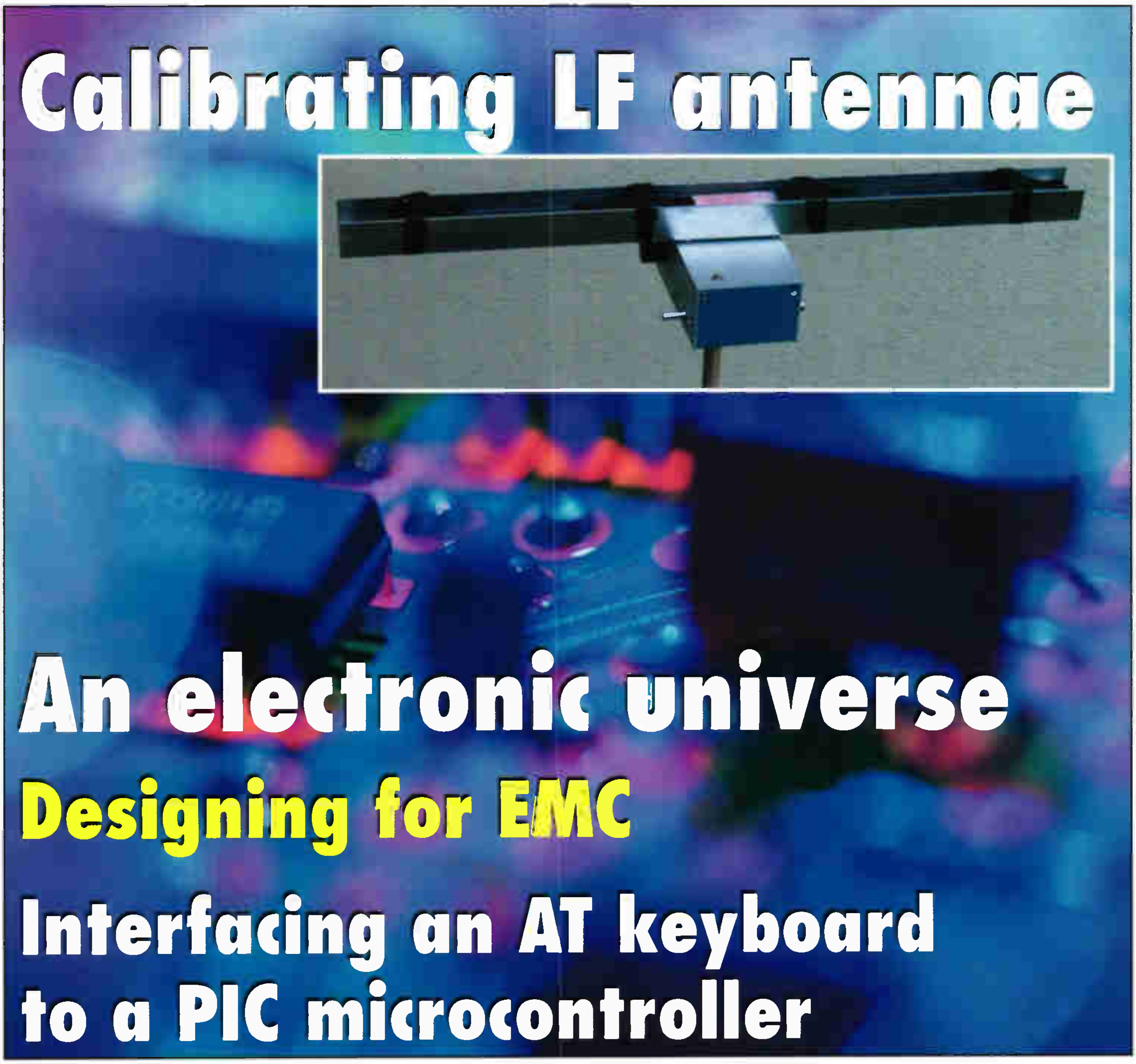
Electronics World's **renowned news section starts on page 5**

ELECTRONICS WORLD

AUGUST 2002 £2.95



Calibrating LF antennae

An electronic universe

Designing for EMC

Interfacing an AT keyboard to a PIC microcontroller

Circuit ideas:

Charger delay unit, Standalone button, latch Ozone generator, 5W Inverter

08

9 770959 833080

Telnet

Quality second-user test & measurement equipment

Fluke 5700A Multifunction Calibrator with 5725A Amplifier	**£17,000**
Hewlett Packard 3314A Function Generator 20MHz	**£1250**
Hewlett Packard 3324A synth. function/sweep gen. (21MHz)	**£2250**
Hewlett Packard 3325B Synthesised Function Generator	**£3250**
Hewlett Packard 3326A Two-Channel Synthesiser	**£3000**
Hewlett Packard 4191A R/F Impedance Analyser (1-1000MHz)	**£4995**
Hewlett Packard 4192A L.F Impedance Analyser (5Hz-13MHz)	**£4000**
Hewlett Packard 4193A Vector Impedance Meter (4-110MHz)	**£3000**
Hewlett Packard 4278A 1kHz/1MHz Capacitance Meter	**£3750**
Hewlett Packard 53310A Modulation Domain Analyser (opts 1&31)	**£6750**
Hewlett Packard 8349B (2 - 20 GHz) Microwave Amplifier	**£2500**
Hewlett Packard 8508A (with plug-in 85082A-2GHz) Vector Voltmeter	**£2500**
Hewlett Packard 8904A Multifunction Synthesiser (opt 2+4)	**£1950**
Hewlett Packard ESG-D3000A (E4432A) 250 kHz-3GHz) Signal Gen.	**£6995**
Marconi 6310 – programmable sweep generator (2 to 20GHz) – new	**£2500**
Marconi 6311 Prog'ble sig. gen. (10MHz to 20GHz)	**£2995**
Marconi 6313 Prog'ble sig. gen. (10MHz to 26.5GHz)	**£4750**
R&S SMG (0.1-1GHz) Sig. Generator (opts B1+2)	**£2750**
Rohde & Schwarz SM1Q-03B (opt11,12,14,20,B42) Vector Signal Generator (300kHz-3.3GHz)	**£8500**

OCSILLOSCOPES

Gould 400 20MHz - DSO - 2 channel	£695
Gould 1421 20MHz - DSO - 2 channel	£425
Gould 4068 150MHz 4 channel DSO	£1250
Gould 4074 100MHz - 400 Ms/s - 4 channel	£1100
Hewlett Packard 54201A - 300MHz Digitizing	£750
Hewlett Packard 54502A - 400MHz – 400 MS/s 2 channel	£1600
Hewlett Packard 54520A 500MHz 2ch	£2750
Hewlett Packard 54600A - 100MHz – 2 channel	£675
Hewlett Packard 54616B 500MHz – 2Gs/s 2 Channel	£2500
Hewlett Packard 54810A 'Infinium' 500MHz 2ch	£3500
Hitachi V152/V212/V222/V302B/V302F/V353F/V550BV650F	from £100
Hitachi V1 100A - 100MHz - 4 channel	£750
Intron 2020 - 20MHz. Dual channel D.S.O (new)	£450
Iwatstu SS 5710/SS 5702 -	from £125
Kikusui COS 5100 - 100MHz - Dual channel	£350
Lecroy 9314L 300MHz - 4 channels	£2750
Meguro MSO 1270A - 20MHz - D.S.O. (new)	£450
Philips 3295A - 400MHz - Dual channel	£1400
Philips PM3070 - 100MHz - 2 channel - cursor readout	£650
Philips PM3392 - 200MHz - 200Ms/s - 4 channel	£1750
Philips PM3094 - 200MHz - 4 channel	£1500
Tektronix 464/466 - 100MHZ - (with AN. storage)	£295
Tektronix 465 - 100MHz - Dual channel	£295
Tektronix 468 - 100MHz D.S.O.	£500
Tektronix 475/475A - 200MHz/250MHz	from £400
Tektronix 2213/2215 - 60MHz - Dual channel	£300
Tektronix 2220 - 60MHz - Dual channel D.S.O	£850
Tektronix 2221 - 60MHz - Dual channel D.S.O	£850
Tektronix 2235 - 100MHz - Dual channel	£500
Tektronix 2245A - 100MHz - 4 channel	£700
Tektronix 2430/2430A - Digital storage - 150MHz	from £1250
Tektronix 2440 - 300MHz/500MS/s D.S.O.	£2100
Tektronix 2445 - 150MHZ - 4 channel +DMM	£850
Tektronix 2445/2445B - 150MHz - 4 channel	£800
Tektronix 2465/2465A /2465B - 300MHz/350MHz 4 channel	from £1250
Tektronix 7000 Series (100MHZ to 500MHZ)	from £200
Tektronix 7104 - 1GHz Real Time – with 7A29 x2, 7B10 and 7B15	from £1950
Tektronix TAS 475 - 100MHz - 4 channel	£850
Tektronix TDS 310 50MHz DSO - 2 channel	£750

SPECTRUM ANALYSERS

Advantest 4131 (10kHz – 3.5GHz)	£3750
Advantest R3272 Spectrum Analyser (9kHz-26.5GHz)	£12000
Advantest/TAKEDA RIKEN - 4132 - 100KHz - 1000MHz	£1350
Ando AC 8211 - 1.7GHz	£1500
Anritsu 54111A Scalar Network Analyser (0.001-3GHz) +dets+SWR	£7000
Anritsu 54154A Scalar Network Analyser (2-32GHz)+detectors+SWR	£9950
Avcom PSA-65A - 2 to 1000MHz	£750
Hewlett Packard 182T Mainframe + 8559A Spec.An. (0.01 to 21GHz)	£2000
Hewlett Packard 853A Mainframe + 8559A Spec.An. (0.01 to 21GHz)	£2500
Hewlett Packard 3582A (0.02Hz - 25.5kHz) dual channel	£1500
Hewlett Packard 8560A (50MHz–2.9GHz) High performance with Tracking Generator option (02)	£5500
Hewlett Packard 8567A -100Hz - 1500MHz	£3400
Hewlett Packard 8590A (opt 01, 021, 040) 1MHz–1.5MHz	£2500
Hewlett Packard 8596E (opt 41, 101, 105,130) 9KHz - 12.8GHz	£9950
Hewlett Packard 8713C (opt 1 E1) Network An. 3 GHz	£6000
Hewlett Packard 8752A - Network Analyser (1.3GHz)	£4995
Hewlett Packard 8753A (3000KHz - 3GHz) Network An.	£3250
Hewlett Packard 8753B+85046A Network An + S Param (3GHz)	£6500
Hewlett Packard 8754A - Network Analyser 4MHz -1300MHz)	£1500
Hewlett Packard 8756A/8757A Scaler Network Analyser	from £900
Hewlett Packard 70001A/70900A/70906A/70902A/70205A - 26.5 GHz Spectrum Analyser	£7000
IFR A7550 - 10KHz-GHz - Portable	£1750
Meguro - MSA 4901 - 30MHz - Spec Anaylser	£600
Meguro - MSA 4912 - 1MHz - 1GHz Spec Anaylser	£750
Tektronix 492P (opt1,2,3) 50KHz - 21GHz	£3500
Wiltron 6409 - 10-2000MHz R/F Analyser	£1250

Radio Communications Test Sets

Anritsu MT 8801C Radio Comms Analyser 300kHz - 3GHz (opt 1,4,7)	£6500
Hewlett Packard 8920B (opts 1,4,7,11,12)	£6750
Marconi 2955	£1250
Marconi 2955A	£1750
Marconi 2955B/60B	£3500
Marconi 2955R	£1995
Racal 6103 (GSM) Digital Radio Test Se	£6250
Racal 6111 (GSM)	£1250
Racal 6115 (GSM)	£1750
Rohde & Schwarz CMT 55 (2GHz)	£7500
Rohde & Schwarz CMD 57 GSM test set (opts B1/34/6/7/19/42/43/61	£7995
Rohde & Schwarz CMT 90 (2GHz) DECT	£3995
Rohde & Schwarz CMTA 94 (GSM)	£4500
Schlumberger Stabilock 4031	£2750
Schlumberger Stabilock 4040	£1300
Wavetek 4103 (GSM 900) Mobile phone tester	£1500
Wavetek 4106 (GSM 900, 1800, 1900) Mobile phone tester	£2000

MISCELLANEOUS

Ballantine 1620A 100Amp Transconductance Amplifier	£1750
Bias unit 3220 and 3225L Cal.Coil available if required.	(P.O.A)
EIP 545 Microwave Frequency Counter (18GHz)	£1000
EIP 548A and B 26.5GHz Frequency Counter	from £1500
EIP 575 Source Locking Freq.Counter (18GHz)	£1200
EIP 585 Pulse Freq.Counter (18GHz)	£1200
Gigatronics 8541C Power Meter + 80350A Peak Power Sensor	£1750
Gigatronics 8542C Dual Power Meter + 2 sensors 80401A	£2500
Hewlett Packard 339A Distortion measuring set	£750
Hewlett Packard 436A power meter and sensor (various)	from £750
Hewlett Packard 3335A – synthesiser (200Hz-81MHz)	£1995
Hewlett Packard 3457A muli meter 6 1/2 digit	£850
Hewlett Packard 3784A - Digital Transmission Analyser	£3750
Hewlett Packard 37900D - Signalling test set	£2950
Hewlett Packard 4276A LCZ Meter (100MHz-20KHz)	£1400
Hewlett Packard 5342A Microwave Freq.Counter (18GHz)	£850
Hewlett Packard 5350B 20KHz Microwave Freq.Counter	£2000
Hewlett Packard 5351B (pt 1 & 6) Microwave Freq.Counter (26.5GHz)	£3000
Hewlett Packard 5385A - 1 GHz Frequency counter	£495
Hewlett Packard 6033A - Autoranging System PSU (20v-30a)	£750
Hewlett Packard 6622A - Dual O/P system p.s.u	£1250
Hewlett Packard 6624A - Quad Output Power Supply	£2000
Hewlett Packard 6626A / 6629A Quad O/P Power Supply	£3500
Hewlett Packard 6632A - System Power Supply (20v-5A)	£695
Hewlett Packard 8350B - Sweep Generator Mainframe	£1500
Hewlett Packard 8603A, B and E - Distortion Analyser	from £1000
Hewlett Packard 8642A – high performance R/F synthesiser (0.1-1050MHz)	£2500
Hewlett Packard 8656A - Synthesised signal generator	£750
Hewlett Packard 8656B - Synthesised signal generator	£995
Hewlett Packard 8657A - Synth. signal gen. (0.1-1040MHz)	£1500
Hewlett Packard 8657B - 100MHz Sig Gen - 2060 MHz	£3950
Hewlett Packard 8657D - XX DQPSK Sig Gen	£3950
Hewlett Packard 8901B - Modulation Analyser	£2250
Hewlett Packard 11729B/C Carrier Noise Test Set	from £2500
Hewlett Packard 53131A Universal Frequency counter (3GHz)	£850
Hewlett Packard 53151B Microwave Freq. Counter (26.5GHz)	£3400
Hewlett Packard 85024A High Frequency Probe	£1000
Keithley 237 High Voltage - Source Measure Unit	£4500
Keithley 238 High Current - Source Measure Unit	£4500
Keithley 486/487 Picoammeter (+volt.source)	£1350/£1850
Keithley 8006 Component Test Fixture	£1750
Marconi 2840A 2 Mbit/s Transmission Analyser	£1100
Marconi 6950/6960/6960B Power Meters & Sensors	from £400
Philips 5515 - TN - Colour TV pattern generator	£1400
Philips PM 5193 - 50 MHz Function generator	£1350
Leader 3216 Signal generator 100KHz -140MHz - AM/FM/CW with built in FM stereo modulator (as new) a snip at	£650
Rohde & Schwarz FAM (opts 2,6 and 8) Modulation Analyser	£3750
Rohde & Schwarz NRV dual channel power meter & NAV Z2 Sensor	£1000
Tektronix ASG100 - Audio Signal Generator	£750
Wavetek 178 Function generator (50MHz)	£750
Wayne Kerr 3245 - Precision Inductance Analyser	£1850
Wayne Kerr 3260A + 3265A Precision Magnetics Analyser with Bias Unit	£5500
Wayne Kerr 8245 - Precision Component Analyser	£2250

All equipment is used - with 30 days guarantee and 90 days in some cases
Add carriage and VAT to all goods.

