contained approximately 3,300 transistors and was the first microprocessor to be supported by a high-level language compiler called PL/M. The 8008 was followed by the 4040, which extended the 4004's capabilities by adding logical and compare instructions, and by supporting subroutine nesting using a small internal stack.

However, the 4004, 4040, and 8008 were all designed for specific applications, and it was not until April 1974 that Intel presented the first true general-purpose microprocessor, the 8080. This 8-bit device, which contained around 4,500 transistors and could perform

200,000 operations per second, was destined for fame as the central processor of many of the early home computers.

Following the 8080, the microprocessor field exploded with devices such as the 6800 from Motorola in August 1974, the 6502 from MOS Technology in 1975, and the Z80 from Zilog in 1976 (to name but a few).

Unfortunately, documenting all of the different microprocessors would require a book in its own right, so we won't even attempt the task here. Instead, we'll create a cunning diversion that will allow us to leap gracefully into the next topic ... Good grief! Did you see what just flew past your window?

### **FIRST PERSONAL COMPUTERS (PCS)**

Given that the 8008 was not introduced until November 1972, the resulting flurry of activity was quite impressive. Only six months later, in May 1973, the first computer based on a microprocessor was designed and built in France.

Unfortunately the 8008-based Micral, as this device was known, did not prove tremendously successful in America. However, in June of that year, the term "microcomputer" first appeared in print in reference to the Micral.

In the same mid-1973 time-frame, the Scelbi Computer Consulting Company presented the 8008-based Scelbi-8H microcomputer, which was the first microprocessor-based computer kit to hit the market (the Micral wasn't a kit – it was only available in fully assembled form). The Scelbi-8H was advertised at \$565 and came





*Altair 8800b microcomputer, 1975. Courtesy Science Museum/Science and Society Picture Library.*

equipped with 1Kbyte of RAM.

In June 1974, *Radio Electronics* magazine published an article by Jonathan Titus on building a microcomputer called the Mark-8, which, like the Micral and the Scelbi-8H, was based on the 8008 microprocessor. The Mark-8 received a lot of attention from hobbyists, and a number of user groups sprang up around the US to share hints and tips and disseminate information.

### **LAUNDROMATS IN ALBUQUERQUE**

Around the same time that

Jonathan Titus was penning his article on the Mark-8, a man called Ed Roberts was pondering the future of his failing calculator company known as MITS (which was next door to a laundromat in Albuquerque, New Mexico). Roberts decided to take a gamble with what little funds remained available to him, and he started to design a computer called the Altair 8800 (the name "Altair" originated in one of the early episodes of *Star Trek*).

Roberts based his system on the newly-released 8080 microprocessor, and the resulting do-it-yourself kit was

advertised in *Popular Electronics* magazine in January 1975 for the then unheard-of price of \$439 US. In fact, when the first unit shipped in April of that year, the price had fallen to an amazingly low \$375 US.

Even though it only contained a miserly 256 bytes of RAM and the only way to program it was by means of a switch panel, the Altair 8800 proved to be a tremendous success. (These kits were supplied with a steel cabinet sufficient to withstand most natural disasters, which is why a remarkable number of them continue to lurk in their owner's garages to this day.)

### **BASIC GATES**

Also in April 1975, Bill Gates and Paul Allen founded Microsoft (which was to achieve a certain notoriety over the coming years), and in July of that year, MITS announced the availability of BASIC 2.0 on the Altair 8800. This BASIC interpreter, which was written by Gates and Allen, was the first reasonably high-level computer language program to be made available on a home computer –



*A Commodore PET 32K computer, 1979. Cassette recorders provided external data storage. Courtesy John Becker*



*An early IBM PC. Its architecture became the foundation that all PC-compatibles must emulate. Courtesy of IBM.*

MIT sold 2,000 systems that year, which certainly made Ed Roberts a happy camper, while Microsoft had taken its first tentative step on the path toward world domination.

In June 1975, MOS Technology introduced their 6502 microprocessor for only \$25 US (an Intel 8080 would deplete your bank account by about \$150 US at that time). A short time later, MOS Technology announced their 6502-based KIM-1 microcomputer, which boasted 2K bytes of ROM (for the monitor program), 1K byte of RAM, an octal keypad, a flashing LED display, and a cassette recorder for storing programs. This unit, which was only available in fully-assembled form, was initially priced at \$245 US, but this soon fell to an astoundingly low \$170 US.

The introduction of new microcomputers proceeded apace. Sometime after the KIM-1 became available, the Sphere Corporation introduced its Sphere 1 kit, which comprised a 6800 microprocessor, 4K bytes of RAM, a QWERTY keyboard, and a video interface (but no monitor) for \$650 US.

### **JOBS AND WOZNIAK**

In March 1976, two guys called Steve Wozniak and Steve Jobs (who had been fired with enthusiasm by the Altair 8800) finished work on a home-grown 6502-based computer which they called the Apple 1 (a few weeks later they formed the Apple Computer Company on April Fools day).

Although it was not tremendously sophisticated, the Apple 1 attracted sufficient interest for them to create the Apple II, which many believe to be the first personal computer



*Two of the ballistic track monitors of SAGE, the massive US military computer that helped defend the Western World during the Cold War. Courtesy of IBM.*

that was both affordable and usable. The Apple II, which became available in April 1977 for \$1,300 US, comprised 16K bytes of ROM, 4K bytes of RAM, a keyboard and a color display.

Apple was one of the great early success stories – in 1977 they had an income of \$700,000 US (which was quite a lot of money in those days), and just one year later this had soared tenfold to \$7 million US! (which was a *great* deal of money in those days).

Also in April 1977, Commodore Business Machines presented their 6502-based Commodore PET, which contained 14K bytes of ROM, 4K bytes of RAM, a keyboard, a display and a cassette tape drive for only \$600. Similarly, in August of that year, Tandy/Radio Shack announced their Z80-based TRS-80, comprising 4K bytes of ROM, 4K bytes of RAM, a keyboard and a cassette tape drive for \$600.

### **WOT! NO SOFTWARE?**

One aspect of computing that may seem strange today is that there were practically no programs available for these early machines (apart from the programs written by the users

themselves). In fact, it wasn't until late in 1978 that commercial software began to appear.

Possibly the most significant tool of that time was the VisiCalc spreadsheet program, which was written for the Apple II by a student at the Harvard Business School and which appeared in 1979. It is difficult to overstate the impact of this program, but it is estimated that over a quarter of the Apple machines sold in 1979 were purchased by businesses solely for the purpose of running VisiCalc. In addition to making Apple very happy, the success of VisiCalc spurred the development of other applications such as word processors.

When home computers first began to appear, existing manufacturers of large computers tended to regard them with disdain (*"It's just a fad ... it will never catch on"*). However, it wasn't too long before the sound of money changing hands began to awaken their interest. In 1981, IBM launched their first PC for \$1,365 US, which, if nothing else, sent a very powerful signal to the world that personal computers were here to stay.

The advent of the general-purpose microprocessor

heralded a new era in computing – microcomputer systems small enough to fit on a desk could be endowed with more processing power than monsters weighing tens of tons only a decade before. The effects of these developments are still unfolding, but it is not excessive to say that

digital computing and the personal computer have changed the world more significantly than almost any other human invention, and many observers believe that we've only just begun our journey into the unknown!

### NEXT MONTH

In the fifth and final installment of this series we shall gird up our loins and pontificate on the future. Where do you think the technology roller-coaster will take us in the next 10, 100 or 1000 years? Start pondering now and see if you agree with us in next month's exciting issue – same time ... same place ... same channel!

### QUOTABLE QUOTES

*"Computers in the future may weigh no more than 1-5 tons."* Popular Mechanics, forecasting the relentless march of science, 1949.

*"I think there is a world market for about five computers."* Thomas Watson, Chairman of IBM, 1943.

*"I have traveled the length and breadth of this country and talked with the best people, and I can assure you that data processing is a fad that won't last out the year."* The editor in charge of business books for Prentice Hall, 1957.

*"There is no reason for any individual to have a computer in their home."* Ken Olson, President of Digital Equipment Corporation (DEC), 1977

*"So we went to Atari and said, 'Hey, we've got this amazing thing, even built with some of your parts, and what do you think about funding us? Or we'll give it to you. We just want to do it. Pay our salary, we'll come work for you.' And they said, 'No.' So then we went to Hewlett-Packard, and they said, 'Hey, we don't need you. You haven't got through college yet.'" Apple Computer Inc. founder Steve Jobs on attempts to get Atari and HP interested in his and Steve Wozniak's personal computer.*

*"640K of memory ought to be enough for anybody."* Bill Gates, CEO of Microsoft, 1981.

### EVER SO HUMBLE

We crave your indulgence and ask you to accept our humblest apologies for all of the things we had to leave out. Surely computer languages like FORTRAN, COBOL, BASIC, C, LISP, FORTH and ... (the list goes on) deserve a mention? How could we neglect microcomputers such as the PDP and VAX from Digital Equipment Corporation (DEC) that had such an impact on the industry? Are operating systems like VMS, UNIX, and Windows to be ignored? What about behemoths like SAGE (which consumed a million watts of power) and CRAY Supercomputers?

The problem is that one could go on forever, so we chose to restrict ourselves only to those topics that we felt were particularly germane to this series. As usual you may of course disagree (or you may simply crave more once this series is finished), in which case please feel free to vent your feelings by inundating the Editor with your letters and emails.

### ACKNOWLEDGEMENT

Portions of this article were abstracted from our book, *Bebop BYTES Back (An Unconventional Guide to Computers)*, with the kind permission of its publisher, Doone Publications. (*Bebop BYTES Back* is available from the *EPE Online Store* at [www.epemag.com](http://www.epemag.com))

# New Technology Updates

**WHILST LOWER OPERATING VOLTAGES ENABLE MICROPROCESSORS TO RUN FASTER, THE PROBLEM OF HEAT DISSIPATION BECOMES MORE SIGNIFICANT. IAN POOLE REPORTS.**

It is a commonly known fact that microprocessor clock speeds are increasing all the time. Only a few years ago, clock speeds of 1GHz were thought to be many years away. Now a number of manufacturers have offerings with speeds around 1GHz that will shortly hit the marketplace. IBM have a 64-bit Power PC chip. Compaq, have their 1GHz Alpha, and Intel a version of a Pentium III. These devices have been able to achieve their speed as a result of a number of developments that have been undertaken in many research institutes and development areas.

All of the devices have geometries that are less than 0.2 microns, and this means that the operating voltages are low. For example the Alpha operates on a voltage of 1.65 volts. Not only is this low voltage required because of the low breakdown voltages associated with the minute geometries, but it also reduces the power consumption.

## **HEAT PROBLEMS**

Power consumption is an increasing problem as demonstrated by the fact that even modest Pentium chips require cooling. However when it is realized that IBM's 64-bit PowerPC uses 19 million transistors, it is hardly surprising that very significant amounts of heat are dissipated. Some of the new chips now under development dissipate levels of heat well in excess of 50 watts,

and the trend of increasing levels of power dissipation is likely to continue. With the increasing levels of power dissipation, thermal control of chips is an integral part of the design and it is every bit as important and challenging as the electrical performance.

It is interesting to note that when the first bipolar integrated circuits were introduced, limits of around 20 transistors were thought to be the limit of integration as a result of thermal considerations. The introduction of CMOS techniques enabled a quantum leap to be made in the levels of integration and the trend towards ever-larger ICs has increased since then.

More recently, the reduction of supply voltage has been of assistance as the thermal boundaries have been approached, because power levels are proportional to the square of the voltage. Even so other effects prevent the picture from being quite so rosy. The design of the transistors in the chip has to be altered to enable them to operate at low voltages. One of the results of this is that they become far more leaky and this effect means that they consume power even when they are switched off.

## **TEMPERATURE RISES**

To ensure the highest speed of operation, devices should be operated at a low temperature. The unwanted

additional power consumption from the leaky transistors raises the temperature and this reduces the electron mobility because of the increased number of collisions that occur as the electrons move around the crystal lattice.

Accordingly, it makes the methods and techniques used for heat extraction from the IC a point of major importance if speeds are to increase at the current rate. A company named Kryotech is already marketing a chip that is cooled, increasing its performance by a half again. To the same end, IBM are optimizing the performance of their basic silicon designs for low temperature operation with a view to this being one of the ways forward for the future.

However, even though speed generally increases with cooling, it also increases the threshold voltage for the individual devices, and this in turn increases the level of leakage and partially offsets any gains that are made. This is one of the factors that makes optimizing the design for low-temperature operation so important. By choosing the optimum level of threshold voltage, the maximum use can be made of any cooling that is used.

## **EXTRACTING HEAT**

There are a number of ways in which heat can be extracted from the chips. One method is to use a system that is effectively a small-scale version



of a domestic refrigerator. These systems are very successful, being already employed in a number of high end products and they are able to cool chips down to a temperature of around  $-50^{\circ}\text{C}$ .

Whilst this can give significant advantages in performance, lower temperatures can provide even greater improvements. To achieve this there are a number of methods that can be adopted. The most popular idea is that of thermo-electric heat pumps. These do not involve the same level of mechanical hardware and are accordingly less expensive. They can also be interfaced to the basic chip more easily, and can actually be made as part of the same assembly.

However, the basic Peltier devices, although attractive at first sight, leak too much heat back into the chip, and as a result they are not as efficient as they are required to be for this function. Fortunately, new work undertaken at the Massachusetts Institute of Technology has resulted in the production of new materials and structures that give far more effective and efficient solutions.

The requirement is to be able to remove a considerable amount of heat from a small area. One of the new solutions using a thin film semiconductor heat pump can extract as much as 100 watts per square centimeter. With further work it is expected that these devices

could be built into the basic chip package, providing a very convenient, efficient and reliable method of extracting heat from the devices.

### **PACKAGES**

Whilst heat is a major problem that is being overcome, new package technology is also part of the solution. Long gone are the days when dual-in-line packages were able to meet most requirements. Even the quad flat packs are not suitable, and in addition to this, equipment manufacturers dislike them because they are easily damaged. Flip chip packages where the silicon is directly bonded to the package are able to give performance improvements. This gives a speed increase as a result of its lower resistance and RC delays as well as giving a physically shorter connection.

Further improvements have been made by adopting a system that enables the critical leads to be kept as short as possible. Although this technique requires the addition of an extra layer of metalisation and a complete re-layout of the chip, it provides an increase that although small still helps to increase the overall speed of operation.

A further increase in performance is achieved by using a dielectric with a low value. In turn this reduces the levels of capacitance and cross

talk, which were large enough to slow down the speed of operation. The material chosen for this is silicon oxyfluoride (SiOF).

### **SUMMARY**

Although different manufacturers use different techniques to give the new higher clock speeds, the overall pattern is clear, and it is likely that in a few years time they will all be used as standard. Many of them give minor improvements on their own, but when used with the other techniques they enable a significant improvement in performance to be achieved in the chip as a whole. This demonstrates the fact that is commonly true in technology that a variety of improvements are required to give the overall improvement in performance.

# Circuit Surgery

by **ALAN WINSTANLEY**

***Our circuit surgeons provide more advice to help with reader's problems and conclude their mini-series investigating the inner workings of operational amplifiers, looking at output stages and short-circuit***

This month we round off our exploration of the opamp by looking at the level shifter circuits which are used to get the DC bias levels correct in different stages of an opamp. We outline typical short-circuit protection techniques and also output stages, which are power amplifiers that share some of the features of basic audio power amplifier output stages. Some of the principles we'll outline also apply to designs, which use discrete transistors instead of integrated circuits.

## SHIFTY CIRCUITS

No coupling capacitors can be used between stages within opamps – they have to work with DC and very low frequency inputs. Biasing is easy in multistage capacitively-coupled amplifiers, because the biasing of each stage is isolated by the coupling capacitor.

In an opamp, life is not so simple. We might, for example, have one stage with an output whose signal varies around a bias point of half the positive supply, which has to be connected to a stage that needs a signal which varies around 0V (ground) instead. Therefore what we would need to do is "shift" the DC bias level of a signal.

Ideally, a circuit for this purpose should provide a stable shift in DC level without

introducing noise, it should not attenuate the signal, and should allow the designer to select any level shift required (within reason). We could achieve a shift using a two-resistor potential divider, but this attenuates the signal. We could use a Zener diode to provide a voltage drop, but these are noisy. We could use diode voltage drops, but these only come in steps of about 0.6V per diode used.

The circuit in Fig.1a acts as a level shifter, changing the DC level from  $V_{in}$  to  $V_{out}$  without significant attenuation of the signal. The current source (see *Circuit Surgery*, May and June '99) provides a current  $I$  that flows through  $R$  to give a fixed voltage drop of  $IR$ . The voltage drop is fixed (it does not depend on the signal) because the current source produces the same current even if the voltage across it varies due to the signal.

The total fixed voltage drop from  $V_{in}$  to  $V_{out}$  also includes the  $V_{BE}$  voltage of the transistor, which will also not vary a great deal as the signal varies. Thus the circuit shifts the DC level of the signal down by  $(IR + V_{BE})$  volts.

## OUT OF THE OPAMP

An opamp output stage must be capable of supplying

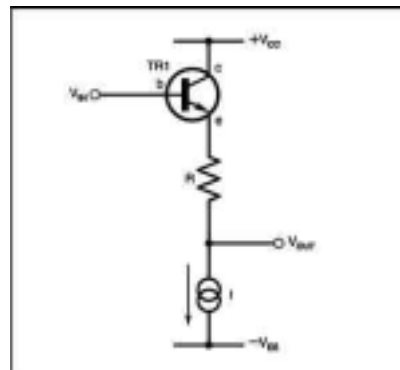


Fig.1a. A level shifter circuit.

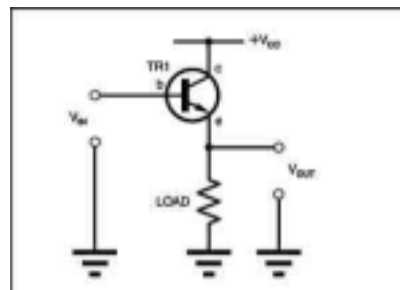


Fig.1b. Emitter follower circuit.

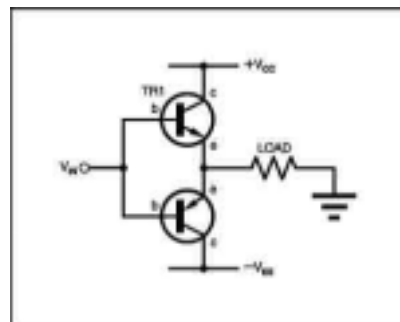


Fig.1c. Basic push-pull amplifier.

sufficient current to the external load (i.e. out of the chip on which the opamp is fabricated). In order to do this it must have low output resistance and

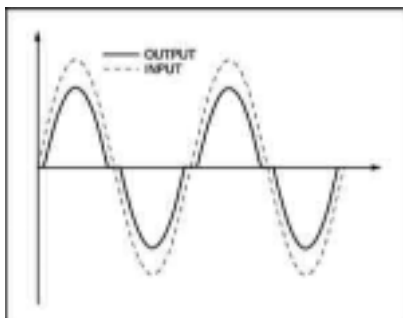


Fig.2. Sinewave with crossover distortion.

provide power gain. It does not have to provide voltage gain as this is done by earlier stages.

The output stage is a power amplifier – a term that conjures images of circuits which deliver many watts of power. This does not have to be the case – it is the fact that power gain is provided rather than the amount of power available that matters. However, there are, of course, high power opamps and the opamp output circuits share features with some types of audio power amplifier.

The well-known emitter follower circuit (Fig.1b) has a voltage gain of just less than unity, high input resistance and low output resistance. So it can deliver a relatively high-current version of a “weak” voltage signal. The circuit is called an emitter follower because the signal voltage at the emitter, which is where the load is connected, “follows” (is the same as) the voltage at the base. The absolute voltage at the emitter is one  $V_{BE}$  drop (about 0.6 to 0.7V) lower than the base voltage, but this is just a shift in DC level.

Our emitter follower circuit of Fig.1b has the right kind of properties for an opamp output stage, but is not suitable as it stands because we require the load to be connected to ground and the output signal to be both

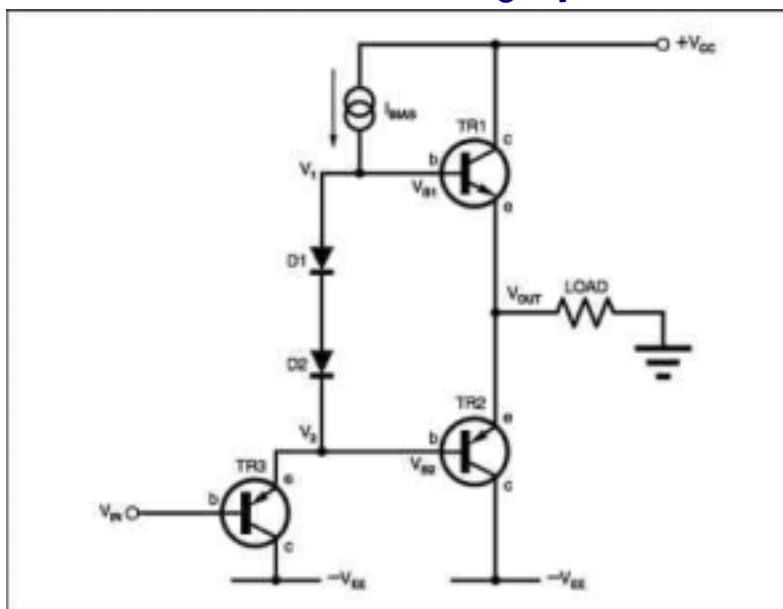


Fig.3. Output transistors biased to prevent crossover distortion. The diodes may be implemented using transistor base-emitter junctions.

positive and negative. In this circuit the transistor would turn off with negative input voltages, so we would only amplify half the signal!

To overcome this, two emitter-followers are used in what is known as a push-pull amplifier (see Fig.1c). This type of circuit is also referred to as a class-B amplifier because each output transistor conducts for one-half of the waveform cycle. Transistors in class-A amplifiers conduct for the whole cycle, and in class-C for less than half.

The basic push-pull output stage suffers from a problem called crossover-distortion. Only one transistor can be on at any time, that is: if  $V_{in} > V_{BE}$  then TR1 is conducting, and if  $V_{in} < -V_{BE}$  then TR2 is conducting instead. However, this means that for small inputs, neither transistor is on: if  $-V_{BE} < V_{in} < V_{BE}$  then TR1 and TR2 are both off.

So signals, or parts of signals, in this range are not

amplified, which leads to distortion of the output. Fig.2 shows a sinewave input to a basic push-pull amplifier (dotted line) and the resulting distorted output (solid line). Although this circuit is not suitable for opamps, it may be of use in other applications where the distortion does not matter, for example in a basic motor control circuit.

## CROSSOVER DISTORTION

To overcome crossover distortion, the output transistors are biased so that with no signal present they are both just on the point of conduction. Then when  $V_{in} = 0$  both transistors are just conducting, when  $V_{in} > 0$  TR1 conducts and TR2 is off, and when  $V_{in} < 0$  TR2 conducts and TR1 is off.

This can be achieved using two diodes, or two transistors connected as diodes, to provide the  $2 \times V_{BE}$  difference in bias voltage required between the

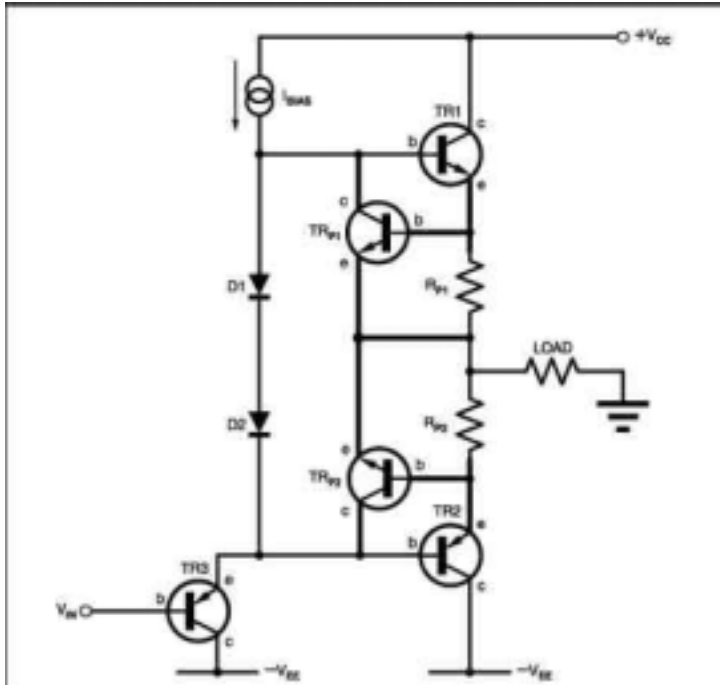


Fig.4. Output stage with protection circuit (protection components are shown using bold lines).

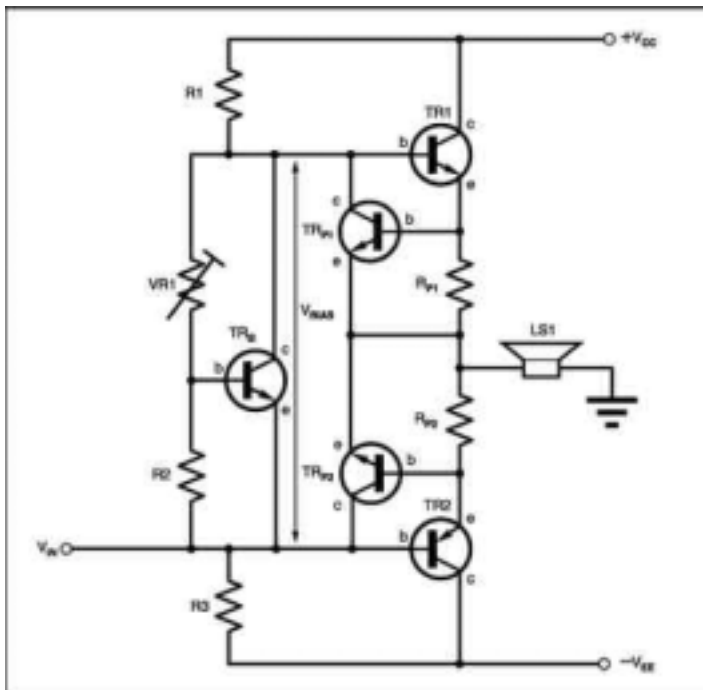


Fig.5. Audio power amplifier using similar configuration to opamp output stage.

transistors' bases (see Fig.3). The diodes are biased with the current required to give the correct  $V_{BE}$  value by means of a current source.

As the input signal varies the diodes maintain a

constant  $2 \times V_{BE}$  difference between the two base voltages. The actual base voltages will vary with the signal, but the difference between them is fixed by this biasing arrangement.

The diodes are ideally at the same temperature as the output transistors so that changes in their voltage drop with temperature tracks those of the output transistor. This applies on opamp ICs and for discrete component power amplifiers using this type of circuit.

### SHORT CIRCUITS

The push-pull amplifier is likely to be damaged if its output is short-circuited to ground, due to excessive collector current in the conducting transistor. A short-circuit protection arrangement may be added to overcome this problem. The protection circuit monitors the current flowing in the output and turns off the output transistor if the current exceeds some pre-defined limit. The current detection is usually achieved by using a small resistor in the output signal path, and a transistor to switch off the output (see Fig.4); the output current causes a voltage drop across the resistor.

A protection transistor switches on when the resistor voltage reaches about 0.6V to 0.7V. The protection transistor is connected so that when it is on, it effectively short-circuits the input to the power transistors, so they have no signal to amplify. The protection resistor values,  $R_{p1}$  and  $R_{p2}$  may be chosen using  $R_{p1} = R_{p2} = V_{be\_TRP1} / I_{max}$  where  $V_{be\_TRP1}$  is the turn-on voltage of the protection transistor (typically 0.6V to 0.7V) and  $I_{max}$  is the maximum output current, i.e. the current at which the protection kicks in. This kind of protection circuit is what enables opamps to have the "infinite output short circuit duration" quoted on many data sheets.

### AUDIO POWER AMP

The circuit shown in Fig.5 is a discrete component version of the circuit in Fig.4, which could form the basis of an audio power amplifier output stage. Resistors are used instead of the current sources ubiquitous in IC circuits.



Biasing is achieved using what is known as a  $V_{BE}$  multiplier and is manually adjustable using preset VR1 to give the required quiescent current for the circuit (the degree to which the output transistors are "just on" with no signal). The  $V_{BE}$  multiplier circuit consists of  $TR_a$ , preset VR1 and resistor R2. The voltage  $V_{bias}$  is effectively fixed by virtue of the fact that  $TR_a$ 's  $V_{BE}$  voltage does not vary much, resulting in a fixed voltage across R2 and hence a fixed current through it.