Telnet, 8 Cavans Way, Binley Industrial Estate,
Coventry CV3 2SF.

Tel: 02476 650 702
Fax: 02476 650 773
Web: www.telnet.uk.com
Email: sales@telnet.uk.com

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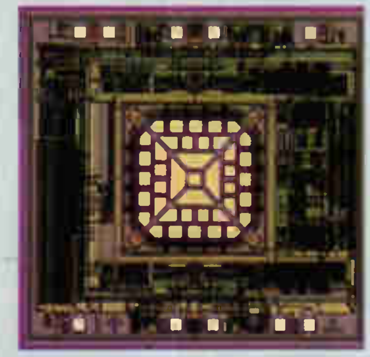

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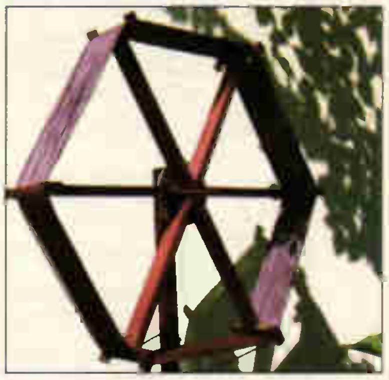

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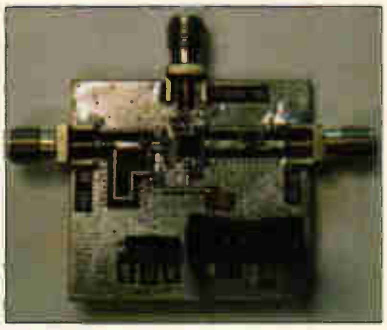

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September issue on sale 1 August

£1 BARGAIN PACKS
Selected items

PIEZO ELECTRIC SOUNDER, also operates efficiently as a microphone. Approximately 30mm diameter, easily mountable, 2 for £1. Order Ref: 1084.
LIQUID CRYSTAL DISPLAY on p.c.b. with i.c.s etc. to drive it to give 2 rows of 8 figures or letters with data. Order Ref: 1085.
30A PANEL MOUNTING TOGGLE SWITCH. Double-pole. Order Ref: 166.
SUB MIN TOGGLE SWITCHES. Pack of 3. Order Ref: 214.
HIGH POWER 3in. SPEAKER (11W 8ohm). Order Ref: 246.
MEDIUM WAVE PERMEABILITY TUNER. It's almost a complete radio with circuit. Order Ref: 247.
HEATING ELEMENT, mains voltage 100W, brass encased. Order Ref: 8.
MAINS MOTOR with gearbox giving 1 rev per 24 hours. Order Ref: 89.
ROUND POINTER KNOBS for flatted ¼in. spindles. Pack of 10. Order Ref: 295.
REVERSING SWITCH. 20A double-pole or 40A single pole. Order Ref: 343.
LUMINOUS PUSH-ON PUSH-OFF SWITCHES. Pack of 3. Order Ref: 373.
SLIDE SWITCHES. Single pole changeover. Pack of 10. Order Ref: 1053.
PAXOLIN PANEL. Approximately 12in. x 12in. Order Ref: 1033.
CLOCKWORK MOTOR. Suitable for up to 6 hours. Order Ref: 1038.
TRANSISTOR DRIVER TRANSFORMER. Maker's ref. no. LT44, impedance ratio 20k ohm to 1k ohm; centre tapped, 50p. Order Ref: 1/23R4.
HIGH CURRENT RELAY, 12V d.c. or 24V a.c., operates changeover cocntacts. Order Ref: 1026.
3-CONTACT MICROSWITCHES, operated with slightest touch, pack of 2. Order Ref: 861.
HIVAC NUMICATOR TUBE, Hivac ref XN3. Order Ref: 865 or XN11 Order Ref: 866.
2IN. ROUND LOUDSPEAKERS. 50Ω coil. Pack of 2. Order Ref: 908.
5K POT, standard size with DP switch, good length ¼in. spindle, pack of 2. Order Ref: 11R24.
13A PLUG, fully legal with insulated legs, pack of 3. Order Ref: GR19.
OPTO-SWITCH on p.c.b., size 2in. x 1in., pack of 2. Order Ref: GR21.
COMPONENT MOUNTING PANEL, heavy paxolin 10in. x 2in., 32 pairs of brass pillars for soldering binding components. Order Ref: 7RC26.
HIGH AMP THYRISTOR, normal 2 contacts from top, heavy threaded fixing underneath, think amperage to be at least 25A, pack of 2. Order Ref: 7FC43.
BRIDGE RECTIFIER, ideal for 12V to 24V charger at 5A, pack of 2. Order Ref: 1070.
TEST PRODS FOR MULTIMETER with 4mm sockets. Good length flexible lead. Order Ref: D86.
LUMINOUS ROCKER SWITCH, approximately 30mm square, pack of 2. Order Ref: D64.
MES LAMPHOLDERS slide on to ¼in. tag, pack of 10. Order Ref: 1054.
HALL EFFECT DEVICES, mounted on small heatsink, pack of 2. Order Ref: 1022.
12V POLARISED RELAY, 2 changeover contacts. Order Ref: 1032.
PROJECT CASE, 95mm x 66mm x 23mm with removable lid held by 4 screws, pack of 2. Order Ref: 876.
LARGE MICROSWITCHES, 20mm x 6mm x 10mm, changeover contacts, pack of 2. Order Ref: 826.
COPPER CLAD PANELS, size 7in. x 4in., pack of 2. Order Ref: 973.
100M COIL OF CONNECTING WIRE. Order Ref: 685.
WHITE PROJECT BOX, 78mm x 115mm x 35mm. Order Ref: 106.
LEVER-OPERATED MICROSWITCHES, ex-equipment, batch tested, any faulty would be replaced, pack of 10. Order Ref: 755.
MAINS TRANSFORMER, 12V-0V-12V, 6W. Order Ref: 811.
QUARTZ LINEAR HEATING TUBES, 306W but 110V so would have to be joined in series, pack of 2. Order Ref: 907.
REELS INSULATION TAPE, pack of 5, several colours. Order Ref: 911.
LIGHTWEIGHT STEREO HEADPHONES. Order Ref: 989.
THERMOSTAT for ovens with ¼in. spindle to take control knob. Order Ref: 857.
MINI STEREO 1W AMP. Order Ref: 870.

SELLING WELL BUT STILL AVAILABLE

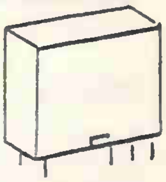
IT IS A DIGITAL MULTITESTER, complete with backrest to stand it and hands-free test prod holder. This tester measures d.c. volts up to 1,000 and a.c. volts up to 750; d.c. current up to 10A and resistance up to 2 megs. Also tests transistors and diodes and has an internal buzzer for continuity tests. Comes complete with test prods, battery and instructions. Price £6.99. Order Ref: 7P29.
INSULATION TESTER WITH MULTIMETER. Internally generates voltages which enable you to read insulation directly in megohms. The multimeter has four ranges: AC/DC volts, 3 ranges DC milliamps, 3 ranges resistance and 5 amp range. These instruments are ex-British Telecom but in very good condition, tested and guaranteed OK, probably cost at least £50 each, yours for only £7.50 with leads, carrying case £2 extra. Order Ref: 7.5P4.
REPAIRABLE METERS. We have some of the above testers but slightly faulty, not working on all ranges, should be repairable, we supply diagram, £3. Order Ref: 3P176.
PHILIPS 9in. MONITOR. Not cased, but it is in a frame for rack mounting. It is high resolution and was made to work with the IBM 'One per disk' computer. price £15. Order Ref: 15P1.
METAL CASE FOR 9in. MONITOR. Supplied as a flat pack, price £12. Order Ref: 12P3.
ANOTHER PROJECT CASE. Should be very suitable for a non-recognisable bug or similar hand-held device. It is 150mm long, 36mm wide and 15mm thick. Originally these were TV remote controls, price 2 for £1. Order Ref: 1068.
A MUCH LARGER PROJECT BOX. Size 216mm x 130mm x 85mm with lid and 4 screws. This is an ABS box which normally retails at around £6. All brand new, price £2.50. Order Ref: 2.5P28.
BT TELEPHONE EXTENSION WIRE. This is proper heavy duty cable for running around the skirting board when you want to make a permanent extension. Four cores properly colour coded, 25m length only £1. Order Ref: 1067.
HEAVY DUTY POT. Rated at 25W, this is 20 ohm resistance so it could be just right for speed controlling a d.c. motor or device or to contraol the output of a high current. Price £1. Order Ref: 1/33L1.
1mA PANEL METER. Approximately 80mm x 55mm, front engraved 0-100. Price £1.50 each. Order Ref: 1/16R2.
VERY THIN DRILLS. 12 assorted sizes vary between 0·6mm and 1·6mm. Price £1. Order Ref: 128.
EVEN THINNER DRILLS. 12 that vary between 0·1mm and 0·5mm. Price £1. Order Ref:129.
D.C. MOTOR WITH GEARBOX. Size 60mm long, 30mm diameter. Very powerful, operates off any voltage between 6V and 24V D.C. Speed at 6V is 200 rpm, speed controller available. Special price £3 each. Order Ref: 3P108.
FLASHING BEACON. Ideal for putting on a van, a tractor or any vehicle that should always be seen. Uses a Xenon tube and has an amber coloured dome. Separate fixing base is included so unit can be put away if desirable. Price £5. Order Ref: 5P267.
MOST USEFUL POWER SUPPLY. Rated at 9V 1A, this plugs into a 13A socket, is really nicely boxed. £2. Order Ref: 2P733.
MOTOR SPEED CONTROLLER. These are suitable for D.C. motors for voltages up to 12V and any power up to 1/6h.p. They reduce the speed by intermittent full voltage pulses so there should be no loss of power. In kit form these are £12. Order Ref: 12P34. Or made up and tested, £20. Order Ref: 20P39.
BALANCE ASSEMBLY KITS. Japanese made, when assembled ideal for chemical experiments, complete with tweezers and 6 weights 0·5 to 5 grams. Price £2. Order Ref: 2P44.
CYCLE LAMP BARGAIN. You can have 100 6V 0·2A MES bulbs for just £2.50 or 1,000 for £20. They are beautifully made, slightly larger than the standard 6·3V pilot bulb so they would be ideal for making displays for night lights and similar applications.
SOLDERING IRON, super mains powered with long-life ceramic element, heavy duty 40W for the extra special job, complete with plated wire stand and 245mm lead, £3. Order Ref: 3P221.
HIGH AMP THYRISTOR. Normal two contacts from the top and heavy threaded fixing underneath. We don't know the amperage of this but think it to be at least 25A. Price 50p each. Order Ref: 1/7RC43.
THREE LEVEL PRESSURE SWITCH. All 3 are low pressures and the switch could be blow-operated. With a suitable tubing these switches could control the level of liquid, etc., price £1. Order Ref: 67.
BREAKDOWN UNIT, Order Ref: BM41001. This is probably the most valuable breakdown unit that you have ever been offered. It contains the items specified below, just 2 of which are currently selling at £3.50 each. Other contents are:
Computer grade electrolytics, 330μF 250V DC, you get 4 of these. 4,700μF at 50V DC, you get 2 of these. 1,000μF at 16V DC, you get one of these, and 16A 250V double rocker switch, 115V to 250V selector switch. You also get a standard flat pin instrument socket, a 250V 5A bridge rectifier, 2 x 25A bridge rectifiers mounted on an aluminium heatsink but very easy to remove.
2 *NPN* power transistors ref. BUV47, currently listed by Maplins at £3.50 each, a power thyristor, Mullard ref. BTW69 or equivalent, listed at £3.
All the above parts are very easy to remove. 100s of other parts not so easy to remove, all this is yours for £5. Order Ref: 1/11R8.

RELAYS

We have thousands of relays of various sorts in stock, so if you need anything special give us a ring. A few new ones that have just arrived are special in that they are plug-in and come complete with a special base which enables you to check voltages of connections of it without having to go underneath. We have 6 different types with varying coil voltages and contact arrangements.

Coil Voltage	Contacts	Price	Order Ref:
12V DC	4-pole changeover	£2.00	FR10
24V DC	2-pole changeover	£1.50	FR12
24V DC	4-pole changeover	£2.00	FR13
240V AC	1-pole changeover	£1.50	FR14
240V AC	4-pole changeover	£2.00	FR15

Prices include base
MINI POWER RELAYS
For p.c.b. mounting, size 28mm x 25mm x 12mm, all have 16A changeover contacts for up to 250V. Four versions available, they all look the same but have different coils:



6V Order Ref: FR17
12V Order Ref: FR18
24V Order Ref: FR19
48V Order Ref: FR20
Price £1 each less 10% if ordered in quantities of 10, same or mixed values.
4 CIRCUIT 12V RELAY. Quite small, clear plastic enclosed and with plug-in tags, £1. Order Ref: 205N.
NOT MUCH BIGGER THAN AN OXO CUBE. Another relay just arrived is extra small with a 12V coil and 6A changeover contacts. It is sealed so it can be mounted in any position or on a p.c.b. Price 75p each, 10 for £6 or 100 for £50. Order Ref: FR16.
BIG POWER RELAY. These are open type fixed by screws into the threaded base. Made by Omron, their ref: MM4. These have 4 sets of 25A changeover contacts. The coil is operated by 50V AC or 24V DC, price £6. Order Ref: 6P.
SIMILAR RELAY but smaller and with only 2 sets of 25A changeover contacts. Coil voltage 24V DC, 50V AC, £4. Order Ref: 4P.
BIG POWER LATCHING RELAY. Again by Omron, their ref: MM2K. This looks like a double relay, one on top of the other. The bottom one has double-pole 20A changeover contacts. The top one has no contacts but when energised it will lock the lower relay either on or off depending on how it is set. Price £6. Order Ref: 6P.
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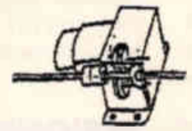

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Changing times

Welcome to the August issue of Electronic World and let me introduce myself as your new editor. My name is Phil Reed and I'll tell you a bit about myself later on in this leader.

But firstly, I'd like to thank Martin Eccles for many years of superb editorship of this respected journal and I can only hope that I come up to the high standards he has already set.

So, who on earth is Phil Reed? Well, I am an engineer by trade, having worked in the broadcast industry for the last 32 years. Whilst I have rarely had to pay the mortgage by designing electronics – I do understand most of what goes on in these pages – and have certainly had to fix some of the circuitry designed by some *EW* readers! And it was only a couple of weeks ago that my soldering prowess was earning me a crust (and a burnt thumb). My career has taken me to all corners of the broadcasting world, from acquisition to post production and even touching upon delivery technologies, stopping short of actually working on a transmitter station. I am not new to scribbling for a living, either. I have written regular columns in the broadcast trade press and my journalistic career reached new heights when I was editing the esteemed *'International Broadcast Engineer'* magazine. But I have decided that I needed to get back to my roots and have do some proper engineering. In my spare time I'm engineering for a London based post production company, building and looking after many video editing suites and sorting out all manner of technical problems with a popular 'reality TV' series, based in Elstree film studios.