If the preset VR1 and resistor R2 are chosen so that their current is much larger than  $TR_a$ 's base current then we can assume all of the current in R2 also flows in VR1. Thus the total dropped across VR1 and R2 (i.e.  $V_{bias}$ ) is equal to  $V_{BE}$  multiplied by the ratio of the total resistance of VR1 and R2 to the value of R2, i.e.

$$V_{bias} = V_{BE} (VR1 + R2) / R2$$

We hope that our discussion on the opamp over the past few months has given you some insight into what is inside these chips that get used in so many constructor's projects. Of course, there is a lot more to the circuitry of modern opamps than we have space to discuss in this series – as a browse through the schematics in manufacturers' data sheets will reveal.

Hopefully, however, you would also be able to recognize at least some of the basic sub-circuits (e.g. differential amplifier) in these schematics, even if there are one or two extra transistors present. We also hope that some of you might find other uses for the circuits we have shown in your own designs – let us know if you do. Ian Bell.

### BATTERY FLATTERY

Briefly on the subject of troubleshooting lead acid chargers, **Mr. Alister Bottomley** wrote: *"Am I correct in assuming that in order to charge a 12V lead acid battery it must receive a voltage greater than 12V across it – the greater the voltage the greater the charging current?"*

*My battery charger has suddenly reduced its output to 11.7V as measured on its 'high' tapping. I can't find any losses or problems in the circuit."*

A lead acid battery requires something like 2.2V per cell or higher constant voltage to charge. A higher voltage could be used but the battery life will be shortened, and it is true that the greater the applied voltage, the greater the charge current will be. Current gradually reduces to a trickle as the battery charges up.

The reason you are measuring a strange DC voltage is because it isn't a smooth level DC voltage you are actually testing. Ordinary car battery chargers have a rectified DC output, which is unsmoothed. However, your multimeter will want to read a pure DC voltage, or it will read an RMS voltage on its AC range instead. An oscilloscope would highlight the problem.

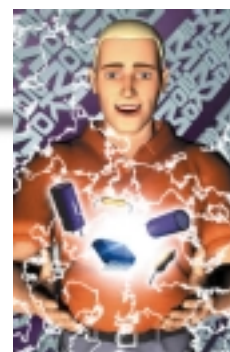
An electronics mains power supply uses a smoothing or "reservoir" capacitor to iron out the ripple, to produce a higher peak value and much smoother DC voltage. The capacitor then charges to the peak value of the rectified DC sinewave. In fact, it's the car battery itself that acts as a giant smoothing capacitor across the supply. Hooking this across the battery charger means that the voltage seen across the battery will then increase.

Also, your test equipment may actually cause you to misinterpret the result, and sometimes the very use of test equipment can affect the operation of the circuit as well. Constructors gradually learn to compensate for this with experience.

# TEACH-IN 2000

## PART PART 7 – Op.amps

by John Becker



Over the previous six parts of Teach-In 2000, which we know you have been greatly enjoying, we have covered passive components and several digital logic circuits. Via the interactive computer programs and the simple interface you assembled, you have also been able to observe the various waveforms generated by the experimental breadboard circuits, showing how a few electronic components can be connected to achieve interesting results.

Probably the most important electronic component in the analog designer's armory is the operational amplifier. Better known, perhaps, by its abbreviated name of opamp (or op-amp, or even op.amp) this family of devices seemingly has more applications than there are designers who use it!

In this month's Tutorial we illustrate some of the opamp's major features as an amplifier. In next month's Tutorial we follow on by going into a bit more simple experimental detail, discussing what else opamps can do, and getting you to try it.

### FIRST DEMONSTRATION

From your stock of components (as described in Part 1), select one of the 8-pin dual-in-line (DIL) devices labeled LM358, call it IC4. Now assemble your breadboard according to Fig.7.1. Any previous components in the area illustrated should be removed (all your counting and logic gate experiments from last month have already served their

We now move on from the "interesting" to the "practical", in terms of describing active components which can be used to amplify and otherwise modify the waveforms generated. It is opamps we now examine, those simple robust components that feature so frequently in audio and other analog circuits. This month we demonstrate their basic nature, next month we get you experimenting with some useful applications.

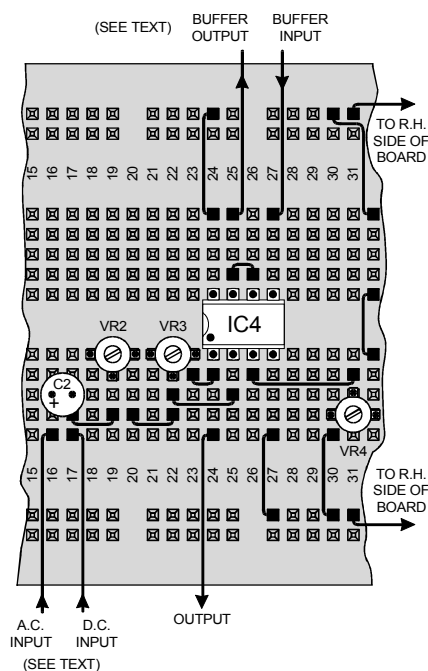
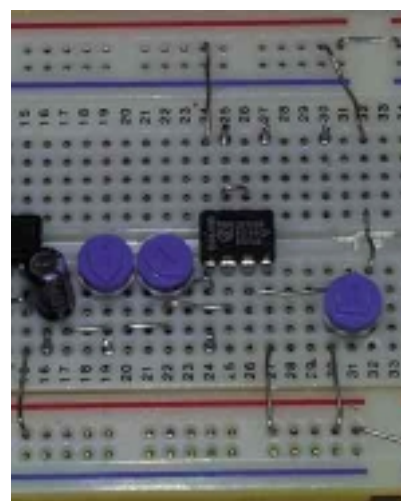


Fig.7.1 Breadboard layout for the first opamp experiments.

purpose, we hope!). Leave the oscillator components intact for now.

The equivalent circuit diagram and the component values are shown in Fig.7.2.

Connect the oscillator waveform from the junction of

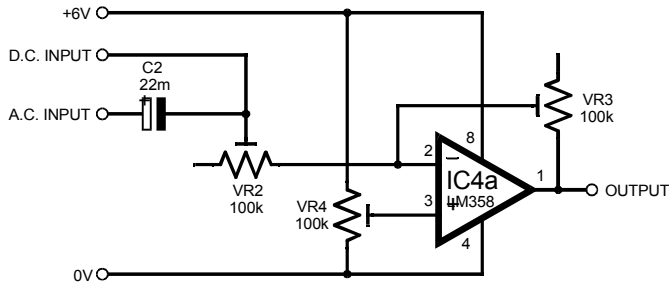


Breadboard showing the components for the first opamp experiments, part of IC1 is just visible at the left.

capacitor C1 and IC1a pin 1 (see Fig.4.3 of Part 4) to the point marked "DC INPUT". Use a crocodile-clipped link.

Ignore the points labeled "Buffer Input" and "Buffer Output", their purpose will be discussed later on in the Tutorial.

The oscillator should have diodes D2 and D3 included; its



*Fig. 7.2.  
Circuit diagram associated with  
Fig 7.1*

capacitor C1 value should be 100uF. Set the frequency control VR1's wiper to midway, so that the generated waveform will be roughly triangular.

Set each of the Fig.7.1 presets (VR2 to VR4) so that their wipers (moving contacts) are also in a midway position, providing approximately equal resistance to either side of the wiper.

Referring to Fig.5.6 of Part 5, connect IC4 pin 1 to the input to the analog-to-digital converter (IC2 pin 2), and then connect IC2's output to IN1 of the computer interface section. Run the *Analog Input Waveform Display* program.

Connect up your battery to the breadboard (as you've done a good few times before – is the battery power still OK?) and observe the computer screen displaying the triangular waveform being generated by IC1a and associated components.

## VARIABLE AMPLITUDE

We are now going to ask you to make various adjustments on the opamp's three presets and observe the screen responses. We shall discuss what you observe in due course. First, carefully adjust the wiper position of VR4 until the waveform is roughly central on the screen.

Next, slowly adjust the wiper

of VR3 in a clockwise direction (to the "right") while observing the screen. This action increases the resistance between the wiper and the end connected to IC4 pin 1, the opamp's output.

It will no doubt interest you to see that the vertical size of the waveform increases, in other words, its amplitude increases the further you adjust VR3. The limit will be reached when you cannot turn the wiper any further. The amplitude will now be about twice that you started with.

Note, though, how the waveform's relative position on the screen probably changes as

you rotate VR3. Carefully adjust the wiper of VR4 to set the waveform back to a mid-screen position if it does.

Now rotate VR3's wiper anticlockwise. The waveform amplitude will be seen to decrease, and once the wiper goes beyond the midway position, the waveform amplitude will begin to fall below that at which it started. The waveform is now said to have been attenuated.

Towards the far end of the anticlockwise rotation the waveform should be seen just as a straight-ish horizontal line.

Set VR3's wiper to its fully clockwise position and leave it there.

## PEAK FLATTENING

Turn your attention now to preset VR2. First rotate it clockwise, to increase the effective resistance between its wiper and IC4 pin 2, one of the opamp's two inputs. Note how an

## PANEL 7.1 – OPAMP MANUFACTURING CONSTRUCTION

The opamp type (LM358) used in this *Teach-In* is manufactured using a structure called bipolar. In essence, this uses many transistors internally interconnected on the opamp chip and which require current to flow through them. In most cases the current is not great, but can still place a load on the circuit, which is being fed into the opamp inputs.

Another type of opamp manufacturing process uses the field effect transistor (FET) technique. FET devices operate on a different principle to those used in bipolar devices and respond to the voltage (field) on their inputs rather than through their inputs. These devices, therefore, do not draw current from the circuit feeding into them and so place no load on them.

All the circuits discussed in this *Teach-In* part could probably have used FET opamps instead of the bipolar LM358. Such devices include TL062, TL072 and TL082.

Component suppliers' catalogs and manufacturers' data sheets should be consulted for information about the different opamp types available. Internet access to various manufacturers' web sites and data sheets can be gained via the EPE web site at [www.epemag.wimborne.co.uk](http://www.epemag.wimborne.co.uk)

increase in resistance here causes a decrease in the waveform amplitude.

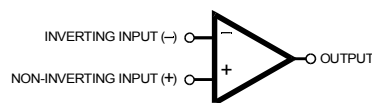
Next adjust VR2's wiper anticlockwise. Once it goes beyond the original midway position, note how rapidly the waveform amplitude increases. You may also notice a change in the waveform's frequency (fewer cycles per screen-full!). Note also that its top and bottom peaks become flattened the more that VR2's resistance is decreased. The peaks are unlikely to be evenly flattened, however. Carefully adjust VR4 until they become more equal.

As you further rotate VR2's wiper, you will eventually see a waveform somewhat resembling a square wave instead of a triangle. Adjusting VR4 will change the waveform's mark-space ratio (discussed in Part 4). Before VR2 reaches its minimum resistance, and with VR4 set too much to either side of midway, the oscillator might stop functioning.

## WAVEFORM INVERSION

That's the first set of observations – on to the next. Return all three opamp wipers (VR2 to VR4) to a midway position. If the oscillator had indeed ceased functioning, this action should restart it. If it doesn't, briefly disconnect the power and then reconnect it.

Adjust IC1's preset VR1 so that a rising-ramp waveform is seen (ramps were discussed in Part 5). Leave all presets as they are and connect the ADC



*Fig.7.3. Opamp symbol and connection names.*

input to the input of IC1a (pin 1). Look back at the screen. Whereas you had a rising ramp a few moments ago, you should now see a falling ramp – curiouser and curiouser!

Time, then, to discuss your findings in relation to an opamp's basic nature.

## BASIC OPAMP NATURE

In essence, an opamp is a two-input single-output device, which has the capability of greatly amplifying a voltage difference between its two inputs. For this reason, it can be called a differential amplifier. Within limits, the amplification is according to a linear relationship. (You will recall that we discussed linear relationships when we discussed potentiometers in Part 3.) For each unit of change at the input, an equivalent but linearly amplified increase will result at the output.

For some purposes (but not all) the amount of amplification (gain) available is far too great to be of use – it can be several hundred thousand times for some opamps. However, there is a simple technique that can be used to restrict the amplification to a more manageable level.

In Fig.7.3 is shown the basic symbol for an opamp (no longer cluttered as it is Fig.7.2). The symbol shows that one input is marked as inverting (–), and the other as non-inverting (+). The different input modes have great significance to the way in which the opamp can be used and controlled.

Note that the “–” and “+” symbols have nothing to do with power supply connections, they merely symbolize the inverting

and non-inverting nature of the respective input.

## INPUT TO OUTPUT

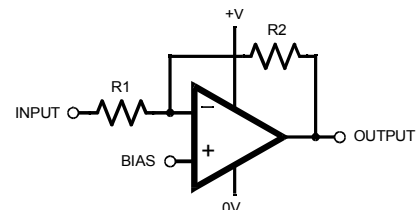
First, suppose that both inputs have the same voltage level applied to them. Because there is no difference between the voltages, the output will be held at the same voltage. If the voltage on the non-inverting input rises fractionally above that on the inverting input, the output voltage will try to rise by the same amount amplified (multiplied) by the gain factor (of, say, 100,000).

Conversely, should the voltage on the non-inverted input fall below that on the inverted input, so the output will try to fall by an equivalently amplified amount.

Obviously, a similar effect will occur, but in the opposite direction, if it is the inverting input voltage that changes while the non-inverting input voltage remains constant.

## NEGATIVE FEEDBACK

Consider, though, what happens if part of the output voltage is fed back to the inverting input, see Fig.7.4. Feedback into this input (via resistor R2 in this case) is known as negative feedback. The output will try to swing in the direction prompted by the relative voltage difference



*Fig.7.4. Feeding back part of the output voltage to the inverting input.*



across the two inputs, but the effect will be diminished according to the amount of that change which is fed back to counteract it.

The output might be trying to change by 100,000 times, but the feedback might be set for 99,990 times. The net difference is thus only 10. Therefore, the effective amplification is only 10 times that of the difference originally fed into the two inputs. The gain is thus said to have a value of 10.

More strictly, when the signal is being applied to the inverting input, the gain should be said to be  $-10$  (minus 10) because of the inversion. For the most part here, though, we shall just refer to the gain as a positive value.

Low gain values are of much better use if you want to just slightly raise the amplitude of a waveform, as you have just done with the triangle waveform. In fact, when you first adjusted preset VR3 to its maximum resistance, the gain you gave to the waveform was about 2, i.e. you doubled the waveform amplitude. So let's explain the mechanism that is used in the circuit of Fig.7.2 to control the signal gain.

## CONTROLLING GAIN

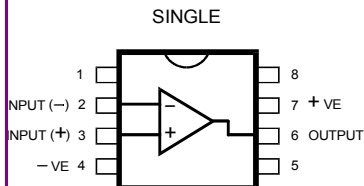
First, assume that the waveform being sent to the inverting input of IC4 via preset VR2 is alternating about a midway voltage level. Let's say the midway level is at 3V (half the voltage applied to the full circuit, as supplied by your 6V battery).

Your initial adjustment of preset VR4 applied just about the same midway voltage (which we refer to as the bias) to the non-inverting input (you will

## PANEL 7.2 – OPAMP PACKAGES

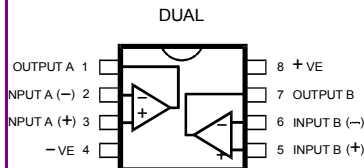
Opamps are manufactured with encapsulations (packages) containing one, two or four individual opamps – these packages being known respectively as single, dual and quad.

The vast majority of opamps have the same pinout configuration per packaging type, as shown here. A few of the opamp types available are listed below their packages. There are hundreds of other type numbers manufactured. Note that some specialist opamps do not conform to these pinouts.



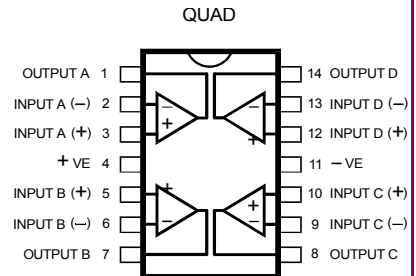
### EXAMPLES

741 (VARIOUS PREFIXES) BIPOLAR  
NE531 BIPOLAR  
TL061 F.E.T.  
TL071 F.E.T.  
TL081 F.E.T.



### EXAMPLES

LM358 BIPOLAR  
NE5532 BIPOLAR  
1458 (VARIOUS PREFIXES) BIPOLAR  
TL062 F.E.T.  
TL072 F.E.T.  
TL082 F.E.T.



### EXAMPLES

324 (VARIOUS PREFIXES) BIPOLAR  
TL064 F.E.T.  
TL074 F.E.T.  
TL084 F.E.T.

control such matters as, for instance, the fine adjustment of the DC output level (offset) to match the basic zero-differential input voltage. Manufacturers' data sheets should be consulted for more information.

recall that you were asked to originally set its wiper to a midway position). This action roughly balanced the two inputs at the midway voltage. The changes in voltage caused by the triangle waveform's swing thus became evenly balanced as seen across the two opamp inputs.

The voltage being fed into the inverting input, however, passes through the resistance offered by preset VR2. On its own that resistance has no appreciable effect on the voltage actually reaching the input. Preset VR3, though, is

connected so that it feeds back part of the output voltage to the inverting input. Jointly, the effect of both resistances, VR2 and VR3, determines the amount of negative feedback that occurs. Respectively, they are the equivalent of R1 and R2 in Fig.7.4.

If both resistances are equal, then the negative feedback amount is the same as the basic input amount, but inverted. The result is that the voltage actually "seen" at the inverting input is the input voltage minus the feedback voltage, i.e. nil! At least, that

would be the case if you ignored the non-inverting input.

But you can't and don't. The internal circuitry of the opamp effectively adds this input's voltage (3V in this case) to the voltage on the other input. Thus both inputs end up with the same voltage on them! Confirm this point using your meter to monitor the voltage on opamp pins 2 and 3, and that from IC1a pin 1.

What's the good of that? you might ask. Well, there's a lot! In order to achieve that balance between inputs, the output has had to change its voltage level. And that's what we are interested in – the change in output level in response to a change in input level.

## BALANCING ACT

In the above equal resistance example ( $VR2 = VR3$ ), the output changes by the same amount as the input, but in the opposite direction. An input change of 1V upwards, for instance, causes an output voltage change of 1V downwards.

If, though,  $VR3$  resistance is twice that of  $VR2$  resistance, twice the amount of feedback is required in order to achieve the balance at the opamp inputs. Consequently, a 1V input change results in a 2V output change in the opposite direction.

Similarly, if  $VR3$  resistance is half that of  $VR2$  resistance, then the output change required to achieve balance is only half that fed into  $VR1$ . Thus, a 1V input rise will cause a 0.5V output fall.

Indeed you have already proved the truth of these statements when observing the affect of changing the values of  $VR2$  and  $VR3$ . You have proved both signal gain (amplification) and signal reduction (attenuation).

## INVERTING GAIN FORMULA

There is a simple formula which defines the gain in relation to the value of the inverting input resistance (call it  $R1$ , as in Fig.7.4) and the negative feedback resistance (call it  $R2$ ):

$$\text{Gain} = R2 / R1$$

Thus if  $R2$  is 100k $\Omega$  and  $R1$  is 10k $\Omega$  the gain is 100k/10k = 10. The output signal will be ten times greater than that coming in through  $R1$  (within certain limits, as discussed in a moment).

Similarly, if  $R2$  is 10k $\Omega$  and  $R1$  is 100k $\Omega$  then the gain will be 10k/100k = 0.1. The output signal will then be 0.1 (one tenth) of the input signal.

## VIRTUAL EARTH

There is a term used to describe the effect seen at the inverting input when there is a balance of voltage directly at the two inputs when feedback is employed – “virtual earth”. This is not a “true” earth in the sense that applies when referring to the common or 0V line of a circuit, but nonetheless it is one into which voltages can be fed via resistances from many sources without causing a change in the virtual earth voltage level at the inverting input. Under feedback conditions, only adjusting the voltage level on the non-inverting input will cause a change in level on the inverting input, this occurring due to the opamp's internal circuitry, as said earlier.

Note that a virtual earth condition does not exist if negative feedback is not employed.

## WAVEFORM CLIPPING

What we have not yet accounted for is the “flattening” of the waveform peaks as the gain is increased beyond a certain point. The term given to this effect is “clipping”.

The clipping has two possible causes. First, the opamp is powered at a particular voltage, 6V (or thereabouts) in your experiments. Reason must tell you that the opamp cannot output a voltage greater than its power supply.

In a perfect opamp, the output voltage would be capable of swinging fully between the two power line levels, 0V and 6V in this case. The flattening occurs when the swing can increase no further, irrespective of the amount of amplification available.

There are, indeed, some more-specialized opamps manufactured whose outputs can swing almost completely between the power line levels. The term given is that they have a “rail-to-rail output capability”, where rail means power-rail (power-line).

Most general purpose opamps, though, do not have rail-to-rail output. Most will only swing within limits somewhat less than the power rail range. The actual range depends on the opamp type, the voltage that it is being powered at, and the amount of current that is being drawn from its output by the load into which it is feeding. Under no-load conditions, the LM358 you are using here has a typical swing of about 0.5V to 3.8V for a 5V power supply.

## PANEL 7.3 – OPAMP POWER LINES

Most opamps are designed to be run from a dual-rail power supply, i.e. one having positive, negative and zero (ground) output voltage rails, typically  $\pm 15\text{V}$  but may not be as high as this with some devices.

As we deliberately demonstrate in this *Teach-In*, opamps can also be powered from a power supply having only positive and 0V (ground) connections. In this case the middle rail voltage is provided by using the voltage at the center of an equally-divided potential divider (as used in the demos).

Note that whilst in theory all opamp circuits shown in this *Teach-In* part can be powered from dual-rail supplies, on no account should dual-rail supplies be used if the circuit is to be connected to the ADC device or to a computer. Additional circuitry would be required in order to permit computer connection. Failure to observe this could seriously harm the ADC and/or computer.

For optimum stability of an opamp circuit, the power supply should be regulated at fixed voltage levels. Power supplies will be discussed in Part 9.

## INPUT CAPACITOR

Earlier, we drew your attention to the likelihood that, when the gain was being adjusted, the waveform position seen on screen would change as well as amplitude. This is in part due to the fact that the triangular waveform tapped from IC1a pin 1 may not be swinging about an exact midway voltage level.

Consequently, any DC voltage difference between the waveform's midway level and that set by VR4 is amplified by the opamp, causing the vertical shift observed.

There is a very easy cure for this – to stop the DC level from the oscillator reaching the opamp, just allowing the AC voltage change through.

In *Teach-In 2000* Part 2 we discussed capacitors in terms of their ability to be charged and discharged through a resistance. We displayed it via one of the computer demos and gave formulae for it.

Capacitors have another attribute, the ability to stop direct current (DC) passing through

them whilst allowing alternating current (AC) to pass through. We shall discuss this ability more fully in a future *Teach-In* part, but for the moment let's accept this as a fact. But bear in mind that future discussions will point out that this ability is governed by the capacitance value and the load resistance into which the "output" side of the capacitor is fed. Two other terms come into use in that discussion, differentiation and integration.

## AC COUPLING

So let's prove the point even though we don't explain it. Remove the oscillator connection from the "DC Input" point on your breadboard and connect it to the "AC Input" point. This now provides the input path with what is known as AC coupling (as opposed to DC coupling, which has been the situation so far).

Run the same group of adjustments using opamp presets VR2 to VR4 as you did earlier and observe the screen results.

You should find that once VR4 has been set midway, there should be no vertical shift of the

waveform as you adjust gain, just the amplitude change.

There is, though, a much more pronounced effect that you may observe, that of a reduction in oscillator frequency with the additional capacitor in circuit. Furthermore, the frequency and shape of the waveform are likely to vary when adjusting opamp preset VR2.

The effect is due to the oscillator now seeing two capacitors in parallel, its own C1, and C2 of the opamp circuit. The effective value of the latter is also changed by the amount of resistance it sees from VR2.

We have a cure for this as well!

## SIGNAL BUFFERING

There is a scenario that we have not yet explored, that of feeding a voltage into the non-inverting input, and merely feeding the output straight back into the inverting input, but without any additional voltage or current being fed into that input. Such a circuit is shown in Fig.7.5.

The interesting thing about this circuit is that the total negative feedback ensures that the voltage applied to the non-inverting input receives neither amplification nor attenuation at the output. Whatever change there is on this input is exactly followed by the output, and in the same direction. In this configuration, the circuit is known as a unity gain amplifier, i.e. the gain is 1. The circuit is also said to function as a buffer.

What is now worth noting is that inputs to opamps draw very little current (some types draw none at all, see Panel 7.1). They are said to have high impedance inputs, where impedance can loosely be described as

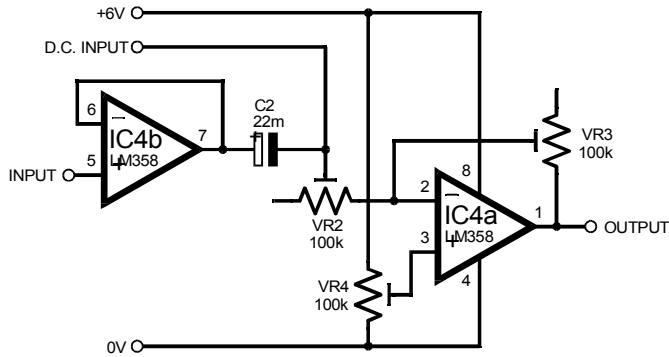


Fig.7.6  
Adding a  
buffer to the  
circuit of  
Fig.7.2

## SIGNAL NON-INVERSION

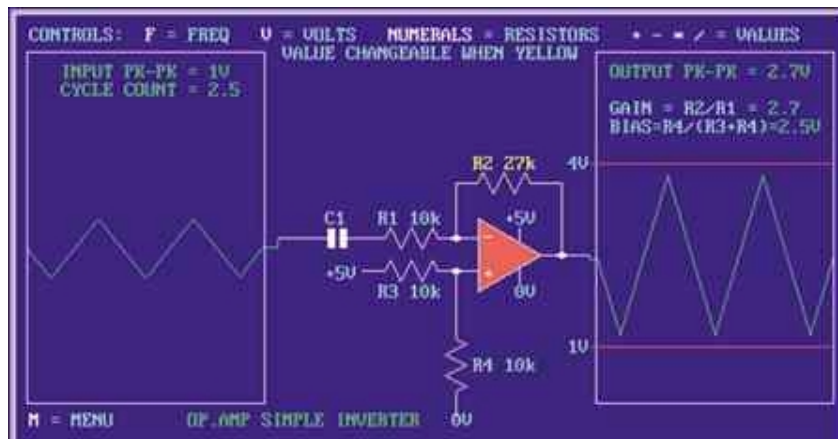
We have not fully discussed the fact the waveform being output from IC4a is an upside down (inverted) version of that generated by the oscillator. There are occasions when this inversion might be undesirable, in DC voltage amplification, for example.

As another example, in audio amplification involving many simultaneously processed sources, signals must often remain the "right-way-up" with respect to each in order to maintain their correct relationships. Failure to do so could have severely detrimental effects on the overall sound quality. It could even result in two signals canceling each other (a principle we shall demonstrate next month).

One way that we can maintain the correct phase relationship, as it is known in waveform processing, is to use the amplifier stage in its non-inverting mode rather than its inverting mode. We can still provide the same amount of amplification.

## NON-INVERSION CIRCUIT

First we need to connect the signal to the non-inverting input of the opamp. We must then provide the correct midway bias voltage to the inverting input. It is, though, this input that is still responsible for partly controlling the negative feedback, and thus the gain. Consequently, the resistance of the bias setting



Interactive computer screen illustrating a non-inverting opamp circuit.

resistance.

In the earlier experiments, capacitor C2 caused a frequency change at the oscillator because the current/voltage flowing through the resistance provided by VR1 was being partly diverted into C2. If we insert a unity gain opamp to isolate (buffer) the charging process for C1 from the effect of C2, then the oscillator frequency will be unaffected by the presence of C2.

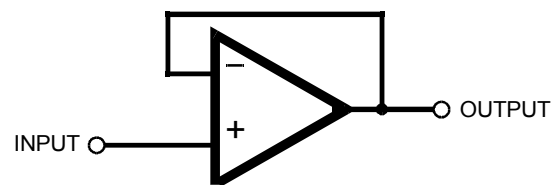
The circuit diagram for this simple improvement is shown in Fig.7.6. Here we now use the second half of the dual opamp, IC4b, to provide the unity gain buffer stage and then feed its output into the amplifier stage

around IC4a, still via C2 and VR2.