I used to be an avid reader of EW's predecessor, Wireless World, for many years and it has been an eye-opener to me to see how the design industry has moved on in the intervening 20 years or so! I am quite thrilled to be involved in this side of the business and look forward to be able to serve the readership with some ideas of my own. As with all things technical, the industry is changing rapidly – only a few years ago the things that you can do with PCs now would have seemed impossible. The same thing goes for DSP chips whose power to do ridiculously clever things in a cheap mass produced package is legendary and I hope to reflect some of these profound changes in these pages in the future.

As you can imagine, there are lots of boxes of article and circuit ideas that I've inherited – and it's going to take me some while to go through them all, so if you were expecting a reply about any submissions you've made – it might be an idea to send me an email to remind me. But do keep the circuit ideas and article submissions rolling in.

Over the next few months I will start the process of making some subtle changes to *EW*, nothing major you understand, just some small adjustments spurred on by feedback from you, which came from our 2002 reader survey. It appears that most of you (70%) are electronics professionals, 31% of you spend over £200 on components each month and 71% of you have a PC with internet access. So, armed with all this info, I'll be tweaking the content to suit. Suffice to say, though, that any comments are always welcome (even negative ones) and the best ones will be published. Editorial comments should be sent to me directly at p.reed@highburybiz.com.

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Half a million on broadband

Over half a million broadband connections have been set up in the UK, claims telecoms watchdog Oftel. "With over 20,000 broadband connections a week, the current level of growth outstrips the equivalent demand for mobile phones and dial-up Internet when they were first introduced," said David Edmonds, Oftel's director general of telecoms.

The figures include all four main access technologies; cable modems, DSL technology, broadband fixed wireless and broadband satellite services.

The lure of broadband access will continue, Edmonds said: "Over 10 million homes use the traditional dial-up Internet access, including four million with unmetered packages.

"I am confident that more Internet users will take up high speed broadband as the range of services increases and prices fall."

Douglas Alexander, the Government's e-commerce minister, said: "The milestone of half a million connections represents a 54 per cent increase since the beginning of 2002. Of course there is more to do, but the work of building Broadband Britain is under way."

Carbon in missing link

The continued research into carbon nanotubes continues with IBM of the US and Infineon Technologies of Germany pushing the integration of nanotubes with silicon.

IBM has taken a major step towards transistors and ICs made from carbon nanotubes by proving that devices can outperform silicon transistors.

Researchers at the firm created prototype nanotube transistors with twice the transconductance of the best prototype silicon devices, IBM said.

"Proving that carbon nanotubes outperform silicon transistors opens the door for more research related to the commercial viability of nanotubes," said Dr Phaedon Avouris, manager of nanoscale science at IBM Research.

Avouris' team used single walled nanotubes (SWNTs) in a conventional Mosfet-like structure, with the nanotube forming the channel between the source and drain.

However, the gate dielectric was thicker than a Mosfet, at 10 to 15nm, even at gate voltages of 1V. Transconductance of 2,300µS/µm is more than double that of a 15nm length Mosfet with a 1.4nm gate oxide.

IBM was also able to make both p- and n-type nanotube Fets.

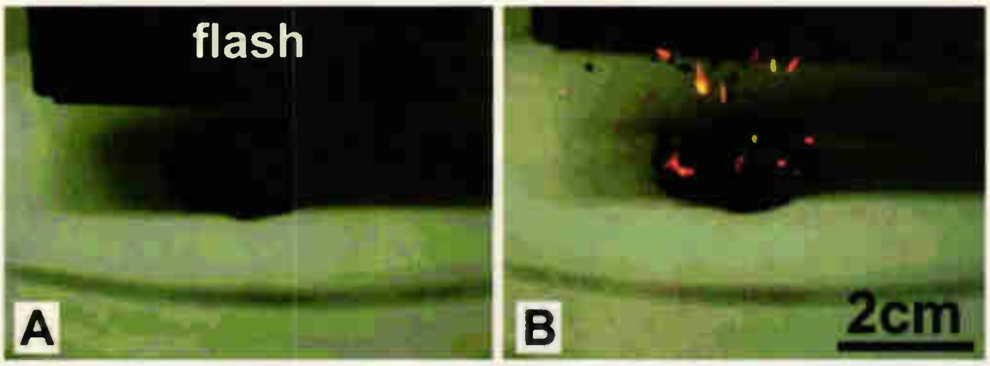
Meanwhile Infineon has managed the controlled placement of nanotubes on standard 150mm silicon wafers.

The firm sees nanotubes replacing both the Fets and the interconnect in integrated circuits. Nanotubes allow current densities up to 10[super]10A/cm[super]^2, three orders of magnitude higher then copper can manage. Interconnect in conventional silicon chips is expected to reach its thermal limits in around ten years' time.

Finally, a group of researchers from the UK, France and the US have shown carbon nanotubes can ignite after exposure to a photographic flash.

A flash gun with more than 100mW/cm[super]2 of light power is enough to ignite SWNTs, which reach temperatures of at least 1,500°C, said the team.

The light leads to a photoacoustic effect caused by the expansion and contraction of trapped gasses. The high thermal conductivity of nanotubes helps propagate heat through a bundle.



After the flash, image B shows the ignited SWNT burning with red and yellow spots.

The first US airborne laser missile-defence aircraft, a modified Boeing 747-400 freighter, is being prepared for flight testing later this summer. Flight-worthiness testing will be followed by a trip to Edwards Air Force Base in California where the laser and optics will be fitted.

Green power gets go-ahead

The Department of Trade and Industry has rubber stamped plans for the country's largest wind farm at Cefen Croes, near Aberystwyth.

With 39 turbines, the £35m project will be one of the largest of its type in Europe, said the Renewable Development Company, which is backing the project.

The scheme is part of the Government's plan to supply ten per cent of the UK's energy needs through renewable sources by 2010.

It is hoped that the wind farm will provide up to half of the local area's demand for electricity, and a full one per cent of Wales' total generation capacity.

However, the size of the scheme meant it bypassed the Welsh Assembly and went straight to the DTI in London for approval, a move that angered many activists in the West Wales area.

Energy Minister Brian Wilson has also unveiled a £2.3m plan for off-shore wave energy systems. The development and demonstration systems will be installed off the Western Isles.

Cash for this scheme comes from the £100m fund set up by the Government last year.

Three devices, located in shallow water, will generate power based on the oscillating water column principle. These techniques have already been used closer on-shore.

Zetex moves to p-channel

Analogue chip specialist Zetex has developed a p-channel Mosfet using its trench semiconductor process.

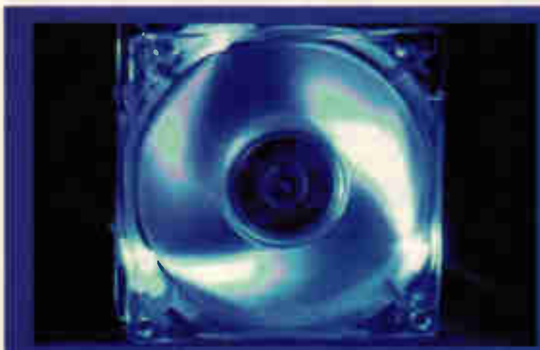
Zetex licensed techniques from an unnamed company that allow the Fets to be made without any critical alignment steps.

"P-channel Mosfets are tricky to make," said company product development manager Peter Blair. Swapping materials in a existing n-channel design is not the answer, "there are additional challenges", he said.

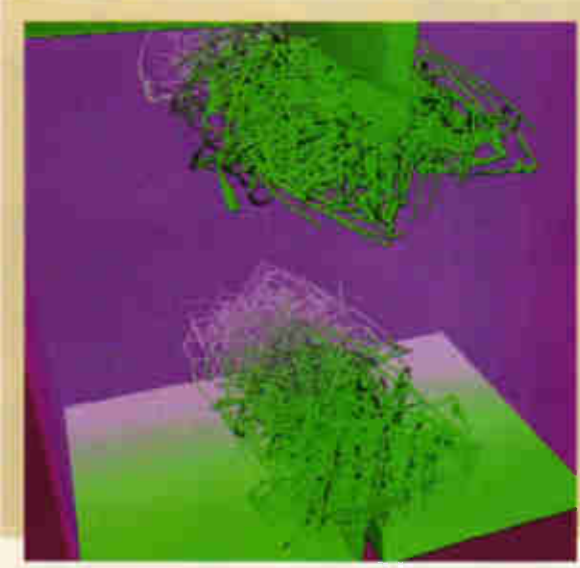
The photo shows the device mid-process, with two and a bit recessed polysilicon gates in trenches. Oxide will back-fill the trenches to make a planar surface for metalisation after sources are implanted in the mesa sides.

The oxide layer on the mesa tops is sacrificial and will be removed before metal deposition.

The first devices made using the p-channel Fets will be a 40V, 70mΩ SOT223 for digital audio.



Not perhaps the most essential piece of kit, but a fun way to brighten-up an otherwise boring box. Antec sells clear plastic fans illuminated with blue, or red, green and blue LEDs.



A virtual crystal of more than a billion atoms has two 90 atom-deep cuts in the middle of opposing faces, then the crystal is stretched by four per cent.

One of the most powerful supercomputers has been used to calculate cracks forming in a crystal - one atom at a time.

ASCI White, the IBM computer built last year for the Lawrence Livermore Labs did the work and displayed it as a video.

"Handling the data was a research project in itself," said physicist Tomas Diaz de la Rubia. "Visualising and navigating within huge datasets such as these is a milestone of the Accelerated Strategic Computing Initiative [ASCI] project that we have now achieved."

The work suggests brittle-fracture cracks can travel far faster than the local speed of sound - something thought impossible until recently.

According to the lab, the two 1999 earthquakes in Turkey seem to have featured faster-than-sound cracking, now the simulation gives a theoretical footing to such claims and "will result in improved tools to understand and predict the behaviours of earthquakes and to design new materials that can resist brittle fracture".

Dual bit memory is very flash

A new flash memory cell that stores two bits per cell without using multi-level techniques has been announced.

AMD calls the technology MirrorBit and partner Fujitsu calls it MirrorFlash.

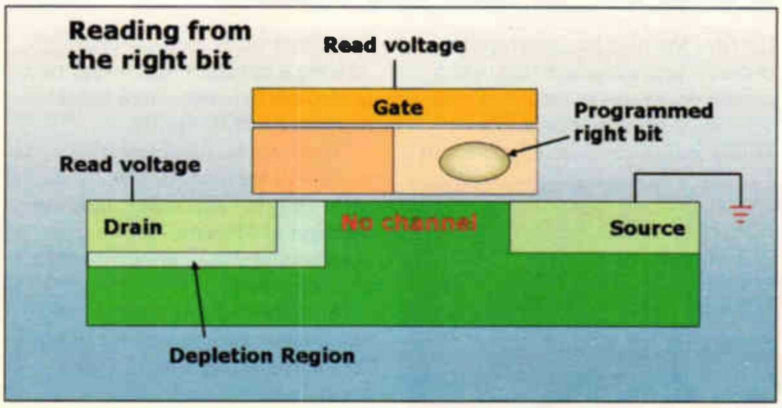
There are two main differences between MirrorBit and normal flash: the transistor is symmetrical in MirrorBit and the floating gate in which data is stored is insulating silicon nitride, not the usual conductive polysilicon.

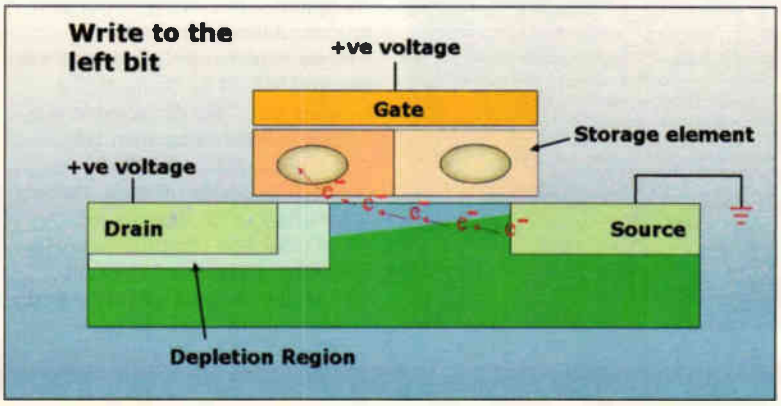
The new floating gate is the critical element as, being insulating, is can store regions of different charge.

In a normal floating gate injected electrons swim about as they wish. In an insulating gate electrons "are injected into traps in the nitride", said Joe Raushmayer, v-p of engineering at AMD.

Trapping allows electrons that make up one bit of data to be stored at one end of the gate while the second bit resides at the other end.

Being symmetrical, the underlying transistor allows both ends of the floating gate to be treated equally. Reading and writing the bits involves manipulating the two transistor electrodes appropriately.





Erasure is performed like a normal flash memory. The main gate is set negative and the transistor electrodes and its substrate are set positive. This forces the trapped electrons out of the storage structure erasing both bits.

US firm Digit Wireless has come up with a novel method of adding characters to a standard mobile phone keypad. Raised letters are placed inbetween the number pads while software copes with letters being pressed on the way to a number. The firm said the design should dramatically increase text entry speeds, and make it easier for partially sighted users.

Government pushes RF tags

Major UK firms have signed up to a Home Office initiative to add radio frequency identification (RFID) tags to consumer goods.

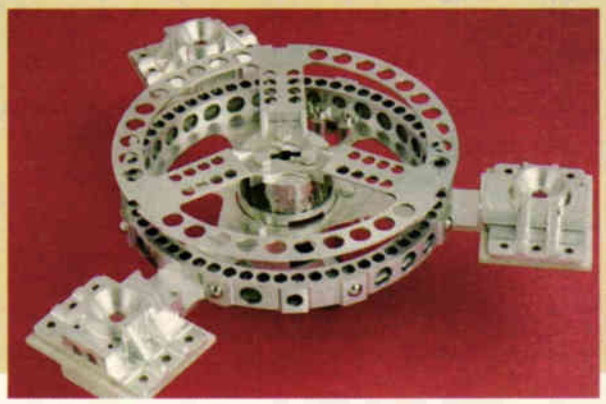
Woolworths, Dell, EMI and Asda are part of the scheme, which aims to stamp out the trade in stolen and counterfeit goods. Items tagged will include CDs, laptop PCs and clothing.

Goods will be fitted with a unique tag that stores information such as their origin, current location and final retail destination.

"As criminals are using increasingly sophisticated methods so we must harness the latest technology available to us if we are to catch them," said Crime Reduction Minister John Denham.

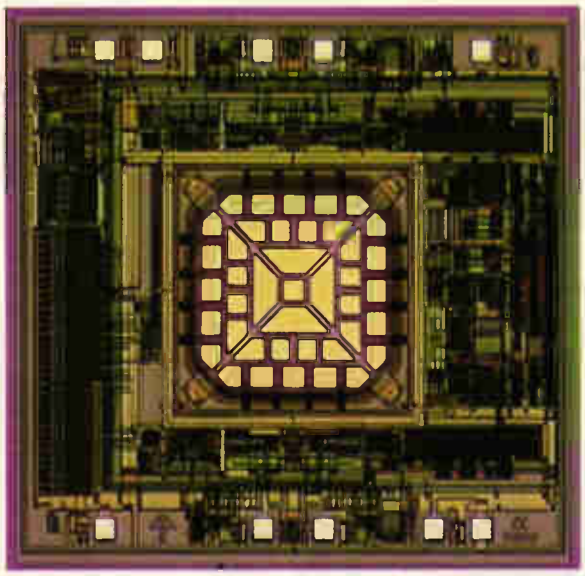
The Government is putting £5.5m into its Chipping of Goods initiative. It has already tested the system on mobile phones, watches, alcohol and boats.

Made by Bedfordshire-based INSYS, this will be the last thing to touch UK satellite Beagle 2 before it rendezvous with the Red Planet. Called the spin-up and ejection mechanism (SUEM), it has just passed qualification testing at Astrium in Stevenage. The SUEM will hold the satellite in place on its rocket during launch and on the six month cruise to Mars.



Sensor is all hot air

US firm Memsic has developed a two-axis accelerometer that uses a bubble of hot gas as the proof mass. The Massachusetts-based firm is selling its hot gas accelerometers in 5x5x2mm surface mount packages.



Using a bubble of gas brings two immediate benefits - high shock resistance and low noise.

"There are no moving parts except air. It will survive 50,000g," claimed Mike Higgins, marketing and sales manager at Memsic, (where g is acceleration due to gravity (9.8ms -2), not grams).

This seems like overkill for any imaginable application, but Higgins sees it as a safety margin above normal production processes. "Snapping a circuit board out can produce 3,000g," he said.

Noise is particularly low, and was recently halved by changing the working gas. "We can resolve very small g-forces: better than 1mg," said Higgins. Over frequency he claims 0.2mg/√Hz on some variants.

Accuracy in the devices, which range from 1 to 10g full-scale with options to 100g, is 0.2 per cent typical, 0.4 per cent max. Due to the tiny amount of air involved, response time is small, 40ms and 120ms worst-case claims Higgins.

So what are the disadvantages of thermal accelerometers?

"Dependence on temperature. The sensitivity changes and this has to be compensated externally," said Higgins. Although he points out that the compensation curve does not vary between devices as it derives from the gas law.

A datasheet and application note including compensation circuits is available from the company website.

Power consumption small - 3.6mA at 5V - and can be cut by pulsing, but may be enough to deter use in some battery powered applications.

As noise is so low, well under 1° of tilt can be measured, the accelerometers could be used to control cursors in portable devices where tilting the device moves the cursor or view. Car alarms, rollover detectors and navigation are all being considered as well.

www.memsic.com

How it works

In principle, the hot air accelerometer is simple. Hot air is less dense than cold air.

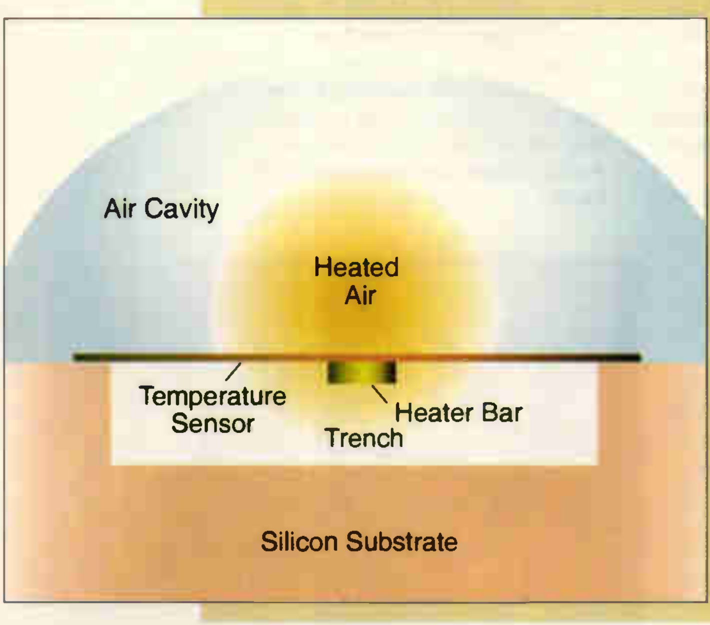
If they co-exist in a sealed environment and the environment is accelerated the hot air gets displaced in the direction of acceleration.

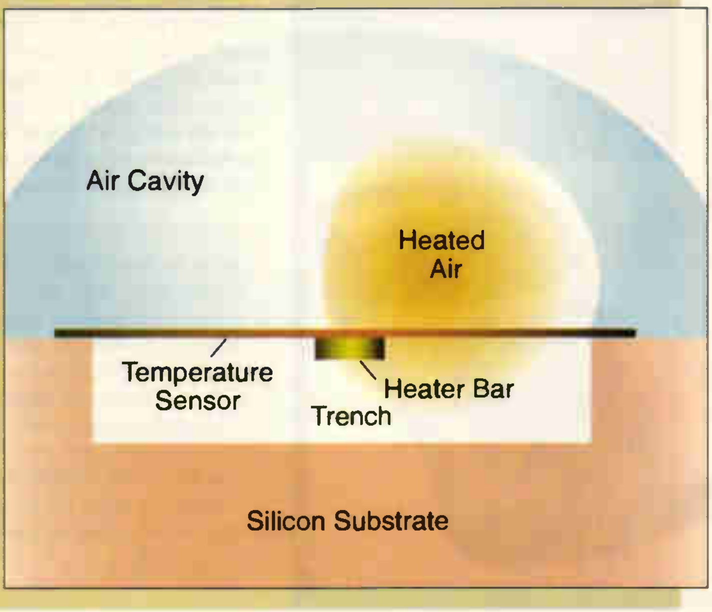
A similar effect can be seen if a toy helium balloon is let loose in a car. Accelerate the car and the balloon moves towards the windscreen. Brake and it moves towards the boot.

Memsic devices work in two-dimensions. The gas is held in a domed void with a flat silicon bottom within the chip packaging.

In the centre of the silicon is a heater. This maintains the hot air "bubble" as Memsic's Higgins describes it. "[Silicon] thermopile sensor under the bubble detect the way it moves," he said.

The chip, which includes conditioning circuitry and is made by TSMC, is standard CMOS except that the heater trench is added post-foundry by Memsic in its own Chinese plant.





Scots go for power dressing

Practical power generating fabrics are possible, is the conclusion of a research project at Heriot-Watt University in Edinburgh, although the team has not actually made any yet.

"We can see several ways to put silicon photo-voltaics directly onto fabrics without a glass substrate," said Professor John Wilson of the university.

What the team has done is to make photo-sensitive cloth and prove that photo-coated cloth can be stable, flexible and reasonably durable.

Polymer and similar organic photo-semiconductors may in future be ideal for photo-cloth, but were rejected from the project as they are too immature. Instead thin-film silicon was chosen and has been coated onto both woven and non-woven (felt-like) materials.

To make a cloth photosensor, silicon layers and electrodes are plasma-coated onto the fabric over a sealing layer.

The result is a cell which follows the contours of the fabric strands and is flexible. "The cell is unlikely to be the problem," said Wilson. "Reliable connections between cells are more difficult."

Photo-clothing is far into the future. Wilson sees photo-voltaic lorry tarpaulins and tentage as initial applications. "A roll-up canvas photo cell would be much easier to transport over rough roads than a glass one."

Finding a large-scale roll-to-roll plasma coating processes should not be a problem for production, as these are currently under development for a number of markets and, said Wilson, some carpets are currently being coated using a related high-tech process.

Heriot-Watt is seeking partners and funding for the next project phase.

John Andrews, Heriot-Watt researcher, examines woven textile substrate in front of the university's silicon plasma coating system.

Jelly foils fingerprint checks

A Japanese mathematician has broken the security on 11 fingerprint sensors by copying fingerprint patterns using cheap kitchen ingredients such as gelatine.

Tsutomu Matsumoto, from the graduate school of environment and information sciences at Yokohama National University, can fool fingerprint detectors 80 per cent of the time with his jelly-mould fingers.

His technique is to take an impression of a finger in a plastic mould, easily available in hobby shops, and then pour in liquid gelatine, which sets to form the fake finger. From start to finish the whole process takes less than one hour.

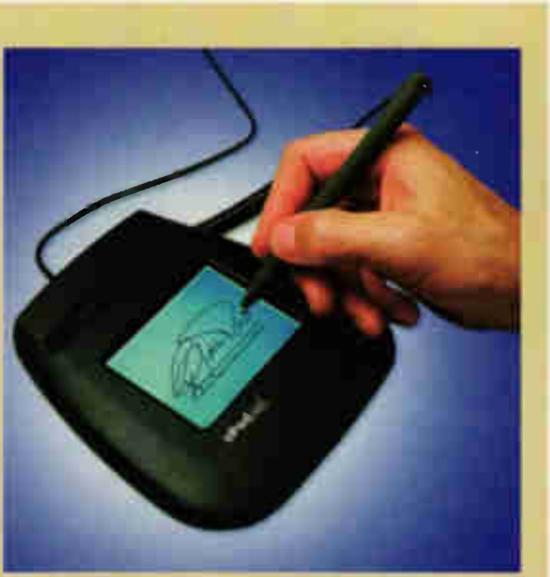
Fingerprint sensors can usually detect when a silicone prosthetic is used, but Matsumoto's use of gelatine deceives the technology. He can also fool sensors that claim to detect only 'live' fingers, by moistening the gelatine before pressing onto the sensor.

In a presentation to the International Telecommunications Union's workshop on security, Matsumoto said: "The experimental study on the dummy fingers will have considerable impact on security assessment of fingerprint systems."

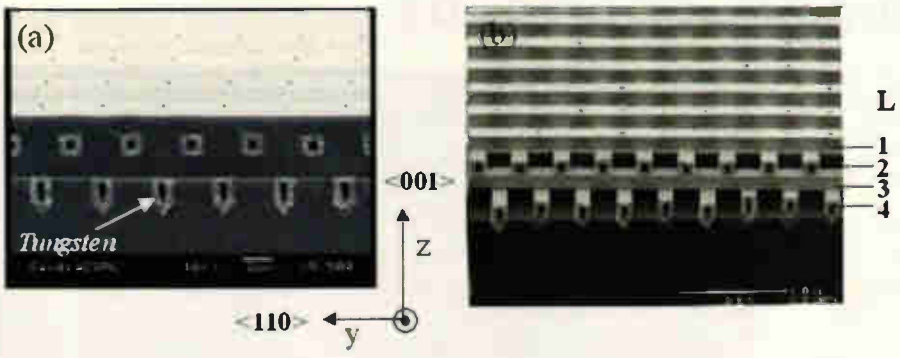
More significantly, Matsumoto is able to copy prints made on surfaces such as glass. The process involves fixing and enhancing the print with cyano-acrylate (superglue) fumes and photographing it, exactly as forensic scientists would do. The image is enhanced in a software package such as Photoshop and then copied onto a blank copper PCB. The print is then etched and pressed into a mould ready for the gelatine.

Whether copying fingers direct, or reproducing them from prints on glass, Matsumoto was able to break 11 commercially available sensing systems. These included optical and capacitive systems.

In his conclusions, Matsumoto pointed out that manufacturers and users of biometric systems should carefully check their security against artificial clones.



An LCD and touchscreen have been combined by Interlink Technologies to create a system for capturing digital signatures. The ePad-ink can add a signature to documents in standard software packages such as Microsoft Word, Access, Outlook and Adobe Acrobat. The LCD allows the document being signed to be displayed as they sign. The ePad-ink can also capture handwriting biometrics, including stylus pressure and timing.



Sandia's 3-D tungsten photonic crystal could revolutionise light bulbs.

The images, with (a) and without (b) oxide, show fabricated tungsten rods 1.2nm in diameter end-on. Spacing is 4.2nm, and the filling fraction of tungsten is 28 per cent.

New life for old filaments

Good old tungsten-filament bulbs, currently left behind in the efficiency stakes, could catch up through a development at Sandia National Laboratories in New Mexico.

The lab has combined a traditional filament with a recently invented structure called a photonic crystal lattice.

These lattices consist of loosely spaced regular three-dimensional arrays of rods or balls. By tuning the spacing, object size and lattice type, the optical properties of the resulting structure can be varied.

Lenses, prisms and filters can in principle be made.

The problem with conventional filaments is that most energy is emitted at infra-red wavelengths, so most energy fed into a light bulb is wasted as heat.

Sandia researchers reasoned that a photonic filament designed to block the passage of infra-red radiation might somehow emit more light than heat, and experiments suggest this is the case.

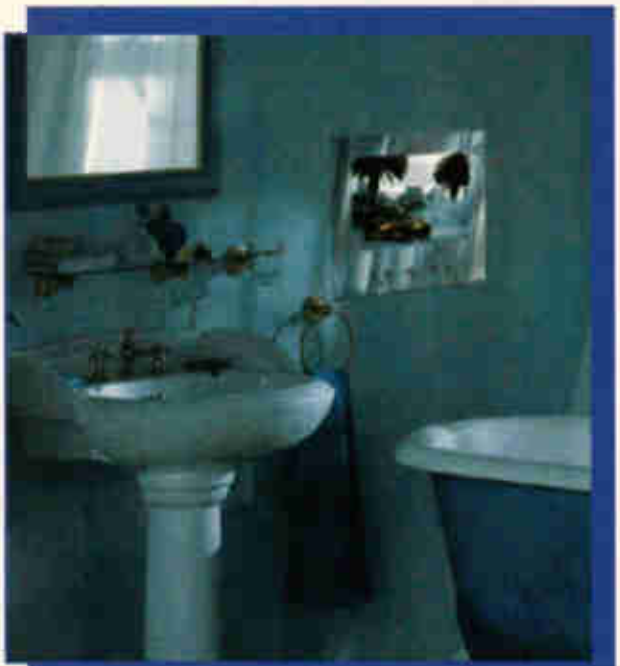
"This would raise the efficiency of an incandescent electric bulb from five per cent to greater than 60 per cent," said Sandia.

So far the experiments have not been extended to visible light. Instead a filament below dull red heat that would normally emit mostly medium-wave infra-red has been made to emit much more short wavelength infra-red.

"Energy was being preferentially absorbed into a selected frequency band. Meanwhile periodic metallic-air boundaries led to an extraordinarily large transmission enhancement. Experimental results showed that a large photonic band gap for wavelengths from 8 to 20 microns proved ideally suited for suppressing broadband blackbody radiation in the infrared and has the potential to redirect thermal excitation energy into the visible spectrum," said Sandia.

Could it work at visible frequencies?

"The work was performed with a photonic crystal operating in the mid-infrared range," said the lab, "but no theoretical or practical difficulties are known to exist to downsizing the structure into the visible light range."



Marata Vision has produced the ultimate luxury for telly addicts, a TV for the bathroom.

It is sized to replace a standard large tile, includes a 26cm (10.4in) screen in the standard 4:3 picture format, and is designed to work in wet environments.

TileVision, as it is called, comes as standard with a mirror finish or can be specially ordered to colour co-ordinate with bathroom décor or mounted into custom-designed solid marble surrounds.

Patented heated screen technology cuts steam-up and a built-in amplifier drives an external loudspeaker. Retail price is £1695 plus VAT, or £2145 plus VAT for a forthcoming 38cm version.

Hard drive hits 300Gbit/in [super2]

Fujitsu is claiming to be able to achieve a record hard disc drive density of 300Gbit/in^2 after developing a new read head and a new magnetic material.

"The new technologies are expected to lead to the commercial introduction within two to four years of 2.5 inch hard disc drives with capacities up to six times the recording density available today," said the company.

Current-perpendicular-to-plane mode is used in the new giant magneto-resistive (GMR) heads. These are credited with three times the playback output levels of existing hard drive heads which operate in current-in-plane mode are considered to have a limit of approximately 100Gbit/in^2, said Fujitsu.

Fujitsu engineers have developed a synthetic ferromagnetic media that can handle one million flux changes per inch to surface its proposed discs.