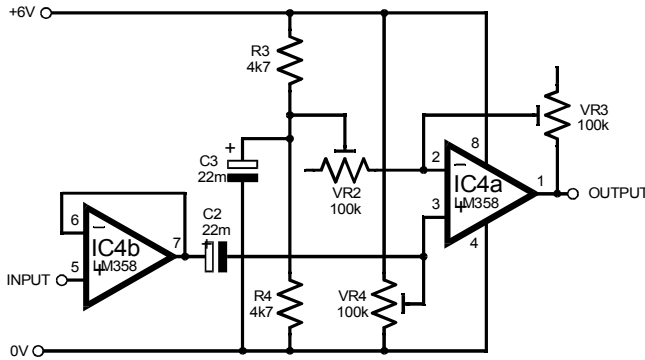
Referring back to the breadboard layout in Fig.7.1, connect the oscillator output from IC1a pin 1 to the point labeled "Buffer Input" and connect "Buffer Output" to "AC Input". Ensure that the small link between columns 25 and 26 of row G is inserted.

Having made the changes, observe that the frequency is now unaffected by the presence of the amplifying stage.

Fig.7.5. Unity gain  
opamp buffer.







*Fig.7.7. Non-inverting opamp amplifier circuit.*

breadboard layout to that shown in Fig.7.8.

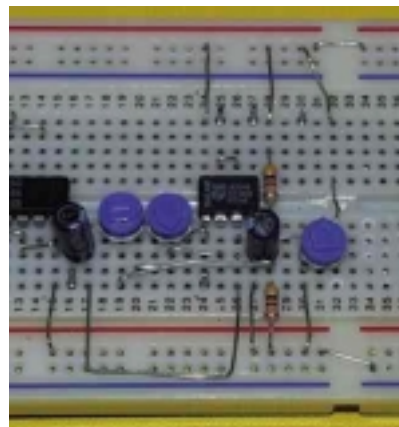
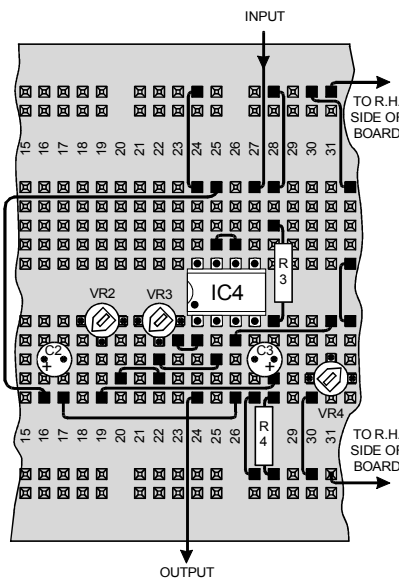
The signal is still being fed in via capacitor C2 in order to isolate the amplification from the affects of the DC bias that might exist from the oscillator. However, we must provide the opamp side of C2 with a discharge path, as supplied via preset VR4.

Note that in the “real world”, the discharge resistance value in relation to the value of capacitor C2 affects the frequency range that can be correctly handled (to be discussed when we examine integration in a later part of the series), and should be chosen accordingly. For the sake of this demo, however, we’ll ignore such niceties – the relationship is OK for what are trying to show.

We retain presets VR2 and VR3, but have to provide a second midway bias voltage into the now “loose” wiper of VR2. This is provided by the voltage divider formed by resistors R3 and R4. At their junction is added a capacitor (C3) to “smooth” the voltage here, which could otherwise vary significantly with the changing signal levels in the feedback path. As we discussed when considering voltage dividers feeding into another resistance (Part 1), the resistance of R3 and R4 should be equal in order to provide the midway voltage, but also of a value about ten times less than the load resistance (effectively VR2 in this case). A value of 4k7Ω has been chosen on the assumption that VR2 is set about midway (about 47kΩ). Fine adjustment of the midway level can be made using preset VR4.

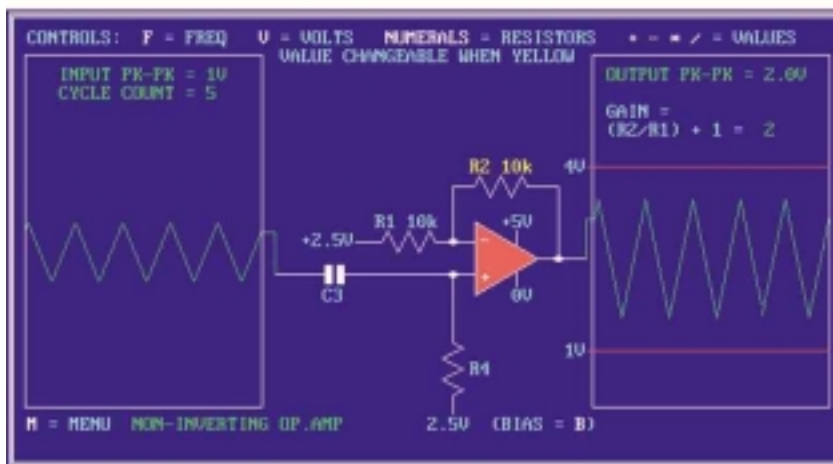
Note that the wrong figure was published for Fig.1.12 of

*Fig.7.8 and photo. Breadboard layout for Fig.7.7. Note that the second half of IC4 is now required to be connected into the circuit.*



There are several approaches to this problem. We shall just take an option that is easy to implement with the breadboard layout we are already using. The circuit is shown in Fig.7.7. Change the

control must also be taken into account.



*Interactive computer display illustrating an inverting opamp circuit.*

Part 1. The correct figure, which illustrates a voltage divider feeding into another resistance ( $R_m$ ), is shown now as Fig.7.9. The circuit in Fig.7.7 does not invert the signal output. Examine the output at IC4 pin 1 as shown on your screen (via the ADC) and confirm that it is the same way up as the original. Now that you have a buffer amp in circuit, you can monitor the basic oscillator waveform from its output (IC4 pin 7).

## NON-INVERSION GAIN

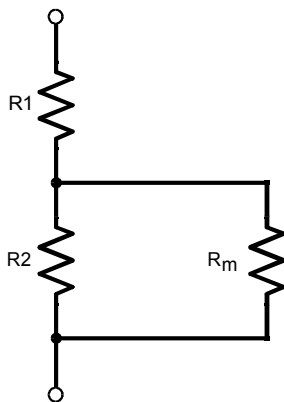
Earlier we defined the formula for calculating inversion gain as:

$$R_2 / R_1$$

...where  $R_1$  and  $R_2$  represented the inverting input and feedback resistances respectively.

Using the inversion configuration, signal attenuation can be achieved as well as amplification.

For the non-inverting amplifier, the lowest level of signal amplification is 1 (unity), attenuation can never be achieved. Consequently, the



*Fig.7.9. Why a meter (represented by resistance  $R_m$ ) affects the voltage reading at resistor junctions. Corrected Fig.1.12 for Part 1.*

## PANEL 7.4 – RESISTANCE VALUES

The question of what decade ranges the resistance values should be chosen from for opamp designs is a slightly tricky one. You will recognize that a uniform potential divider, for instance, can be made up from any two equal resistance values. So, should the values each be  $1\Omega$ ,  $10k\Omega$  or even  $10M\Omega$ ? We have to say first that only a text book heavily dedicated to opamps can really give definitive answers. There are, though, some basic considerations that it is appropriate to mention here:

One consideration is that power economy should always be at the forefront of any designer's mind. Since power consumption is less with higher value resistors, this does not favor very low resistances for the divider. We have already said that a divider's resistance should ideally be at least ten times less than the load into which it feeds. When the divider is feeding into the non-inverting input simply as bias, its resistance can therefore be comparatively high. When it is providing bias to the inverting input of a feedback circuit, the load is provided by the effective input resistance and so the divider resistance should be chosen with respect to that.

The input resistance is chosen in relation to the gain required and the resulting value of the feedback resistor. One matter to consider here is that the gain of an amplifier (as opposed to a comparator) is usually best kept below about 200, and preferably below 100.

In DC amplification circuits, another factor to be considered is that (again, ideally) both opamp inputs should have equal current flow, and the resistances should be chosen to meet this condition. In choosing gain setting values, and those of the dividers, it should be borne in mind that very high values of resistance are prone to causing the circuit to pick up signals from external electrical sources, such as mains "hum", motorbike ignition, frequency radiation from TV or computer monitors, etc.

Additionally, the relationship between signal capacitors and resistors affects the frequency response of the circuit as a whole. Some of this capacitance can be due to that which exists in the opamp itself, as well as the proximity of one printed circuit board track to another.

With some opamps a further problem is that if the load they feed into has quite a low resistance, distortion of the output can occur if the feedback resistance is too high.

As a very rough guide, however, the ranges of input and feedback resistances are usually best kept between about  $1k\Omega$  and  $1M\Omega$ , but it does depend on the circumstances. It is then usually best if the values are chosen from the "commonplace" decade multiples, such as those in the E12 range (see Part 1): 1, 1.2, 1.5, 1.8, 2.2, 2.7, 3.3, 3.9, 4.7, 5.6, 6.8 and 8.2.

To help you become more conversant with what resistance values can be chosen for different opamp circuits, study the published circuits of other electronics designers.

Finally, despite this list of considerations, for general experimentation opamps are really easy devices to use successfully! You can play around with component values to your heart's content with an excellent chance of achieving results (even if they are not perfect). Furthermore, opamps are such hardy devices that you are highly unlikely to ever kill one!

gain calculation becomes feedback resistance (R2) divided by inverting input resistance (R1), as before, but a value of 1 is then added:

$$\text{Gain} = (R2 / R1) + 1$$

You will probably spot that if R2 has a value of zero, then the unity gain condition exists, irrespective of the value of R1.

## DC AMPLIFICATION

For the last several paragraphs we have concentrated heavily on an opamp's ability to amplify waveforms (i.e. AC signals). You may not have recognized it, but you have already proved that the opamp is equally suited to amplifying DC levels.

When you were initially experimenting with the relationships of the three presets in Fig.7.2, you needed to adjust VR4 in order to compensate for the DC bias coming from the oscillator. You may have noticed that the adjustment became more sensitive when the gain was set high by either VR2 or VR3.

This was entirely due to the DC bias from the oscillator and VR4 being amplified. At that time the DC amplification was undesirable. There are, though, many occasions in which a DC level needs to be amplified in order to be useful.

One example that comes to mind is the way in which the thermistor (heat sensor) and light dependent resistor (LDR) you were encouraged to try as part of various oscillator experiments could be used (Part 3). We'll examine how voltage change with temperature or light intensity can be monitored on your multimeter and computer screen as part of next month's Tutorial.

## DC STABILITY

We must comment now, however, that amplifying DC voltage is not necessarily as easy as one might like. We have said that the values of electronic components can change with temperature, indeed the thermistor is an exaggerated example of this (but intended to do so beneficially). Unfortunately, opamp circuits are no exception to this rule. Not only can the components that are used in conjunction with opamps have their values changed according to temperature, but so too can the characteristics of the opamp itself.

The subject is actually too complicated to fully discuss or demonstrate as part of Teach-In, but it is something of which you should be aware. There are many circuit techniques by which the problem can be overcome, and more sophisticated (and expensive) opamps in which the situation is less pronounced.

## TEMPERATURE DRIFT

A particular example of an opamp's temperature dependency affects the DC output relative to the input. In a DC amplification circuit you can set up a bias level on one input in order to bring it closer to the DC level on the other input (i.e. narrow the differential voltage between the two). The resulting DC output level, however, may only hold true at the temperature at which the adjustment is made.

As the ambient (surrounding) temperature changes, so the DC output level can change, even though the voltage difference on the two

inputs seemingly remains the same. Such a change is known as temperature drift. It will be far more pronounced at higher amplification settings. Typical temperature drift values are usually quoted in component data sheets, often in the form of graphs.

You should also be aware that an opamp can heat up internally when the current into or out of its output increases, and that this will affect its characteristics.

For AC amplification (waveforms fed in and out via capacitors), though, temperature drift is seldom of any significance.

## COMPUTER DEMOS

We suggest that you now run two of the opamp demo programs, which interactively illustrate the functioning of inverting and non-inverting opamp circuits.

From the main menu select *Opamps – Menu*, this will bring up another screen from which five opamp demo programs can be selected. The two we suggest you play with now are *Simple Inverting Amp* and *Simple Non-Inverting Amp*. We shall discuss the other three options next month.

The inverting demo illustrates an opamp's response to an AC-coupled input triangle waveform in respect of different resistance values. Resistors R1 and R2 control the gain, while R3 and R4 change the bias on the non-inverting input.

The non-inverting demo also inputs an AC-coupled triangle waveform. Resistors R1 and R2 control the gain. R4 has a fixed unspecified value; it is the "bleed" resistor required following input capacitor C3. The bias voltage applied via R4 can

be changed.

Signal input amplitude and frequency rate (Cycle Count) can also be changed. The power supply voltage is fixed at +5V/0V. Note that the demo opamp has been given output min/max limits of 1V and 4V.

The controls are stated on screen, press the appropriate keys to activate the function to be changed. Note the varying conditions under which the

output signal can become clipped. You can press the <PAUSE> key to stop the waveform scrolling, then press any other key to restart scrolling.

### ***NEXT MONTH***

This seems a convenient point at which to end this month's Tutorial. We do not have room for an Experimental section as such, this has been

moved forward to next month and becomes Tutorial Part 8.

In reality, Part 7 and Part 8 are both a mixture of Tutorial and Experimental. What we discuss in Part 8, though, is all based on the characteristics we have been describing here in Part 7, and illustrates some interesting ways in which opamps can be used.



# Practically Speaking

## Robert Penfold looks at the Techniques of Actually Doing It!

It is said that the simplest inventions are the best ones, and, for the electronics hobbyist, stripboard possibly ranks alongside sliced bread and the wheel in the "best inventions" stakes.

Stripboard is a proprietary printed circuit board that is noted for its versatility. For most projects it represents the only practical alternative to using a custom printed circuit board (PCB).

A project based on a custom board is actually the best choice for a complete beginner due to the relatively foolproof nature of these boards. However, many small and medium sized projects are based on stripboards, and newcomers to the hobby soon find themselves using this method of construction.

Although stripboard is not quite as straightforward to use as custom PCBs, it is not really that difficult to use either. There are a few traps waiting for the unwary, but once you are aware of the pitfalls it is not too difficult to obtain perfect results almost every time.

### RIGHT PITCH

So what exactly is stripboard? It is based on a board about 1.6mm thick that is made from an insulating material. Presumably the color of the board varies from one manufacturer to another, but it seems to be supplied in a variety of yellow-brown colors from almost white to virtually black.

The board is drilled with one-millimeter diameter holes on a regular matrix. In the past it

was possible to obtain stripboards with the holes spaced at 0.1-inch, 0.15-inch, or 0.2-inch intervals, but these days only 0.1-inch boards are readily available. It is only 0.1-inch pitch boards that are of any real use with modern projects, because many components will not fit onto 0.15-inch or 0.2-inch boards.

One side of stripboard is plain, while the other side has copper strips running along the rows of holes. It is, of course, from these copper strips that the stripboard name is derived. Many people still refer to this material by the old proprietary name of "Veroboard".

Like an ordinary single-sided printed circuit board, the components are mounted on the plain side. The leadout wires are trimmed short on the other side and soldered to the copper strips, which then carry the connections from one component to another. Fig.1 shows the plain and

copper sides of two scraps of stripboard.

### BRITTLE EXPERIENCE

With a custom PCB there is usually no preparation required. When you are ready to start construction you simply begin fitting the component to the board. With stripboard a small amount of work is needed before the board is ready to accept

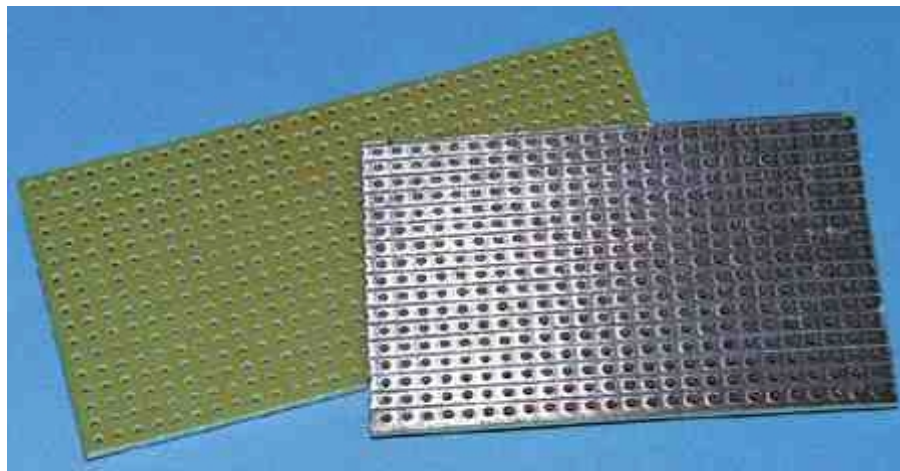


Fig.1. Stripboard only has the copper strips on one side.

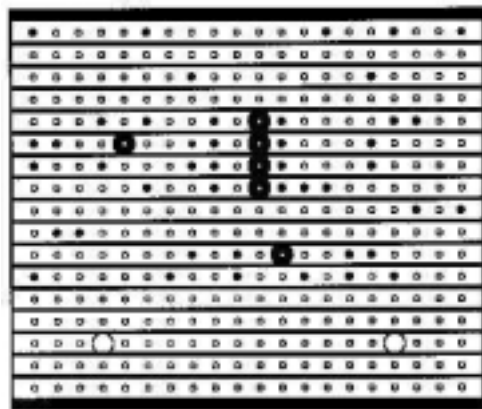
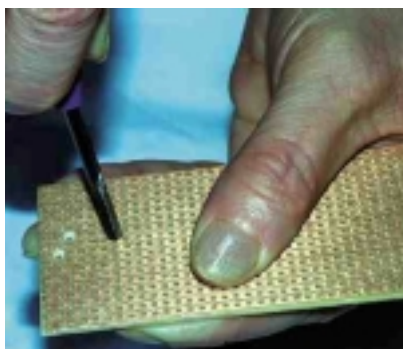


Fig.2. The underside view of the board will clearly show the positions of any breaks required in the copper strips.

the components, and the normal first step is to cut out a board of the required size.

As pointed out previously, stripboard comes in a range of yellow-brown colors, reflecting a range of materials used in the board. Some of these materials are tougher than others, but most stripboards seem to be slightly brittle. It is best to err on the side of caution and assume that all these boards are brittle,



*Fig.3. Using the special tool provides the easiest way of making breaks in the copper tracks.*

and exercise due care when working on them. Use the “hammer and tongs” approach and you may well end up with three or four small boards instead of one large one!

Over the years various suggestions have been made for quick and easy ways of cutting stripboard to size using implements such as glass and tile cutters. The problem with these methods is that they work well with some makes of stripboard, but can produce disastrous results with others.

The only truly reliable method found so far is to carefully cut along rows of holes using a hacksaw. Due to the close spacing of the holes and width of the blade it is not practical to cut between rows. Cutting along rows of holes inevitably pro-

duces some very rough edges, but these are easily filed to a neat finish using a flat file.

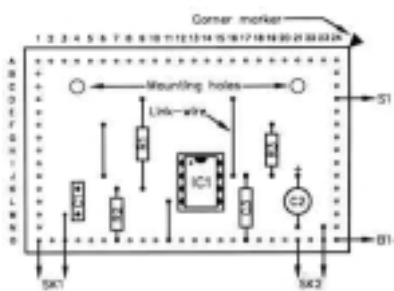
The finished board might slot into place in the case, but it is more likely that it will be bolted in place. Any mounting holes should be drilled at this stage using an ordinary HSS twist drill. Use a piece of scrap timber, chipboard, etc. underneath the board, and use only moderate pressure. This should give good “clean” holes and avoid any cracking around them.

When drilling any form of copper laminate board it is best to drill the board with the copper side uppermost, as there is otherwise a risk of the copper being torn away from the board.

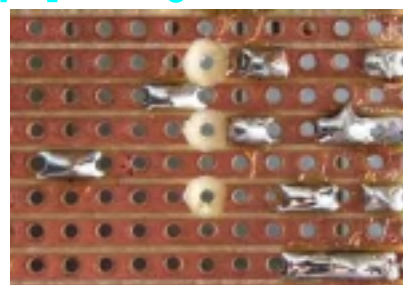
### BIG BREAKS

With anything but the most simple of projects it is necessary to make some breaks in the copper strips. Without any cuts each strip can only carry one set of interconnections, but by breaking a strip into (say) three pieces, it can carry three sets of connections.

The article describing the project should include a diagram that clearly shows the positions of the breaks, as in the example of Fig.2. Double-check the position of each break before actually making it. If a mistake should be made it is possible to solder a small piece of wire over



*Fig.4. An example stripboard layout diagram.*



*Fig.5. Removing some excess flux rendered this solder bridge fairly obvious.*

the break, but more than the occasional repair will give scrappy looking results and poor reliability.

A special strip-cutting tool is available, and it is often referred to as a “spot face cutter” in component catalogs. This is basically just a drill style cutting tool fitted in a handle. In order to cut a strip the point of the tool is placed in position and the handle is given a couple of rotations while applying moderate pressure (Fig.3).

If you will be producing anything more than the occasional stripboard project, it is certainly worthwhile buying this tool. Initially you may prefer to use a handheld twist drill bit of about 5mm in diameter, which will do the job quite well.

Either way, make quite sure that the strips are cut right across their full width. Very fine residual tracks of copper can be difficult to see with the naked eye, so it is worth checking the board with the aid of a magnifier.

Although you need to make sure that the strips are cut properly, do not go to the other extreme and practically drill through the board. With a large number of breaks this would seriously weaken it. Brush away any copper shavings as these could otherwise cause short circuits.

### MOVING IN

At this stage the board is ready for the components to be added. This is one respect in which stripboard is rather more awkward than a custom printed circuit board. With a PCB there is one hole per leadout wire or pin, but with stripboard less than 10 percent of the holes are normally used.

Mistakes with component placement are more easily made, and when they do occur they can be difficult to spot. To compensate for this it is necessary to proceed more carefully and to double-check the positioning before fitting and soldering each component in place.

Having to remove and refit a small component occasionally is not a major disaster, but getting a multi-pin component, such as an integrated circuit (IC), in the wrong place can be more difficult to deal with. Removing this type of component requires proper desoldering equipment and risks damaging the board.

Getting a large number of components shifted out of position is time consuming to correct, and all the soldering and desoldering could take its toll on the board. It is much better to proceed carefully and get things right first time.

### ON YOUR MARKS

Stripboard layout diagrams often have letters to identify the copper strips and numbers to identify the columns of holes, as in the dummy layout diagram of Fig.4. Many constructors find it useful to mark the board itself with these letters and numbers, so that they can quickly and easily match any point on the board with its equivalent point on the diagram.

A fine point fiber-tip pen is required, as there is not a great deal of space available for the labels. Also, it needs to be a type that is capable of writing on glass and other non-porous surfaces. Otherwise it will not mark the board properly, or the labels will rub off the first time you handle the board.

It is difficult to mark numbers for all the columns of holes, but navigating your way around the board should still be easy if only every fifth or tenth column is labeled. Similarly, it is only necessary to label every other copper strip, or even every fourth or fifth strip.

Do not make the classic mistake of getting the orientation of the board wrong so that all the components are fitted in the wrong places. There are usually mounting holes that make the correct orientation obvious, but the diagrams for the two sides of the board normally have a marker that indicates the same corner of the board in both views. This is included in Fig.2 and Fig.4, and leaves no excuse for getting it wrong.

### MISSING LINK

With the preliminaries out of the way, assembling a component panel is much the same whether it is based on stripboard or a PCB. There are a couple of differences though, one of which is the higher number of *link-wires* encountered when building projects based on stripboard.

The copper tracks of a custom PCB can weave all round the board if necessary, but this is clearly not possible with stripboard. Link-wires provide a means of compensating for the lack of versatility in the track pattern, and enable connections

to run from any given point on the board to any other point. Virtually every stripboard layout has at least a few link-wires, and the larger boards can have dozens of them.

The usual way of fitting link-wires is to pre-form a piece of wire to fit into the layout in much the same way as resistors and axial capacitors are fitted. The ends of the wires are then trimmed to length and soldered to the board in the usual way.

An alternative method is to cut a piece of wire that is slightly over-length and then solder one end of it to one of the holes in the board. Next thread the other end of the wire through the second hole and pull it tight using a small pair of pliers. Finally trim the wire and solder it to the board.

The trimmings from resistor leadout wires are ideal for short link-wires, but for longer wires 22s.w.g. or 24s.w.g. (or about 0.6mm diameter) tinned copper wire is needed. Where a layout has a lot of link-wires be sure to meticulously check that every link has been fitted to the board.

There is no need to insulate short links, but with wires of around 25mm or more in length there is a slight risk of short circuits occurring, particularly where there are several wires running side by side. In this case, it is advisable to fit the longer link-wires with pieces of PVC sleeving.

### BUILDING BRIDGES

The second potential problem with stripboard is accidental short circuits due to solder splashes and excess solder on joints. This can be a problem with any form of printed circuit board, but it tends to be more problematic with stripboard due



to the very narrow gap between one track and the next. There is actually only about 0.3mm between adjacent tracks.

Usually it is fairly obvious when excess solder bridges two tracks, and remedial action can be taken straight away. Small amounts of excess solder can usually be wiped away with the bit of the soldering iron, but large amounts should be removed using a desoldering pump. The affected joint or joints can then be carefully remade.

The real problems are caused by the tiny trails of solder that are barely visible. In fact, they are sometimes buried under excess flux and can only be seen if the board is cleaned (Fig.5).

Having completed a stripboard it is definitely advisable to

clean the copper side of the board and thoroughly check it for solder bridges. Cleaning fluids for removing excess flux are available, but simply scrubbing the board vigorously with something like an old toothbrush seems to do an equally good job.

Any reasonably powerful magnifying glass will provide a good close-up view of the board, but something like an 8x or 10x loupe is best. These are primarily intended for viewing slides and they are available from most camera shops. The cheapest of loupes is adequate for this application.

If a stripboard refuses to work for no apparent reason it is worthwhile making some checks using a continuity tester. Check that there are no short circuits between adjacent copper strips

or across any breaks in the strips. Usually, once you know a short circuit is there it will miraculously appear when the board is given another visual check!

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## BACK TO THE FUTURE WITH MILLIPEDES

*Millipedes may help bring back punched card technology for PC data storage. Barry Fox reports*

A team of researchers from IBM's laboratory in Zurich recently revealed their road map for the future of data storage. One surprise is that punched cards are due for a comeback, but around a million times smaller than they were the first time round.

The real density of hard disk recorders is now increasing at 120 percent per year, thanks to IBM's 1988 discovery of GMR, the giant magneto-resistive material which was ready for commercial exploitation two years ago and is now used in 70 percent of all hard drive read heads – either made by IBM or under license.

GMR is a multi-layer sandwich of magnetic and non-magnetic materials, which show dramatic changes of resistance in a changing magnetic field. This makes the read head ten times more sensitive, and so lets it detect smaller magnetic domains.

### Hard Drive Density

Currently hard drives can record around 20 Gigabits of data for every square inch ( $6.45\text{cm}^2$ ) of surface area and 35 Gigabit per square inch drives are already working in the lab. The likely practical limit looks like being 100 Gigabits. At this density, the individual magnetic domains are so small and close that they affect each other, making storage unreliable. Before this limit is reached, the cur-

rent method of recording a signal, with a miniature inductive head, will have become unworkable.

IBM's Magneto-electronics team leader, Dr Stuart Parkin, believes that in two years time hard drives will have to use vertical recording (VR) instead of

horizontal recording (HR). For VR the domains are switched by a field that aligns the magnetic particles through the disk coating.

IBM's Microdrive, the hard drive no bigger than a large postage stamp, currently stores 340 Megabytes, or nearly 900

## Microchip Handbook



Many of you will already have found how useful Microchip's *Embedded Control Handbook* can be when writing PIC microcontroller software. The latest update to this book has been released and provides a comprehensive reference tool for anyone using PICs and related products.

The 848-page updated handbook provides current application notes, technical briefs and reference designs which have been written and published since the previous edition. The book can be obtained through any authorized Microchip representative. The material is also available individually on Microchip's website at [www.microchip.com](http://www.microchip.com)

It is interesting to note from another Microchip press release that the organization is offering a comprehensive University Program within the UK, designed to help university professors give their engineering students a hands-on understanding of PICs and related products. Details can be found via [www.microchip.com/university](http://www.microchip.com/university)

Microchip's UK HQ is at Microchip House, 505 Eskdale Road, Winnersh Triangle, Wokingham, Berks RG41 5TU, UK.