Within four years, Fujitsu claims it is likely to be making 360Gbyte hard drives. ■

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All components provided including a plastic case (140mm x 110mm x 35mm) with pre-punched and silk screened front/rear panels to give a professional and attractive finish (see photo). with screen printed front and rear panels supplied. Software utilities & programming examples supplied.

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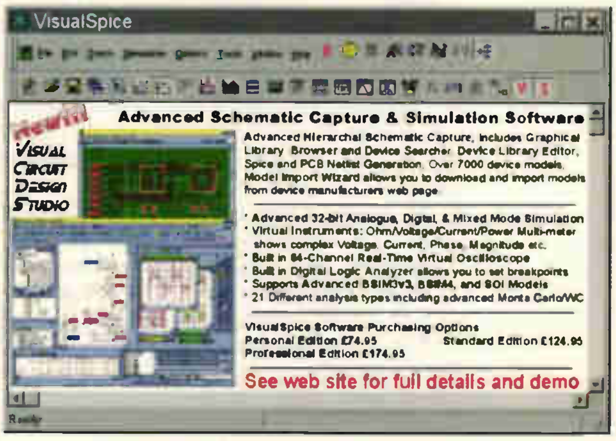

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There's no need to spend money on expensive instrumentation for calibrating your LF antennas, as Paolo Antoniazzi and Marco Arecco show. It's easy to calibrate LF loops aerials using the high power DCF39 signals at 138.83kHz.

Calibrating LF antennae using DCF39

Our first attempt at making an LF loop antenna was disastrous. After months of study, measurements and discussion though, we are now true supporters of the loop antenna for receiving LF signals.

A simple loop with 38 turns at about 80cm diameter is a good competitor for a vertical rod and a 2m diameter loop will result in a superb antenna – the equivalent of 20 to 50m height at 136kHz!

An important question is how to make reliable measurements of the performance of loop antennas and other similar configurations. Here we propose a solution to the problem using the high-powered DCF39 station in Germany in conjunction with a small and simple reference loop.

Bear in mind that a loop antenna that performs wonderfully when receiving signals will not necessarily achieve the wonderful performance when transmitting.

Loop antennas for 136kHz

A loop antenna comprises a large coil wound on a suitable isolated support with an appropriate base. The main advantages of the loop used as an LF receiving antenna are

- directivity and narrow band if tuned
- less sensitivity to local electric noises
- smaller dimensions relative to an equivalent vertical rod
- easy to build.

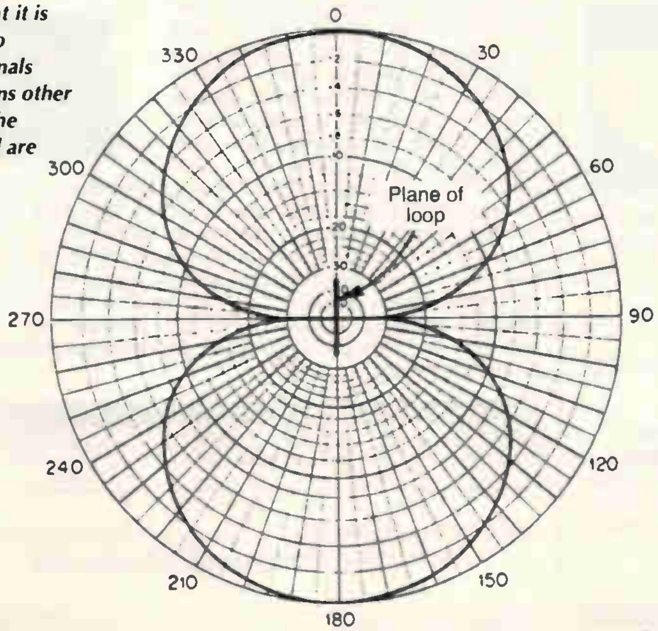

Fig. 1. The loop antenna has the advantage over a monopole that it is directional, so unwanted signals from directions other than that of the wanted signal are attenuated.

The antenna works by taking energy from the incoming wave, due to the phase differences between the voltages induced in the two vertical opposite sides. When the plane of the loop is perpendicular to the direction of the propagation wave, no voltage results at the aerial terminals. In contrast, when the loop antenna's plane is parallel to the incoming wave, the voltage across the antenna reaches the maximum value.

The directivity of a loop is about 90° in the front and at the back (–3dB perpendicular to the antenna plane) This is certainly an advantage in comparison to a vertical rod because it prevents unwanted signals coming from different paths, **Fig.1**.

The following relation describes the voltage across a loop receiving aerial submitted to an electric field.[1]

$$V = \frac{2\pi ENA\cos\theta}{\lambda} = Eh_e\cos\theta$$

where:
V = voltage at the ends of the loop (mV)
E = electric field (mV/m)
N = number of turns of the loop
A = average turn area (m^2)
λ = wavelength (m)
θ = angle between loop plane and the arriving wave: if the angle is 0°, $\cos\theta=1$ and this term disappears
h_e = antenna equivalent height (m)

This equation is applicable to any loop shape provided that the antenna's dimensions are small compared with the wavelength – i.e. less than approximately 0.1λ. In the low-frequency range, it is very easy to satisfy this requirement.

You can tune the loop by placing a variable capacitor across the antenna terminals. This cause a larger voltage to appear at the balanced preamplifier inputs because of the Q of the parallel-resonant circuit.

#	Turns (N)	Dia (m)	A (m^2)	Total Wire Length (m)	N x A (m^2)	Q Unloaded	Induct. (µH)	Tuning Cap. (pF)	Equiv. height h_e (m)	Notes
Loop 18M008	18	0.31	0.0754	17.5	1.36	200	148	8200	0.774	Plastic covered 1.8 mm diameter wires Moplen support
Loop 38M047	38	0.77	0.470	92	17.9	210	1700	806	9.17	Plastic covered 1.8 mm diameter wires Wood support
G3LNP (*)	54	0.90	0.640	153	34.6	70	4320	318	6.90	Litz Wires Wood support
Loop 18M2 (**)	18	1.60	2.00	91	36	200	1032	1327	20.5	Plastic covered 1.8 mm diameter wires Wood support
Loop 24M4 (**)	24	2.26	4.00	171	96	200	2631	520	54.7	Plastic covered 1.8 mm diameter wires Wood support

(*) Tony Preedy, G3LNP (**Ref. 16**)
(**) Calculated only

Table. 1. Tuned loops comparison at 136kHz.

Loaded Qs of 100-200 are easy to obtain with carefull loop construction using wire with a diameter of more than 1mm and an air-spaced capacitor.

In this case, the gain improvement can be more than 40dB.

$$h_e = \frac{2\pi NAQ}{\lambda}$$

This equation can be also considered to represent the antenna's efficiency. The equation that describes the voltage across the receiving loop antenna can be written again as a function of the arriving magnetic field[2]:

$$V=2\pi f\mu_0 HNA$$

where:

f = frequency (Hz)
μ_0 = absolute magnetic permeability of air = $4\pi\times10^{-7}H/m$
H = magnetic field (mA/m)

During the loop antenna's design, it is not essential to minimise the RF resistance of the wires, as it is with the load coil of a vertical transmitting antenna.

It is useful to remember that a merit factor of 200 at 136kHz means a bandwidth of 680Hz with a 3dB loss at the cut-off frequencies (–3dB). This fact allowed us to use low-cost electrical wire with a 2.5mm^2 cross section with polyethylene insulation. For applications that require very-low RF resistance, such as vertical antenna loading coils, much more expensive Litz wire is necessary.[3,4]

Presented in **Table 1** are the physical and electrical characteristics – calculated and measured – of the loop aerials we made during our recent study .

It is not always necessary to use a coaxial cable to improve the insensitiveness to local electric noises of loop antennas. The high shield capacitance – 60pF/m or more using 75Ω coaxial cable employed in the satellite TV – make the tuning of the loop antenna difficult since it is resonating at a frequency much lower than the desired frequency.

We prefer to achieve the insensitiveness to local electric noises, generally man made, by fully-balancing the whole antenna circuit: the loop, the capacitances (a fixed capacitor plus varicap diodes for the fine tuning) and the preamplifier.

To match the high impedance of the resonant circuit with the LF receiver's low impedances, we use an instrumentation amplifier comprising three op-amps. It provides high input impedance, high gain and bandwidth and a relatively low output impedance.

Considering the electrical characteristics of our 38-turn loop, in which L is 1.7mH and Q is 210 (Table 1), the parallel resistance of the resonating circuit, R_P, is $2\pi fLQ$. At 136kHz, this is 305kΩ . Being in parallel with the 2MΩ input resistance of the operational amplifier, this resistance becomes 265kΩ.

Such a low resistance deteriorates the merit factor of the antenna circuit from 210 to 182. In other words, the load constituted by the input of the operational amplifier produces an insertion loss of 1.25dB.

This loss figure indicated that it was not possible to increase the loop antenna's equivalent height as much as we would have liked. Equivalent height is limited by the impedance that can be connected at the input of the operational amplifier. Increasing this impedance also increases noise.

At this point, it is useful to consider the equation for calculating the thermal noise at the preamplifier input:

$$e_n = \sqrt{(4KTRB)} = 0.29\mu V$$

considering a bandwidth of 20Hz and a room ambient temperature of 25°C. Here:

e_n = noise voltage (V)
K = Boltzman's constant, which is 1.374×10^{-23}J/K
T = absolute temperature in kelvin
R = resistance across which thermal agitation is produced (Ω)
B = bandwidth (Hz)

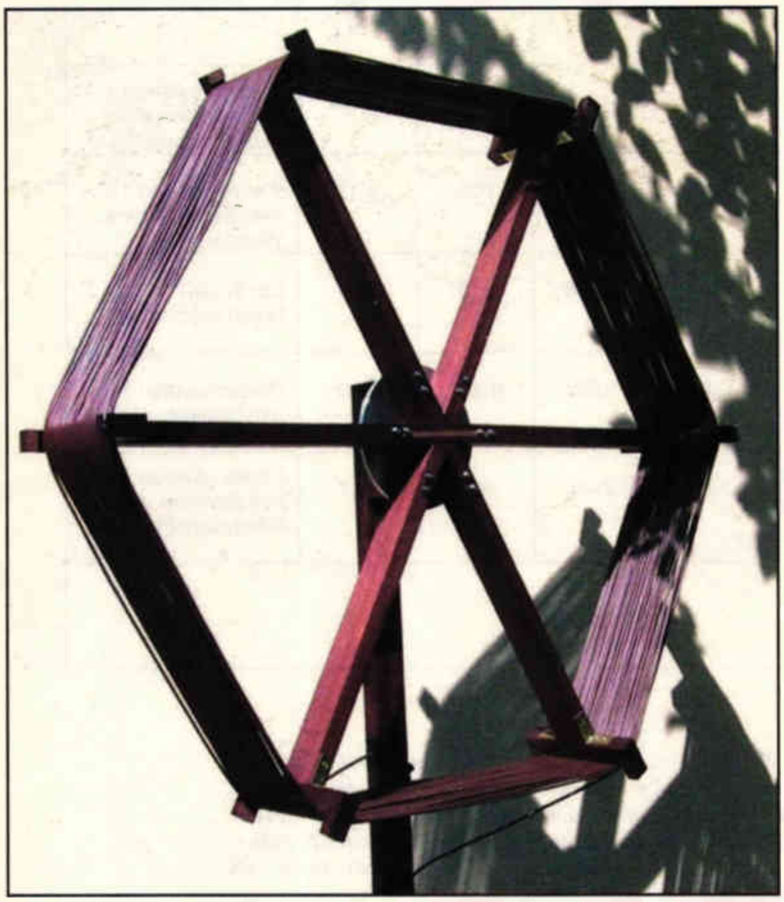

Fig. 2. The Loop 38 with an Equivalent Height (he) of about 9 metres @ 136kHz.

Another limit on how much antenna equivalent height can be obtained is the stray capacitance of the loop. To try to define a limit for the antenna equivalent height, we measured the stray capacitance of our 38-turn loop, **Fig. 2**. It turned out to be 70pF. This seems to be a good trade-off between the physical dimensions and the electrical performance. The disadvantage relative to an optimized antenna is only 10nV more thermal noise and about 1dB lower gain.

Key parameter for loop antennas

The product $N \times A$, where N is the number of turns and A the area of the loop, is the key parameter for loop antennas. However, two antennas with the same $N \times A$ product may be very different in terms of inductance.

Comparing a loop 'A', which has 54 turns and 0.64 area, against a loop 'B' with 18 turns and 2 area, you can see that there's a 4-to-1 inductance ratio. Higher loop inductance means higher parallel input resistance – and hence amplifier noise.

Component choice

To underline the electrical performances of the operational amplifier to be used: the input noise of the circuit, see **Fig. 3**, is 0.4pA/√Hz. This equates to 0.48μV considering an input resistance of 265kΩ and a receiver bandwidth of 20Hz using high quality OP37. The figure increases if TL081 op-amps are used in the first stage.

Gain of the input stage is set at 20dB and gain of the output stage is 6 to 12dB according to your design needs.

You can use a 600Ω direct output or coaxial cable matching with a 300/75Ω output transformer. Full power bandwidth for a 20V pk-pk output is 250kHz.

As you can see from Table 1, our 38-turn loop has an equivalent height of 9.17m – even though its diameter is only 0.77m.

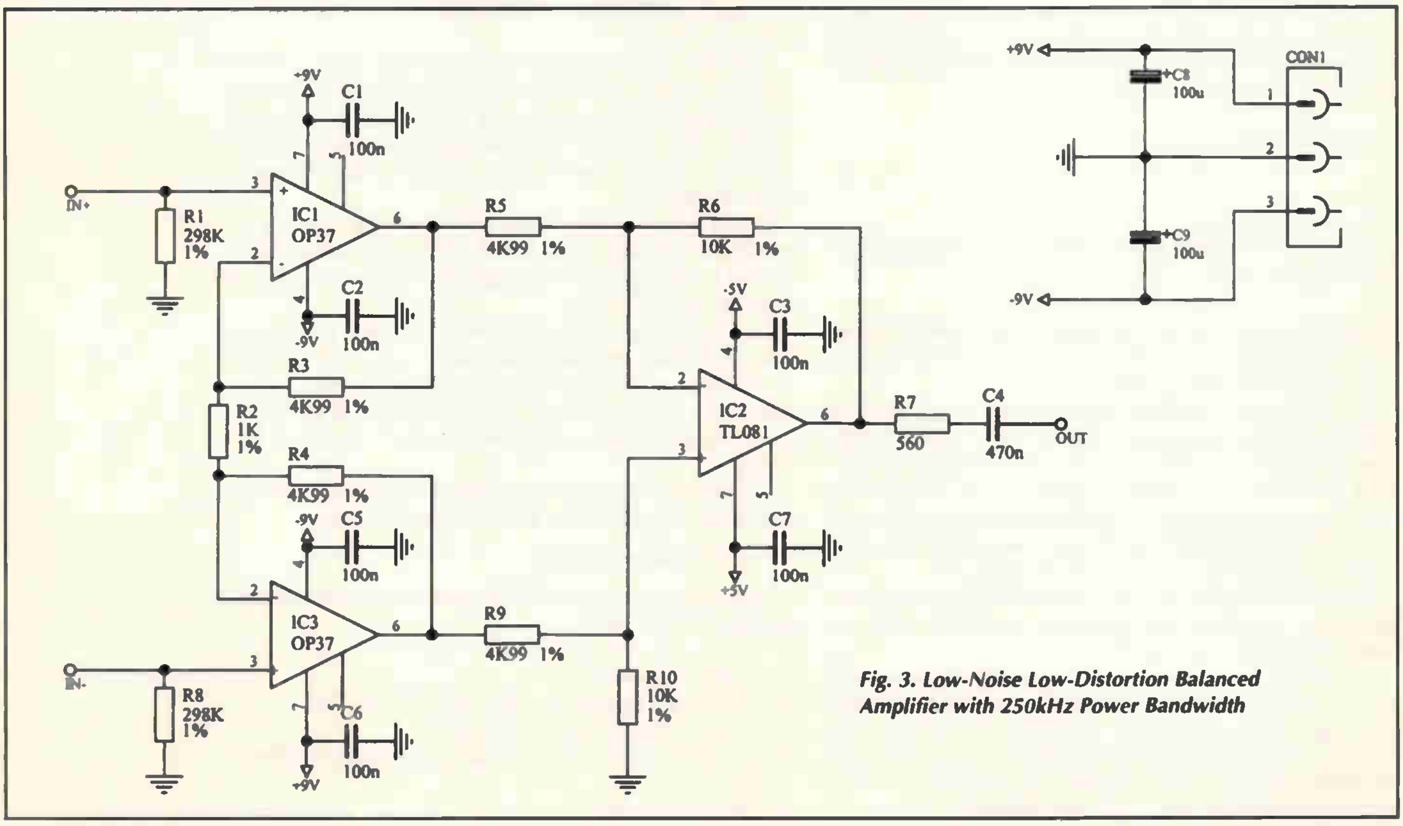

Fig. 3. Low-Noise Low-Distortion Balanced Amplifier with 250kHz Power Bandwidth

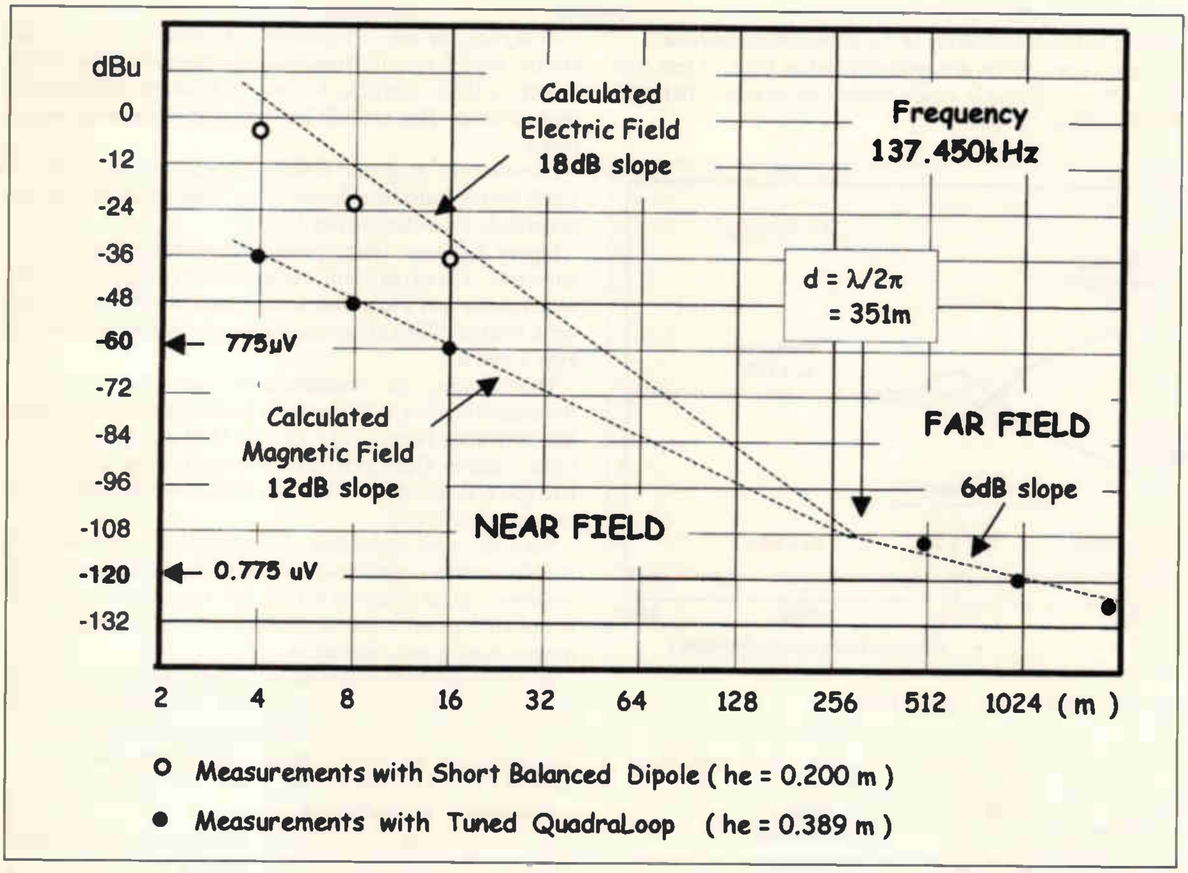

Fig. 4. Measured Values of the Near Field and Far Field (both magnetic and electric field).

Magnetic-cored loop

Loop antennas can be made using a magnetic core, for instance ferrite, instead of air.

If an air-cored loop is placed in a field, it cuts the lines of the flux without disturbing them. On the other hand, when a ferrite aerial is placed in the field, the nearby field lines are redirected into the loop. This is because the reluctance of the ferrite material is less than that of the air. The reluctance is inversely proportional to the relative permeability of the rod core (μ_r).

In this case the equation of the equivalent height becomes:[5]

$$h_e = \frac{2\pi\mu_r ANQ}{\lambda}$$

Using this kind of antenna, it is not possible to reach the equivalent height of a loop wound on wood and air. For this reason, the best use for ferrite aerials is in compact portable instrumentation.

Applying this criterion, we used the ferrite antenna to perform magnetic field measurement from five metres to five kilometres away from the transmitting antenna.

Magnetic or electric field

The field's nearness to the transmitting antenna, whether it is a vertical rod or loop type, can be calculated using the following equations. They assume that the wave path is parallel to the Earth's surface[6]:

$$E = \frac{30 h_e \lambda I}{\pi d^3}$$

Where:

E = near electric field (V/m)
h_e = antenna equivalent height (m)
λ = wavelength (m)
I = effective value of antenna current (A)
d = distance from transmitting antenna (m)

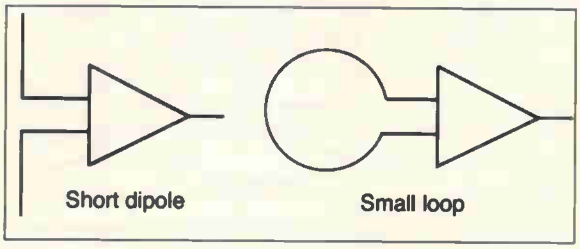

Fig. 5. Principle Circuit of the Reference Loop and Dipole Antennas.

The vector of electric field is perpendicular to the Earth's surface and with the positive direction upwards.

$$H = \frac{h_e I}{4\pi d^2}$$

Here, H is the near magnetic field (A/m).

The relevant vector is parallel to the Earth surface and in quadrature with the electric field with the positive direction

Fig. 6. Ferrite Aerial and Amplified Short Dipole tuned at 138.83kHz and used in the Tests.

rotated rightwards looking at the transmitting antenna.

These relationships are applicable when the h_e is less than 0.1λ. That is, of course, easily verified because at 136kHz the wavelength is 2206m.

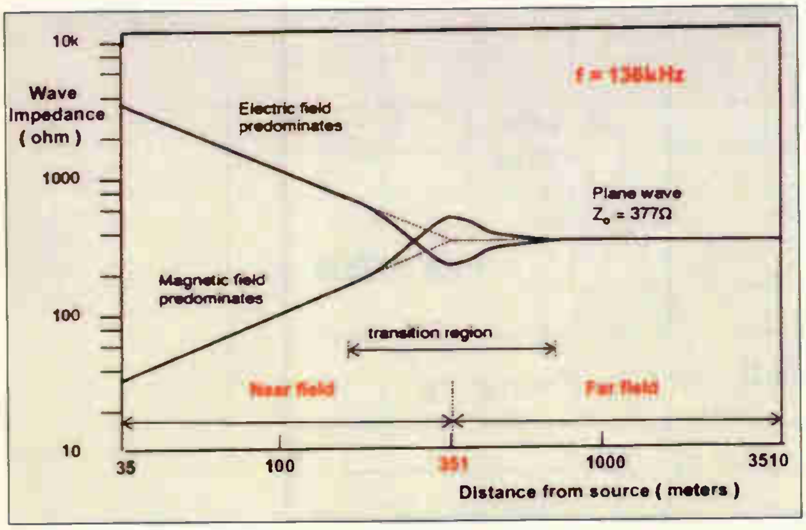

Fig. 7. Wave Impedance in the LF Near Field and Far Field.

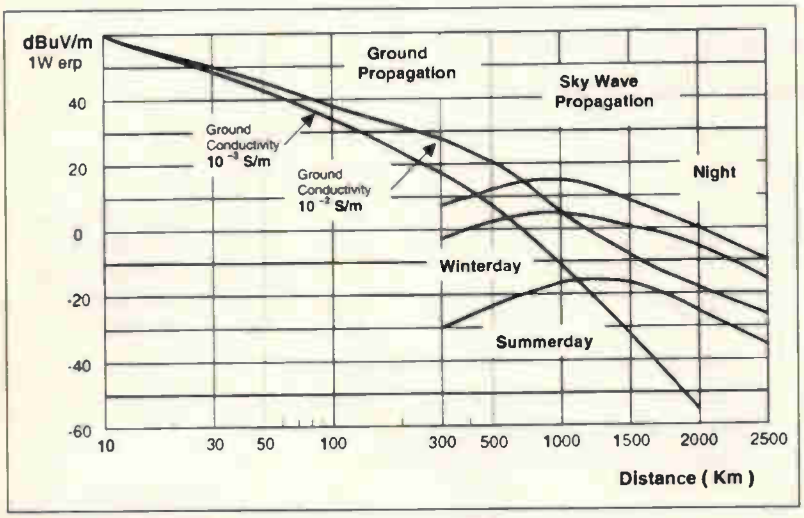

Fig. 8. Ground and skywave propagation at 136KHz.

Distance (Km)	100	200	300	500	700	1000
Groundwave Good Ground	38.6	30.4	25.9	17.9	12.5	1.9
Groundwave Poor Ground	34.7	17.4	8.9	-4.6	-20.4	-31.5
Skywave Night		-2.6	-10	2.1	5.4	8.2
Skywave Day (*)				-25.1	-14.7	-8.2

(*) Low solar angle (winter or late afternoon)

Table 2. Calculated Field Strength vs. Distance in dBμV/m, for radiated power10 of 1W.

Analysing the above equations it becomes clear that the electric field E near the transmitting antenna decreases with a slope of 18dB each time the distance from the radiating element doubles. This is 60dB for each tenfold increase in distance.

Likewise the magnetic field H decreases with a slope of 12dB for each distance doubling, or 40dB for each order of magnitude increment of the distance.

Figure 4 shows experimental confirmation of this attenuation rule. The experiment was performed using both a balanced dipole and a loop antenna to measure the electric/magnetic field at different distances from the radiating element, **Figs 5** and **6**.

These types of measurements are not so easy. Remembering that at 10 metres from the transmitting source the difference between the electric field and the magnetic field is about 30dB, great attention needs to be paid to the balance and shielding of the antennas involved and also to the operating levels.

Since the input impedance of an electrically short dipole is predominantly a capacitive reactance, broadband frequency response can be achieved with a high-impedance load. This is not so important for the 136kHz tests using single-frequency tuning and calibration.

A 40+40cm short balanced and tuned dipole has about a 20cm electrical height, but an accurate calibration is realised by comparison with a reference antenna in the far field zone . By trimming the gain of the high-input impedance dipole amplifier we measure exactly a 1mV out on the precision receiver for a known field of 1 mV/m.

At this moment it is probably necessary to better define what you mean by Near and Far Field.

In the technical literature there are many definitions of the boundary between near and far field[7]:

We prefer to assume the edge of the near field at the distance which the wave impedance Z_0 becomes:

$$Z_o = \frac{E}{H} = \sqrt{\frac{\mu_o}{\varepsilon_o}} = 120\pi \sim 377\Omega$$

where:
μ_0 = absolute magnetic permeability of the air = 4π x 0^{-7}H/m
ε_0 = absolute dielectric constant of the air = 8.85 x 10^{-12} F/m

This occurs at a distance from the transmitting antenna, given by the following equation:

$$d \Rightarrow \frac{\lambda}{2\pi} = 351m\ @136KHz$$

In the near field (d<351m) condition a vertical rod will generate mainly a high impedance electric field, while a loop aerial will produce mainly a low impedance electric field. This kind of behaviour is well shown in the **Fig. 7** in which is also displayed a transition region, about one sixth wavelength wide, between near and far field regions.

This point of view is in accordance[8] with the CCIR 368-7 recommendation that establishes to measure the effective radiated power, through a field measurement, at a distance of 1km from the transmitting antenna because at this distance the plane wave condition is also satisfied.

$$P = \frac{E^2}{90}$$

where:
P = effective radiated power (W)
E = electric field (mV/m)

In the far field condition, the electric field is given by the following equation[6]:

$$E = \frac{60\pi h_e I}{d\lambda}$$

And consequently the magnetic field becomes:

$$H = \frac{h_e I}{2d\lambda}$$

At a distance greater than far field condition (d>351m) the slope of both the magnetic and electric fields versus the distance become 6dB each doubling or, if you prefer, 20dB each decade.

This kind of trend is valid until 300–500km, for the frequency of 136kHz, even if the fall is influenced by the imperfect ground conductivity (σπω) that worsens the slope as reported in the **Fig. 8** where

$\sigma=10^{-2}$S/m and $\sigma_1=10^{-3}$S/m.

Until now the ground wave has been described. It concerns the electromagnetic fields travelling along the earth surface induced and being induced by the current flowing on and slightly below the earth surface. Sometimes those fields are defined as Surface Waves.

At distances greater than 300–500km the Ground Wave drops down faster and becomes significant compared to the wave reflected by the ionosphere.

The model performs some assumptions to simplify the geometric computation of the Sky Wave:

- the ionosphere is a zero thickness layer having a height of 70km daily and 90km nightly
- the Sky Wave path is a straight line
- the Earth is considered a perfect sphere
- the coefficients (ionosphere reflection and focusing factors, RX/TX antenna ground pattern factors) have been introduced in order to meet practical measurements with the theory.
- the ground conductivity $\sigma=2\times10^{-3}$S/m and the ground relative dielectric constant $\varepsilon=15$.

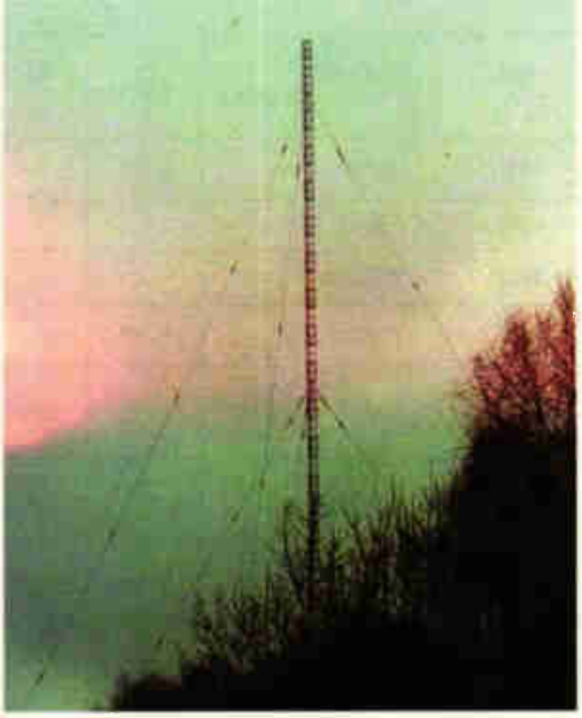

Fig. 9. The Vertical Antenna of the DCF39 station in Magdenburg (324m high!).