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still pictures from a video camera. The next Microdrives will hold 1GB. By comparison an 8MB Compact Flash card holds around 20 pictures.

So what happens when disk drives run out of space? Dr Bernard Meyerson, IBM's Director of Telecommunications Technology, dismisses the idea that optical disk can take over from magnetic hard disks.

"IBM has worked for years on optical storage, including disks with several layers to increase density. But there is a basic limiting factor – the wavelength of light".

### Millipede Tips

Big Blue's *Blue Sky* research efforts are now concentrated on an extraordinary new technology called Millipede. A silicon chip, the size of a fingernail, is made with a matrix of 1024 tiny cantilever arms, each with a sharp tip, around 1nm in size. When the tips are moved, by feeding current to activate drive coils, they press down on a spinning plastic film disk to create tiny indentations. These can then be read by sensor tips.

## Greenweld Catalog

You will be glad to hear that Greenweld have reopened. Chris Knight tells us that after many months of work they have finally got the business going again. You will probably recall that the original Greenweld Electronics ceased trading last year, but the remaining stock was astutely bought by Chris and Tim Knight and Geoffrey Carter.

The trio have a scientific background and wide business

The fundamental science on Atomic Force Microscopy was done in 1980, and won a Nobel Prize for IBM's Dr Gerd Binnig in 1986. The first laboratory demonstrations are now nearly ready. "*It's back for the future*", says Gerd Binnig, alluding to the original punch card, developed in the last century for census data processing and then used by early computers.

But whereas original punch cards had permanent perforations, the new Millipede recording material can be erased, by heating the plastic to re-flow depressed areas. The chip moves across the surface, in a scanning raster, writing 1GB of data in a 3mm x 3mm area.

The write/read system must be kept surgically clean, but the techniques used to keep hard drives clean are applicable. Air is continually blown over the surface, through very fine filters.

### Tunneling Ram

There are also new developments coming in Random Access Memory. Current RAM needs power to retain data. TMJ (tunneling magnetic junction)-RAM retains data even when the

power is switched off. So it works like flash memory, but with much higher capacity, and much lower power needed for writing. With Magnetic RAM a PC could boot up within seconds.

The system relies on the ability to detect and control the spin parameters of electrons in ferromagnetic materials. Switching at low power is possible because of the quantum physics phenomenon known as tunneling, whereby if enough electrons confront a barrier, some will pass through, even though their energy state is theoretically too low to allow it.

Good wishes to Greenweld from us all at *EPE* and *EPE Online*.

For more information, contact Greenweld Ltd., Dept EPE, PO Box 144, Hoddesdon, Herts, EN11 0ZG, UK.

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## WIND POWER

A book called *Windpower Workshop: Building Your Own Wind Turbine*, has been written by Hugh Piggott, the technical consultant to the BBC 1 docu-soap *Castaway 2000*, in which the castaways rely on renewable energy for their power needs.

Hugh has lived for 25 years on a similar island and runs his own wind turbine company. His book is based on his knowledge of wind power harnessing and is aimed at helping budding sur-

experience, along with interests ranging from computers to cars and robots to recycling.

We are pleased to have received the new Greenweld catalog, the first under the new ownership and management team. The catalog lists many ranges of the types of component that anyone involved in electronics is likely to need, not only resistors, capacitors, potentiometers, logic ICs, LCSs and so on, but also items such as meters and tools, hardware and surplus stocks, and there is a selection of books as well.

vivalists, hobby engineers, self-sufficiency hopefuls and students of renewable energy to learn more about wind power.

The book is priced 10 UK pounds (plus 1.75 pounds shipping and handling), and is available by mail order from the Center for Alternative Technology, Machynlleth, Powys SY20 9AZ, UK.

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## MILLENNIUM TIME CAPSULE

The Millennium Time Capsule is a major national UK project in celebration of the new millennium. Businesses, schools, clubs and the general public are invited to take part in this prestigious event and to send a personal message to future generations. The Millennium time capsule will be buried for 200 years. Inside, contributors will have their own box containing whatever they wish to include. Photographs, videos, books, tapes, letters – the list is as long as your imagination.

The time capsule will be the largest ever constructed, providing a snapshot of the UK at the end of the millennium. But it will also be a very personal record. Every contributor will be sent certification, identifying *their* box within the capsule. In this way individual boxes can be passed down from generation to generation and inherited by our descendants in the year 2200.

The massive site will house thousands of time capsules from people from all over Britain and abroad. Time capsules can be

sent to the project throughout the year 2000. The site will be sealed in 2001 and shall remain buried for 200 years. A trust is being established to ensure the site is excavated in 2200. Anyone can take part by filling a time capsule pack and sending it back to the project. Each pack contains a time capsule measuring 340mm x 250mm x 80mm, along with specialized folders and envelopes which help to preserve the items within it.

Records of the project, including the participants and location of the site shall be kept with The International Time Capsule Society in Atlanta, key regional record repositories in Britain and within the records of the project itself.

The location of the site will be announced later this year.

Everyone who takes part receives a certificate giving them legal title to their time capsule and its contents, allowing them to leave their legacy to future generations.

Packs can be ordered by sending a check for 41 UK Pounds made payable to: The Millennium Time Capsule Project and sent with the participants name and address to: The Millennium Time Capsule Project, PO Box 736, Newcastle upon Tyne NE99 1LQ, UK. Alternatively, packs can be ordered through the website shown below.

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Why not tell us, for possible inclusion in Readout, what you are sending or would like to

have sent if the capsules had been large enough? Replies may be serious or humorous (but at least loosely connected with electronics)!

## Three Counties Radio & Computer Rally

Sunday 21 May 2000. By popular demand following the 1999 rally, the Three Counties annual radio and computer rally is to be staged a week before the Spring Bank holiday. It will be held at the Perdiswell Leisure Centre, Bilford Road, Worcester, UK.

For those not familiar with the venue, the following facilities are available: full restaurant services from 7 AM, licensed bar from 11 AM, all traders in two adjacent halls, easy access to the halls which are at ground level, free parking for 900 cars and coaches.

The organizers point out that, being close to the City Center, wives and children can spend a pleasant day in Historic Worcester, sight seeing, shopping or a boat trip on the river Severn (we'd like to ask why wives and children should be shuttled off – we are sure they are just as interested in what the rally has to offer as the rest of us are!).

For more details contact William E. Cotton G4PQZ, Tel/ Fax: +44 (0) 1905-773181 (for fax please ring first).

## Farnell's Catalog

No longer need you complain that *"the Farnell catalog is great but it's just too big"*! This renowned supplier is separating its catalog into six books, split by product. It will be available from April.

Farnell say that this allows emphasis to be placed on their

---

core product strengths, market the full range, provide the "ultimate one stop shop" and to focus on new products three times a year instead of twice, as at present.

From the summer edition onwards, color pages will also be made available for suppliers to advertise their products in these books.

Farnell's catalog always has been a "must" to have in your electronics workshop. This change of binding will surely be welcomed. Don't forget, also, that Farnell have product data on CD-ROM as well.

For more information contact Farnell, Canal Road, Leeds LS12 2TU, UK.

## NEWS.....

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# Readout

**John Becker addresses some of the general points readers have raised. Have you anything interesting to say? Email us at [editor@epemag.com](mailto:editor@epemag.com)!**

## WIN A DIGITAL MULTIMETER

The DMT-1010 is a 3 1/2 digit pocket-sized LCD multi-meter which measures a.c. and d.c. voltage, d.c. current, and resistance. It can also test diodes and bipolar transistors.

Every month we will give a DMT-1010 Digital Multimeter to the author of the best *Readout* letter.

## \* LETTER OF THE MONTH \*

### REGENERATIVE RECEIVER

Dear EPE,

Regarding the Regenerative Receiver (March '00 issue):

The use of positive feedback to increase the Q of tuned circuits was widely used in commercial wireless receivers in the 1920s and early 1930s; amateurs continued to use the technique until the 1950s. The term commonly used was "reaction" and controls with this label appear on many receivers. The feedback in early sets was inductive with a pivotally mounted "reaction" coil that could be turned towards a static "tuning" coil. In later sets the feedback was fed through a variable capacitor, usually with solid dielectric, to a supplementary reaction winding on the coil used to form

the main tuned circuit.

There were disadvantages with using reaction to increase sensitivity. If the feedback exceeded a critical limit the circuit oscillated and, as it was usually coupled to the aerial, became a transmitter. This had disastrous consequences as many receivers in the neighborhood would be swamped by the radiation and those with critically adjusted reaction controls also burst into oscillation.

The BBC Handbook for 1929 has warnings about the problem, leaflets were issued by the Post Office (then the wireless licensing authority) and cartoons on the subject appeared in Punch. (In 1929 the BBC Handbook carried circuit diagrams to assist potential listeners to construct receivers!). People were branded as bad neighbors if they were suspected of oscillating. The addition of an RF amplifier stage alleviated the problem as the oscillating circuit was no longer directly connected to the aerial.

Increasing the Q of a tuned circuit also limits bandwidth. In the early days of broadcasting the signals were Morse (CW) and bandwidth limitation was a positive advantage. By the 1950s, AM broadcast sound quality had reached a standard where this bandwidth limitation was significant.

The oscillation caused by positive feedback in circuits using "leaky grid" detectors was rectified by the grid driving the valve into cut-off until the charge leaked away, so called

"squegging", generating pulses of radiation. This circuit system, as the self-quenching super-regenerative receiver, was also patented by the brilliant Edwin Armstrong. The ratio of signal frequency to squegging frequency needed to be between 100 and 1000 so that audio reception was only possible at Short Wave and higher frequencies.

The circuit was used in the short range "B" set of Wireless Set 19 by the Army, in IFF responders (MkIII) by the Navy and Air Force. The Lichtenstein night fighter radar used by the Luftwaffe also relied on the circuit. Super-regenerative receivers, if mistuned, could receive FM, and Hazeltine "Fremodyne" used a double triode to receive FM and provide an audio output.

PS In an act of generosity, possibly misplaced, I presented my copy of the BBC Handbook 1929 to the East Midland Radio Museum in upstate New York. The place is worth a visit if only to see the spark gaps operated and the poster advertising the return trip of the Titanic. Possibly there is a copy at Amberley.

A book worth reading is *Super-Regenerative Receivers* by J.R. Whitehead, Cambridge University Press, 1950. (Dr Whitehead was a TRE man so the book is biased towards aircraft equipment.)

**Guy Selby-Lowndes  
Patent Attorney  
Plaistow, Billingshurst**

*Thank you Guy, most interesting information. We assume you refer to Amberley Chalk Pits Museum, near Arundel, West Sussex, UK – it has many historic items relating to radio and electron*

### **PIC LOCATIONS 0 TO 3**

Dear EPE,

PICToolkit Mk 2 (May-June '99) forces the addition of a JMP to location 0005 at the Reset Vector and loads any HEX file from location \$0004 onwards, despite the HEX file address information. Similarly, the decode routine used during disassembly totally ignores ANY CODE in locations \$0000 to \$0003 inclusive.

Note that it is common for an interrupt routine code block to start at 0004 and continue through 0005 until the end of the routine. It is also common for other code such as Subroutines to start at 0005, the Reset vector being a JMP to the relevant location.

**Peter Balcombe  
via the Net**

*The reason for Toolkit not allowing programmed access to locations 0 to 3 is historical, having adopted the convention used in the Simple PIC16C84 Programmer of Feb '96, as designed by Derren Crome. The same question was subsequently raised by other readers and we have replied in various ways since then. The following is Derren's original reply:*

*When the PIC is put into programming mode, it sets its internal counter to \$0000, which is the reset vector address. It was decided to have the program set this to \$0005, which is the beginning of the program*

*memory address space.*

*Addresses \$0001 to \$0003 are not of use to the user. Address \$0004 is the interrupt vector which is set by the first line in the assembly code. The user program starts at \$0005.*

### **PIC16F87x PROBLEMS**

Dear EPE,

I have been experimenting with the new PICs ('876 and '877) and *Toolkit Mk2* hardware and software, mostly using a 3.2768MHz crystal clock rate.

I have problems with Port C bits 0 and 1 as outputs at relatively fast state changes. With "slow" switching, e.g. using your TKTEST4 program, all seems OK. However, if I halve the COUNTs to speed up switching, the bit C0 square wave becomes erratic and the bit C1 square wave gets somewhat noisy. If I output \$00 and \$FF to all ports in a rapid loop, these two bits are a mess, while all other bits, on Port C (and Ports A, B, D and E) are OK.

I am setting PAGE0 and PAGE1 OK using both bits RP0 and RP1, and I have even tried ensuring that TIMER1 is off by setting file T1 CON to all zeros. I assume the problem is something to do with the multi-functional nature of these two bits, and most likely to do with TIMER1. I have examined the PIC datasheet and recent issues of *EPE* but I am foxed. I note in the *8-Channel Data Logger* (Aug-Sep '99), that you use these two bits for push-button input, which is slow (and not output), so maybe you have not seen this problem yet. Can you offer any help, please?

TK2 is great! Thanks for adding recognition of TABs for spaces. You asked for suggestions for other facilities: are you

able to add two useful functions to the assembler (functions which TASM supports), I think many people would find they make for clearer programs:

(a) Simple addition in statements, e.g.:  
HIGHBIT EQU %10000000  
RETLW 'P'  
RETLW 'I'  
RETLW 'C' + HIGHBIT  
;end of string 'x' of total 'n' strings

I use this for a useful LCD text driver, with top bit set for end of each string, filtered off before displaying. It currently causes an error in TK2.

(b) Multiple components to a #DEFINE statement, e.g.:  
EQUs for STATUS, RP0, RP1, then:  
#DEFINE SETRPO BSF STATUS,RP0  
#DEFINE CLRRP1 BCF STATUS,RP1  
#DEFINE PAGE1  
SETRPO\CLRRP1 etc. (at the moment this only codes one statement.)

Could you please pass on my appreciation to all your staff for an excellent magazine and a very useful web-site. I find all the PIC stuff extremely clear and very useful.

Incidentally, my first introduction to electronics was ETI magazine, back in the mid-seventies. Since then I have built RAM and I/O boards and data loggers for the NASCOM (Z80), the North Star Horizon (Z80 and S100 bus), the dear old BBC (6520) and all the IBM PCs from 1981 to date, within both my professional work and my hobby.