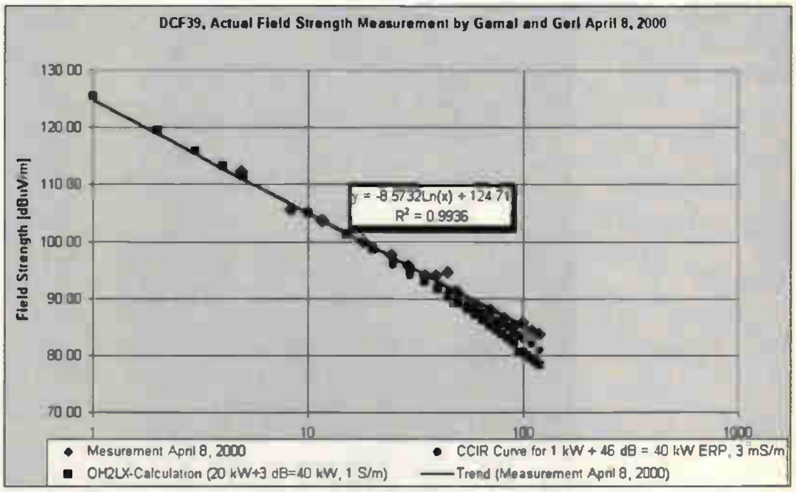

Fig. 10. Measurements of the Far Field Signal from DCF39 (by DK8KW and OH2LX).

The results of these calculations are reported in the right side of **Fig. 8** where three cases are represented: the night (the best case independently of season), the day during the winter and the day during the summer (the worst case). For an other important source of information see references 9,10 and 11.

Table 2. is a simplified extraction from this very important study.

The contacts (QSO) at distances greater than 1500÷2000Km can be performed only if a good antenna-ground system is available (the legal power cannot be over the 1W erp) thanks to the Sky Wave.

DCF39 : An high power radio source

To calibrate LF antennas we need a stable and powerful radio source and the DCF39 station (locator JO52WG) in Magdenburg (Germany) is the perfect solution emitting a stable and strong signal (**Table 3**) that can be heard throught Europe. The Mark frequency of 138.830kHz can be used also very nicely as a frequency alignment source. The ASCII modulation (200 Baud FSK 340Hz shift) switches over the Space frequency every 10 seconds or so. The station is managed by Europaeische Funk-Rundsteuerung Gmbh (EFR), the transmitter power is 50kW and the vertical monopole antenna is 324m high (see photo in **Fig. 9**)! The emitted

Table. 3. Typical DCF39 received signals (dB(V/m) in Europe.

DCF39 (138.830 KHz)
Received Signal

Km.	dBuV/m
100	85
200	79
300	74
500	60-66
750	**45-60**
1000	34-51

Table. 4. Loop antennas:calculated and measured output voltages (using DCF39 signal at 750km).

Measure	DCF39 Field		Reference Loop 18 (*) N=18, A=0.0754m^2 Diameter= 310mm		Ferrite Aerial Length=600mm N=100 Q=120		Tuned 135-139KHz Super Loop 38 N=38, A=0.47m^2 Q=182	
	(μV/m)	(dBμV/m)	Out (μV)	h_e (m)	Out (μV)	h_e (m)	Out (μV)	h_e (m)
Calculated	800	58.1	3.09	0.00386	926	1.16	7338	9.17
Night h. 22.00	800	58.1	3.09	0.00386	880	1.10	6800	8.50
Night h. 21.00	737	57.3	2.84	0.00386	814	1.10	6200	8.41
Day h. 15.00	300	49.5	1.16	0.00386	335	1.12	2622	8.74
Day h. 17.00	580	55.3	2.23	0.00386	638	1.10	4925	8.49

(*) Output voltage measured with RL=100Kohm and BW=20Hz

Fig.11. The Loop 18, an 18 turn, 31 cm diameter reference loop.

EIRP (Emitted Power referred to an isotropical antenna) is about 40kW omnidirectional, confirmed by many mesurements[12] taken by DK8KW and OH2LX, **Fig. 10**, in April 2000.

The DCF39 station is intended for long wave teleswitching which is a new way in load management technology. It replaces the ripple-control technology, which is widely used in the utility industry worldwide. It is used for tariff-switching applications and load management as well as for the control of street lighting (the management of modern power supply systems requires the transmission of commands to control the consumption of electricity at any time). The newly offered LF teleswitching system is using the DCF39 radio channel to transmit the information.

Antenna calibration

With the availability of a suitable radio signal (as DCF39) the calibration of unknown loop or ferrite antennas is not so difficult. The first step consists of realization of a simple reference antenna or sensor (a magnetic-field probe or reference loop consists of an electrically small, balanced antenna) which is obtained by winding N turns of wire on a support of known area (A).

The complete original formula shows the h_e (equivalent height) of a corresponding vertical aerial.

The product of the equivalent height (metres) multiplied by the local field (E=1mV/m) is the received signal. At 136kHz we can use a simplified formula to show the unloaded output voltage of the simple but accurate reference sensor:

$v = h_e \times E = 0.00386 \times 10^{-3} = 3.86\text{mV}$

In our tests a plastic basin with a diameter of 31cm was used as support, **Fig. 11**. With N = 18 turns (of 2.5mm^2 copper wire) and A = 0.0754m^2 loop aerial in a received field (E) of 1mV/m the measured open circuit output voltage is 3.86mV (with S/N>20dB).

This type of reference loop was been tested[12,13] by PA0SE and SM6PXJ with measured and calculated values within better than 0.5dB. The standard method used is that of the Helmholtz coils, but other people proposed a more simple test using the ANSI/IEEE standard[15] 644-1987 normally suggested for 50/60Hz EMF probe calibration. The Helmoltz coil can provide a uniform, known magnetic field (H): the test object (ferrite aerial or small air loop) is centered equidistantly between each side of the coils. The accuracy of the coil was checked with a small calibration loop (5 turns, diameter 76mm) connected to the selective level meter

Ferrite Rods	#	Length (mm)	Equival. Diameter (mm)	L/D	Area (mm^2)	μ_{rod} (*)	μ_{rod} x A	L (μH)	h_e (m)	Q
Single	1	200	10	20	78.5	118	9267		0.31	
Two in series	2	400	10	40	78.5	210	16493			
Three in series	3	600	10	60	78.5	260	20420			
Two series and two in parallel	4	400	14	29	154	166	25554		0.89	
Three series and two parallel	6	600	14	43	154	220	33866	1100	1.16	120
Three series and three parallel	9	600	17	35	227	185	41991			
Three series and four parallel	12	600	20	30	314	170	53407		1.82	
(*) Philips, Soft Ferrites Manual, Aug. 1990, pag.73 (Permeability versus Length/Diameter Ratio)										

Table. 5. Multi rods ferrite aerials : Calculations and Measurements.

or calibrated receiver. The maximum error was found to be within 0.10dB.

For the maximum accuracy of the tests it is very important to avoid resonating frequencies and parasitic capacities. In our 18 turn coil we have: L = 155μH (XL = 132Ω @ 136kHz) and an autoresonating frequency of 1.2MHz. With a 100kΩ input impedance of the test setup we can measure exactly the open circuit voltage generated by the reference loop and also with a 600Ω input impedance we have a load error of only about 1dB.

One secret: all the tests with the DCF39 (at 750km from the transmitter) are made using high selectivity receivers with very narrow bandwidth (example: BW=20Hz).

Starting from a calibrated Reference Antenna we have measured three other interesting aerials: an untuned 38 turn 77cm diameter loop, the same with a tuned and loaded by the preamplifier input impedance (Q = 182) and a very portable Ferrite antenna.

These and other results are shown in **Table 4**. For people interested in the realisation phase of loop antennas the articles in references 16, 17 and 18 are advisable. For the Ferrite Aerials the calculated values for a number of ferrite rods are shown in **Table 5.** Such antennas mainly utilize the magnetic field component of the signal to be received, and the directional characteristics of the antenna correspond to that of a short dipole, which is an "8" with a flat maximum and a sharp null. 100 turns of Litz wire (many thin wires) may be wound on a single rod (basic permeability = 500), or to increase the output, the core may be two or more rods taped together. Best performance is obtained with groups of rods glued end to end contained in a U-shaped electrostatic shield.

As shown in the table, the maximum suggested number of ferrite rods is about six. The calculated improvement with nine or 12 rods is not impressive. The equivalent height (h_e) of our realization (three rods in series × 2 rods in parallel = six) is about 1 metre (calculated 1.16m). This is a good solution for portable use as secondary reference antenna. For more info on the ferrite aerials see also references 19 and 20.

Conclusions

The Loop Aerials are extremely interesting for receiving in the 136kHz band because of their specific characteristics: high gain, high selectivity, directivity and low interference noise. The possible limits for an optimised big loop at 136kHz (Q = 200, BW = 680Hz) are about: area (A) =8 - 10m^2. N = 30 turns, h_e => 50m. This antenna has a good rejection to the local electric noise and an equivalent height not obtainable with any "practical" vertical Marconi antennas.

The more important parameters of a few loop aerials have been tested and the theoretical equivalent heights (h_e) confirmed using the DCF39 comparison method. Our record in the experimental tested antennas was h_e=30m.

Other experiments and statistics are necessary to have a more complete knowledge of Signal to Noise optimization of loops. ■

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Designing for EMC

During the first half of the last century, interference problems began to manifest themselves in valve equipment. One attempt to solve this problem was to wire all the components to a single point on the chassis. The 'star point ground' was conceived.

The desired effect was noise reduction. The opposite effect was achieved, in fact interference problems were created and these problems persisted for the lifetime of the equipment. In spite of this the idea gained widespread acceptance and some influential engineers still recommend it. As a guideline for circuit designers wishing to achieve Electromagnetic Compatibility (EMC) for their products, it has long passed its use-by date.

The fact that it retains wide acceptance identifies an even more deep-seated problem: too great a reliance is being placed on guidelines, tips, fixes and on the pronouncements of EMC gurus. This is a hit or miss approach. Guidelines become outdated as technology progresses, tips and fixes that work beautifully in one application are disastrous in others and gurus distance themselves from the project before problems appear. This note identifies the fallacy in the star point ground concept and points to a systematic approach to those aspects of design that achieve EMC of the product.

The star ground concept

Star point grounding is a method of wiring circuits that minimises the resistive coupling between two separate circuits. **Fig. 1**. illustrates the idea. The boxes A, B, C, and D can be thought of as printed circuit boards containing interface circuits.

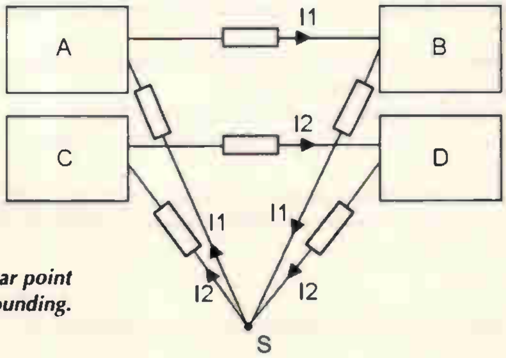


Fig. 1. Concept of star point grounding.

The wiring is organised to carry signal 1 from A to B, and signal 2 from C to D. Return conductors are all routed via the star point, S. Since there is no resistive component common to both circuits, there can be no resistive coupling between them. The reasoning is that, if there is no common coupling, there can be no interference.

The fallacy

The fallacy in this reasoning is that it limits its consideration to resistive coupling. Magnetic and electric field effects are ignored. If inductive coupling is considered, the picture changes completely. In **Fig. 1**. the current I1 flows in a loop enclosing a wide area. A great deal of magnetic flux threads through this area. Inevitably, a significant proportion of this flux also threads through the second loop. Transformer action ensures that a relatively high voltage is developed in series with the second loop. This appears as an interference source; an unwelcome addition to the desired signal.

Where there are magnetic fields, you will find electric fields. These manifest themselves as capacitance coupling between the conductors and add their own contribution to the interference. Signal 2 will interfere with signal 1 in exactly the same way. Star point grounding creates a system in which every signal interferes noticeably with every other. If the system interferes with itself, of what use is it when subjected to an environment where the external field is greater than that of the signals being processed?

Alternative approach

If star point grounding is to be abandoned, what should replace it? Perhaps the best approach is to start with an overview of the system and then to implement the lessons learnt from theory. The initial objective can be formulated: to transmit one signal from A to B and another from C to D, with minimal interference between the two signals. It is assumed that there are a number of other circuits in the overall system and that cable conductors will be used to carry the signals.

Transmission line concept

Some fundamental concepts of electromagnetic theory and circuit theory are combined in the picture of the transmission line shown in **Fig. 3.**. Current in the upper conductor is matched by an equal current in the lower conductor, flowing in the opposite direction. Illustrated are the electric and magnetic field vectors, E and H, at the mid-point between the conductors. There is a flow of electromagnetic power from left to right, identified by the 'P' vector. Some simple points can be made, namely, the currents in the supply and return conductors are equal and opposite at every cross-section of the transmission line and the vector sum of the current at any section of the line is zero. The action of the electromagnetic field tends to provide this equalisation. Don't fight it. Use it.

The most efficient way to transmit electric power between two points is to use a transmission line. Minimal power is transmitted to the environment and minimal power is received from the environment. A logical decision is to use transmission lines to carry the signals defined in the block diagram. Although the vector sum of the currents is zero in **Fig. 3.** the power vector clearly indicates which way the signal is going. This allows a very useful correlation to be made between the transmission line and the block diagram.

Wiring Diagram

If the block diagram is modified to include the conductors of the transmission line, the natural result is a wiring diagram and the components of **Fig. 4.** begin to emerge.

In any practical system, there are a fair number of other conductors. These include the supply conductors necessary to distribute power to the various printed circuit boards. Signals at the individual boards are processed with respect to a common conductor, usually designated as the 'ground' reference. There is also some form of shielding, provided in part by the equipment structure. The inclusion of the conductor marked 'structure' in the diagram allows the existence of the grounding and shielding conductors to be recognised. In the illustration of **Fig. 4.**, the return conductors are all grounded to local points on the structure.

Culprit Circuit

Any interference must have a source, a coupling mechanism, and a receptor. The term 'culprit' can be used to identify a network generating unwanted emissions, whilst a network which could be susceptible to interference is a potential 'victim'.

In the case under consideration, both culprit and victim are part of the same system, and the coupling mechanism is associated with current in the structure. If the culprit is assumed to be the wiring associated with signal 1, then it is logical to focus first on this segment of the system.

A circuit model can be created of the culprit, by treating it as a three-conductor transmission line. **Fig. 5.** is a simplified model, where each conductor is represented by an inductor. Each conductor also possesses the properties of resistance and capacitance, but there is no need to show these in an initial illustration. It is always possible to assign a value to each inductor. Any basic textbook that introduces three-phase power lines will provide equations relating physical dimensions to inductance values. If necessary, tests can be made on a representative assembly to measure the values. From a system point of view, the spurious output of the culprit is transient current in the structure, I3.

Common-mode rejection

There are two loops involved: the differential loop carrying signal current, and the common-mode loop carrying a portion of the signal current via the structure. A wire pair is usually constructed with identical conductors and these are held as close together as is physically possible. The separation between supply and return conductors is usually greater than that between cable and structure. This means that inductors L1 and L2 of **Fig. 5.** are equal, and have as low a value as is possible. Conversely, L3 has a relatively high value.