**Roger D. Redman  
via the Net**

*I've not come up against your Port C problem. Are you sure that your PIC is fully healthy? I have seen erratic waveforms on other devices when part of them has died for some reason. You might want to buy another PIC and try the program on it.*

*Both your TK suggestions seem useful. Thank you Roger. Perhaps one day ...!*

## **PATENTLY DIFFICULT**

Dear EPE,

I have designed a microprocessor-based PC Card for the ISA bus, but no one wants to know. I have tried over 40 UK manufacturers that were specifically selected to do the job of buying the manufacturing rights of my card, and have contacted a telecoms company here as my card uses Distinctive Ring Patterns from them, but not one of them has had the decency to reply.

Are all UK-based inventors of electronic devices treated this pathetic way all the time? Or is there someone you know out there who would be interested in manufacturing my card? I am made to feel that I am insignificant, a has-been, a nobody.

You would not believe the amount of E-mail and snail-mail I have sent out, but nothing whatsoever has come back. I am so depressed with it all. I think the question is, after the Patent, what now?

I would be ever so grateful to you and your colleagues if you could publish this and your reply, as I feel it would benefit other UK Electronics Inventors in the same situation.

**Jim Delaney  
Sheffield, UK**

*Jim's plea was E-mailed to our Online Editor, Alan, who offered the following extremely practical reply:*

*I've worked on both sides of the desk, both designing a wide variety of products as a development manager and also receiving proposals from outside designers hoping that my company would take on their idea. It happens all the time, and it's surprising how badly presented the applicant's case can be. Not every manufacturer would be as sympathetic to the aspiring designer as I was, so first impressions count, and a crisp business-like approach can only help as well as setting you above all the other (amateur) applications vying for the same spot.*

*However, I was one of the few who would always spare a little time to look at an external idea, but my next problem would be selling the merits of the idea to the senior management. If a designer couldn't sell the concept to me, I had no hope selling it up the ladder.*

*Often designers had no idea of the investments needed in tooling, production and distribution either. No basic market research, no sales projections, no budgeting – a design without such initial marketing research really would need to set the world alight. James Dyson found out the hard way and persevered, now everyone buys his vacuum cleaners (even me!). The Black & Decker Lawnraker and their WorkMate bench are two more examples of products designed by amateur designers. The Bayliss wind-up radio is another.*

*In my career in product de-*

*velopment, I have only come across one really switched-on professional-looking designer (a real "ideas man") who presented a very powerful case, with good quality prototypes and lots of ideas that forced us to sit up and listen. He was immensely enthusiastic and positive, and had really thought of everything and had come up with some very cute answers.*

*A personal meeting sold us on the concepts. He had all the ideas and we were prepared to develop the product and tool up for mass production, which is what we did (for a special type of tool kit). It would also be true that, sometimes, manufacturers just don't know what they're looking at and are being very shortsighted, so you have no hope with such firms.*

*Manufacturers usually have their own agenda with their own products currently on the drawing board (CAD screen anyway), so to take on an external design could mean dumping one of their own in-house designs. There would need to be a very good reason to do that.*

*In the case of electronics, there is also the development cost involved with making the product EMC compatible and gaining CE-approval. Maybe the fact it's an ISA card rather than, say, PCI might also detract from it, I couldn't say. I believe that ISA is being phased out in the PC2000 specification, although of course ISA slots will be around on legacy systems for some time to come.*

*It's only worth patenting if you can afford the legal costs of fighting an infringement. A pending patent enables designers to go with an NDA instead and then try to sell All Rights. I think*



*it's not just the treatment of inventors that is the problem, more likely it's the pressure the manufacturers are already under with their own product lines. They get too wrapped up in their own problems to want to go looking for more! But a forward-thinking and progressive company (e.g. Black & Decker) will listen to outside ideas, if only to get the feel for an idea that may subsequently be proposed to their competitors.*

*You should ask yourself whether it's worth sub-contracting the production yourself, and maybe get a small batch made and sell direct if you have to (e.g. on a web site). CE approval is your next hurdle, then give a few samples away and get the market talking about it. If you can make a big enough nuisance of yourself in the marketplace, it could then be that someone will buy the rights. Just make sure you are fully protected with design rights. There are plenty of good electronic engineers who can CAD up a board and polish off its development.*

*Try looking at James Dyson's web site ([www.dyson.com/co.uk](http://www.dyson.com/co.uk)), there used to be an inventor's resource there. There is also an alt. newsgroup for inventors where I'm sure you'll get more help. Also you could try a local University – an example in my case would be the new Product Design & Development Centre based at the University of Hull, with whom I'm working.*

*I'm sorry I can't be of more assistance, but hope the above helps – good luck!*

**Alan Winstanley**

### REGEN RECEIVER AND FETs

Dear EPE,

I am writing to you as a subscriber to EPE and an electronics construction enthusiast for some 35 years. First, thank you for the

superb series of articles on RF Design by Raymond Haigh, culminating in the High Performance Receiver (March '00), which I have decided to construct.

I am not "new" to construction, having built over 23 receivers for short waves over the years, designing and producing my own PCBs for these receivers.

It is the power gain of the 2N3819 FETs used in Raymond Haigh's design that I wish to query. The problem is that many component suppliers use the same manufacturer for 2N3819s and the spread in characteristics of these devices may affect the receiver's performance. In my own designs I use BF244 and BF245. Your comments are requested.

**John B. Dickinson  
Tamworth, Staffs, UK**

*John Dickinson gave a lot more information in his letter and sent an example 2N3819. We forwarded everything to Raymond Haigh, who replied:*

*Thank you for letting me read Mr. Dickinson's interesting and helpful letter. I should be grateful if you would thank him for having taken so much trouble and for his very kind remarks about my recent series of articles. I would offer the following observations:*

*He is, of course, quite correct in pointing out the wide spread in FET characteristics. He is also correct when he says that the specifications for the BF244 and BF245 are tighter than the specification for the 2N3819. Referring to the tables published in Farnell's catalog, the transconductance spread for*

*the BF244 and BF245 is 3 to 6.5mA/V, whilst the spread for the 2N3819 is slightly greater at 2 to 6.5mA/V.*

*Unfortunately, the BF244 and BF245 may not be readily available outside Europe, and regard must be had to the worldwide circulation of EPE. Because of this, I will have to continue specifying the ubiquitous 2N3819.*

*I have built about six versions of the circuit using this transistor as a drain bend detector. They all worked well with the component values quoted and without any selection of the 2N3819s.*

*I have, however, explored this question. The outcome of the trial was as follows:*

*(a) Thirty-three 2N3819 transistors were connected into circuit and provision made for monitoring the audio output voltage. Of these, 23 performed in a completely satisfactory way, three were marginally better than the rest, and seven performed badly, or would not work at all, unless the detector source resistor was increased in value. The transistor kindly supplied by Mr. Dickinson was one of those that would not work at all.*

*(b) When the source bias resistor (R5) was increased to 15k, all 33 specimens of the 2N3819 performed in a completely satisfactory way. With the source bias resistor increased, several specimens of 2SK168, MPF102, TIS14 and J310 (about twenty transistors in total) all worked well in the circuit also.*

*(c) The few transistors that were marginally better than the rest gave a very slightly higher output with the specified 4k7 source resistor. It would seem my earlier endeavors to milk the*



*last drop of performance from the circuit had revealed this. It is unfortunate that I made a chance selection of transistors that would work with this source bias resistor. Had I not done so I would have discovered that the circuit would not suit devices at the other extreme of the characteristic spread.*

*(d) Working and non-working devices in the test were distributed across a random selection of the products of different manufacturers. Presumably, therefore, the problem is primarily one of characteristic spreads rather than manufacturing differences. However, as suggested by Mr. Dickinson, there could well be a tendency for some manufacturer's transistors to drift towards a particular extreme of the tolerance range.*

*(e) I suggest that the value of TR2 source bias resistor, R5, be increased to 15k to ensure that all specimens of 2N3819 are operated in the non-linear region of their characteristic curve. With this value for the source resistor, most other jFETs, including the 2SK88, MPF102 and J310 should also work well.*

**Raymond Haigh**  
**Doncaster, S. Yorks, UK**

### BINARY CONVERSION

Dear EPE,

Your Teach-In 2000 Part 6 (Logic gates, Binary and Hex) brought to mind a system of converting decimal to binary I learnt many years ago.

Dredging through my personal memory-bank and with many false starts, the system is to divide the number to be converted by 2 continuously, ignoring any remainder. Every time the number is odd, put a dash (–) beside it. If it is even put “o”. The top “–” or “o” is the least significant figure and the bottom one most significant. For example, decimal 3353 is converted as follows:

3353	–
1676	o
838	o
419	–
209	–
104	o
52	o
26	o
13	–
6	o
3	–
1	–

Turn the paper through 90 degrees clockwise so that the most significant figure is to the left then read off the binary code. Thus decimal 3353 equals 110100011001 binary.

This method is probably well-known in the “Trade” but it might be new to some readers.

**Harry Nairn**  
**Ashtead, Surrey, UK**

*It's certainly new to me as well Harry. It's a form of long division, of course. How obvious when it's pointed out! Many thanks.*

# Shop Talk

with DAVID BARRINGTON

## Some Component Suppliers for EPE Online Constructional Articles

### Some Component Suppliers for EPE Online Constructional Articles

#### Antex

Web: [www.antex.co.uk](http://www.antex.co.uk)

#### Bull Electrical (UK)

Tel: +44 (0) 1273-203500

Email: [sales@bull-electrical.com](mailto:sales@bull-electrical.com)

Web: [www.bullnet.co.uk](http://www.bullnet.co.uk)

#### CPC Preston (UK)

Tel: +44 (0) 1772-654455

#### EPE Online Store and Library

Web: [www.epemag.com](http://www.epemag.com)

#### Electromail (UK)

Tel: +44 (0) 1536-204555

#### ESR (UK)

Tel: +44 (0) 191-2514363

Fax: +44 (0) 191-2522296

Email: [sales@esr.co.uk](mailto:sales@esr.co.uk)

Web: [www.esr.co.uk](http://www.esr.co.uk)

#### Farnell (UK)

Tel: +44 (0) 113-263-6311

Web: [www.farnell.com](http://www.farnell.com)

#### Gothic Crellon (UK)

Tel: +44 (0) 1743-788878

#### Greenweld (UK)

Fax: +44 (0) 1992-613020

Email: [greenweld@aol.com](mailto:greenweld@aol.com)

Web:

[www.greenweld.co.uk](http://www.greenweld.co.uk)

#### Maplin (UK)

Web: [www.maplin.co.uk](http://www.maplin.co.uk)

#### Magenta Electronics (UK)

Tel: +44 (0) 1283-565435

Email:

[sales@magenta2000.co.uk](mailto:sales@magenta2000.co.uk)

Web:

[www.magenta2000.co.uk](http://www.magenta2000.co.uk)

#### Microchip

Web: [www.microchip.com](http://www.microchip.com)

#### Rapid Electronics (UK)

Tel: +44 (0) 1206-751166

#### RF Solutions (UK)

Tel: +44 (0) 1273-488880

Web: [www.rfsolution.co.uk](http://www.rfsolution.co.uk)

#### RS (Radio Spares) (UK)

Web: [www.rswwww.com](http://www.rswwww.com)

#### Speak & Co. Ltd.

Tel: +44 (0) 1873-811281

### Versatile Mic/Audio Preamplifier

To date, we have only traced two sources for the SSM2166P microphone preamplifier IC used in the *Versatile Mic/Audio Preamplifier* project. It is currently listed by Maplin (code GS39N) and is also carried by Farnell (code 114-7249).

If you are going to include the *Signal Strength Meter* option, the actual selection of the moving coil meter is left to individual choice, hence the small table giving resistor values for meter movements ranging from 50mA up to 1mA. Many component suppliers should be able to offer a suitable small panel meter.

### Low-Cost Capacitance Meter

The only item that needs highlighting when buying parts for the *Low-Cost Capacitance Meter* – this month's Starter Project – is the timer IC.

A low-power version of the 555 timer must be used in this project as, due to its low self-capacitance, it gives better

accuracy on the 1nF range. Therefore, use the TS555 timer instead of the standard NE version. The low-power version should be widely stocked and readily available.

Once again, the meter is left to individual choice as prices seem to vary quite considerably. The model uses a 100uA movement obtained from Maplin (code RW92A).

The 12-way single-pole rotary range switch is a Lorlin type, which has an adjustable rotation limiting "end-stop" that should be set to 5-ways. This was also purchased from the above, code FF73Q.

### Multi-Channel Transmission System

Most of the components called up for the *Multi-Channel Transmission System* should be stock items, even unprogrammed PIC16F84s are now widely available.

The author is able to supply ready-programmed PIC16F84s. You will need to order at least two microcontrollers, one Transmitter (Tx) and one Receiver (Rx). We understand that the first two will cost 6 UK pounds each and any additional PICs 5 UK pounds each, inclusive of postage (overseas readers add 1 UK pound per order for postage). Orders should be sent to: Andy Flind, 22 Holway Hill, Taunton, Somerset, TA1 2HB, UK. Payments should be made out to A. Flind. For those who wish to program their own PICs, the software is available for free download from the *EPE Online Library* at [www.epemag.com](http://www.epemag.com)

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### ***PIR Light Checker***

Nearly all the components needed to build the *PIRLight Checker* project should be obtainable from your usual local supplier. The miniature light-dependent resistor (LDR) and the 7-segment, common cathode, display both came from Maplin (codes AZ83E and FR41U) respectively. (You can, of course, use the good old ORP12 LDR.)

Details and prices for all of this month's printed circuit boards can be found at the *EPE*

Online Store at  
[www.epemag.com](http://www.epemag.com)

### ***Teach-In 2000***

No additional components are called for in this month's installment of the *Teach-In 2000* series. For details of special packs readers should contact:

ESR Electronic  
Components – Hardware/Tools  
and Components Pack.

Magenta Electronics –  
Multimeter and components, Kit  
879.

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## **Shop Talk**

FML Electronics (Tel: +44  
(0) 1677-425840) – Basic  
component sets.

N. R. Bardwell (Tel: +44 (0)  
114 255-2886) – Digital  
Multimeter special offer.

### **PLEASE TAKE NOTE: *Micro- PICscope April '00***

Unfortunately a digit was missed  
from the order code for the  
orange box, which should be  
281-6841. We apologize for this  
error