If the signal source is located on printed circuit board A, and the supply current I1 flows in L1, then the return current will be shared between L2 and L3. Since L2 is less than L3, a greater proportion of the return current will flow in L2. This means that I3 is less than I2. The ratio between I1 and I3 is even greater. That is, there is a useful amount of common-mode rejection, due to magnetic effects.

Coupling Mechanism

Common-mode current flowing in the structure will generate a voltage across L3, and the amplitude of this voltage can be calculated. Interference created by signal 1

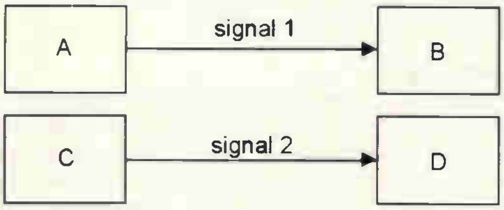


Fig. 2. Block diagram of system under review.

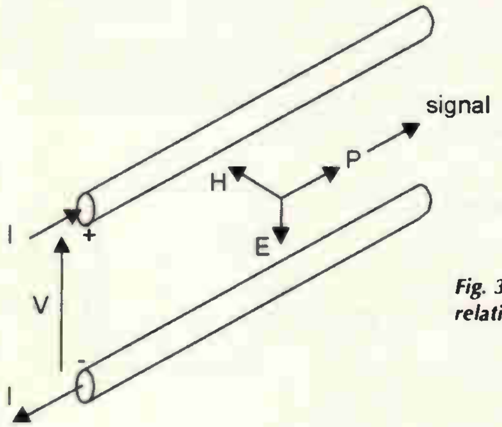
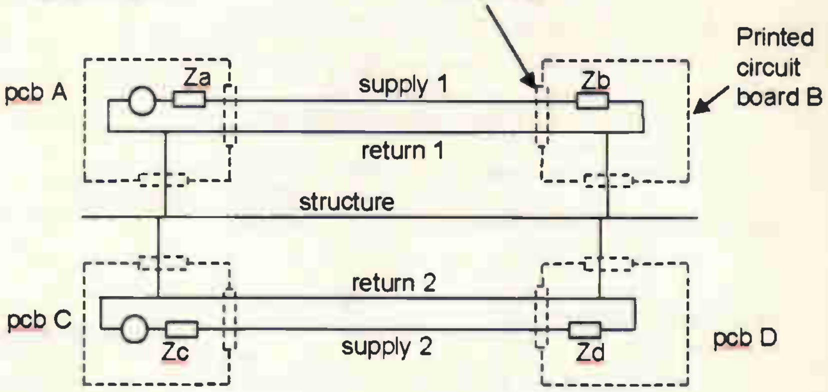


Fig. 3. Transmission line relationships.

Fig. 4. Wiring diagram of system-under-review.



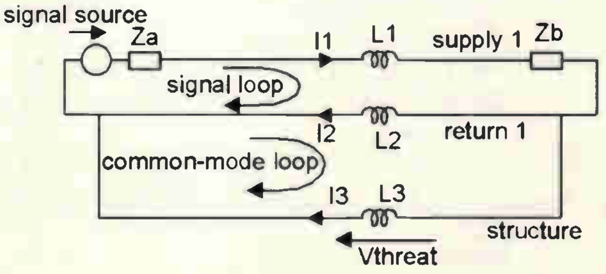


Fig. 5. Circuit model of culprit section of system.

will manifest itself as a voltage along the structure – 'Vthreat'. Invoking the Norton-Thevenin relationship of **Fig. 6.** allows the action of the culprit loop to be represented as a voltage source, Vthreat, in series with the structure.

From the point of view of the culprit, interference can be defined as the current, I3, in the structure. From the point of view of the victim, interference can be defined as the voltage, Vthreat, in the loop formed by structure and cable.

Victim Circuit

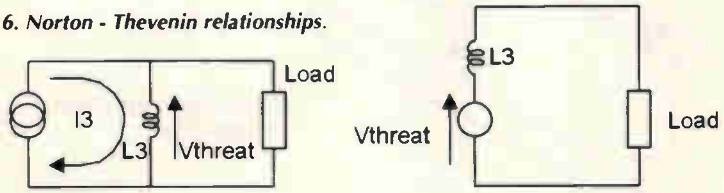
This interference source can then be included in the circuit model for the second signal, as shown on **Fig. 7.**. In this model, common-mode current flows in the cable/structure loop and creates a voltage across L5. Since L4 and L5 act as an inductive potentiometer, the voltage induced in the differential loop will be significantly less than Vthreat. Again, there is a useful amount of common-mode rejection, also due to magnetic effects.

Ground loops

One feature of this approach is that it has introduced two extra loops into the configuration - the common-mode loops of the culprit and victim circuits. It has been shown that the action of the magnetic field in these loops reduces the level of coupling between culprit and victim. Another name can be given to these loops - 'ground loops.' In fact, the terms 'ground loop' and 'common-mode loop' are synonymous.

This means that the dreaded ground loop, which many individuals believe should be avoided if at all possible, actually helps to improve EMC.

Fig. 6. Norton - Thevenin relationships.



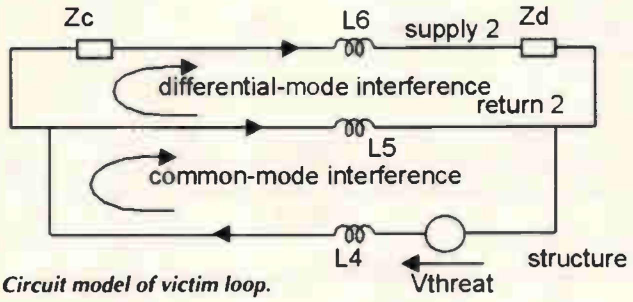
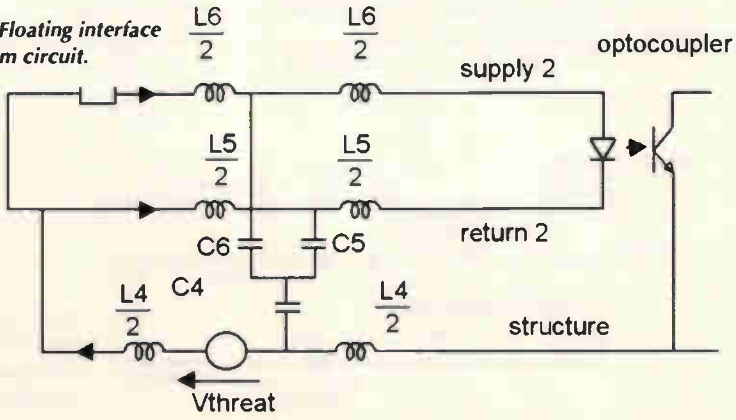


Fig. 7. Circuit model of victim loop.

Fig. 8. Floating interface in victim circuit.



Improving performance

Current in the ground loop is the prime cause of interference. To improve performance, the objective should be to reduce the amplitude of this current. Increasing the impedance of the loop can do this. The most obvious way to increase loop impedance is to open-circuit it. This leads to the familiar concept of the floating termination. From an examination of Figure 7 it could be assumed that a floating termination would reduce common-mode current to zero, and solve the problem. Alas, it is not to be.

Up till now, attention has been focussed on magnetic effects. The action of the electric field has been ignored. There have been no capacitors in the circuit models. If the victim circuit of Figure 7 is modified to show the existence of these capacitors, to 'float' the receiver interface, and to replace the load Zd with an optocoupler, then the picture becomes as shown in **Fig. 8.**.

The capacitors now provide a path for common-mode current. At low frequencies, this current has negligible amplitude, and common-mode rejection can be as high as 60 dB. However, as the frequency of Vthreat increases, common-mode current increases. The common-mode rejection is a function of frequency, and reduces at 20 dB per decade. The combined existence of capacitance and inductance means that, inevitably, there is resonance. At the resonant frequency, the differential voltage can be 10 dB higher than Vthreat. Of even more concern is the fact that the common-mode voltage at the optocoupler (between 'return 2' and structure) can be more than 40 dB higher than Vthreat. This raises more problems.

Implications

These problems can be solved. However and there is no need to describe the solutions here. The point that can now be made is that circuit modelling will provide a clear picture of the coupling mechanisms. When the problem is clearly defined, a solution can always be found.

As well as providing a clear picture, circuit modelling allows actual numbers to be assigned to component values, and for the frequency response of the system to be analysed 1. Circuit analysis software makes the calculations a simple task.

Simple bench tests 2 can be devised to measure the response during product development. If necessary, the circuit can be modified and the analysis repeated, until the system is shown to meet its EMC requirements. The finished product can be submitted for formal EMC Tests with a high degree of confidence

Conclusion

There are many guidelines, tips, and fixes to be found in the literature on EMC, and there is much advice provided by experts on the subject. Some of it is of dubious value. Using circuit models of the system under review, it is possible to identify the hidden assumptions, the limitations, and the errors in any particular recommendation. Circuit modelling allows the electromagnetic coupling mechanisms to be understood and analysed. The systematic use of circuit models will enable any system to be designed to meet its EMC requirements.

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1 Circuit modelling for EMC. Electronics & Communications Engineering Journal. August 1997.
2 Bench testing for EMC. Electronics World. February 2000.

Key Factors in RF Power Amplifier Design

Although radio and amateur radio are a bit old-fashioned, today a lot of engineers have to deal with RF, e.g. on topics like cordless telephones, mobile phones or wireless LAN.

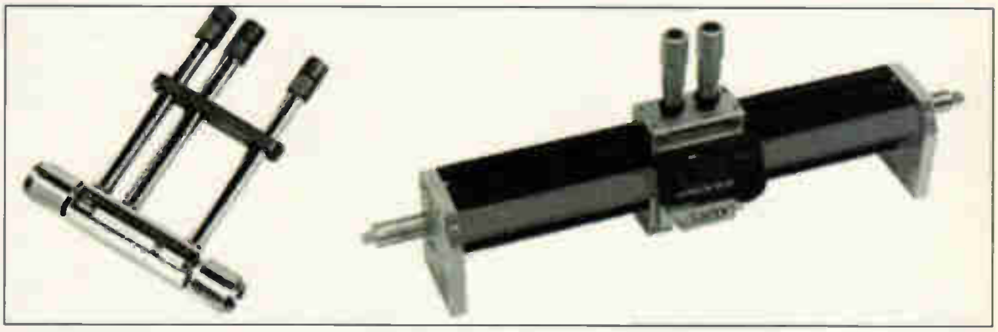


Fig. 1. Two passive RF tuners used to sweep impedances.

For some main-stream systems like GSM or AMPS, RF power amplifier modules are available from manufacturers like Hitachi, Fujitsu, Alps. etc. That eases the application, because they normally have 50Ω RF IOs. But such modules are quite expensive, MMIC´s are often cheaper. For some systems even a discrete solution might be competitive. In these cases - or for module or chip design - a much more detailed know-how is needed.

On a system level, such things like RF TX power at the antenna, power-time template and spurious signals are specified. So the best way to design an RF PA is starting with a level diagram. From this you get the output power of the PA. After designing the final output stage with its matching networks you get the input power needed to drive the last stage. Step-by-step you can go backwards to the fist PA stage which is normally connected to a modulator, VGA or VCO. S-parameters are only a good characterisation for small signal circuits. Power amplifiers are often very non-linear and the S-parameters will depend on power level. Despite this, S-parameters measured at the input port at the power level also used in the application are a very good starting point for the design of the input matching network. Even more critical is the output of an RF power amplifier. Power match based on small-signal S-parameters will result in highest small-signal power gain, but for RF power amplifiers the output power itself and the efficiency (normally specified by the so-called power added efficiency PAE=$(P_{out}-P_{in})/P_{DC}$) are much more important. So the question is: What impedance Z_{Lopt} should be applied at the amplifier output to get a given output power with best efficiency? Many people are using an impedance tuner to search for the best match in the lab by hand. This will lead to a completely different design procedure than typically used in small-signal amplifiers! A faster way is possible here with some theory.

Let us consider a concrete design problem: Design a matching network for an ISM 2400MHz power amplifier (free band for industrial-scientific-medicine applications). In the USA, up to 1W (corresponding to 30dBm) antenna power is allowed for this frequency band. In reality some loss occurs in the TX low-pass or band-pass filter and the antenna switch, so the PA is allowed to deliver approx. 31dBm. Because you need some safety margin for component tolerances, temperature drift, changes of supply voltage and RF input power, a PA with a nominal output power of 29dBm will be well-suited. On the market there are not many low-cost PAs which are able to deliver such high output power at 2.4GHz. For instance, Infineon has a Silicon PA family starting from a 22dBm Bluetooth PA up to the largest 29dBm device. All devices are balanced PAs with push-pull input and output stage. The balanced input eases the connection to the often also balanced transceiver output. To save board space and external components many system functions are included in these PA devices, such as power ramping and antenna switch drivers. A nice feature is the power select function. With two digital pins you can select four different output power levels, e.g. according the distance between handset and base station. For the balanced output we need a balun (balanced-to-unbalanced) to convert

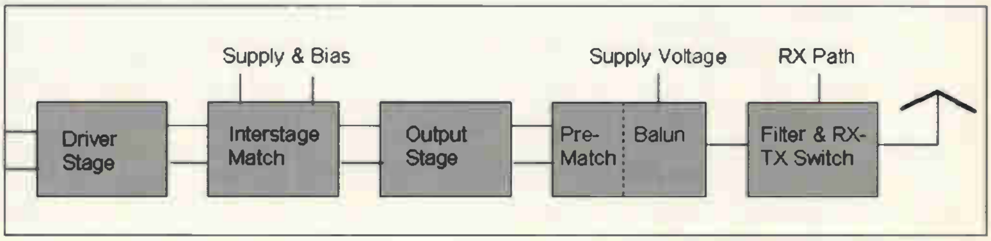


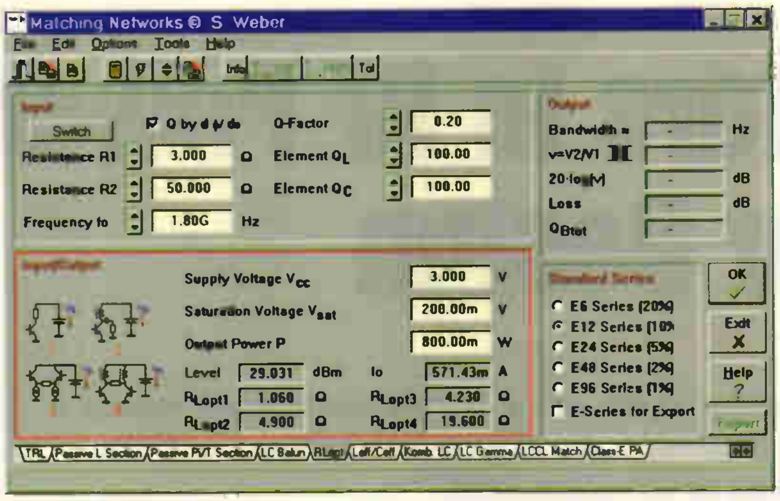
Fig. 2. Our 2-stage PA system topology.

the push-pull signal to the normally used single-ended signal (e.g. for filters, PIN diode switches and antenna).

The output power depends not only on the PA device but also on supply voltage V_{CC} (due to $P=V_{rms}^2/R_L V_p^2/2R_L$) and best efficiency PAE can be expected if the PA is deep in the compression (in this case app. 40%). This operation is allowed for systems like DECT (digital enhanced cordless telephone), HomeRF or Bluetooth (both new standards for general-purpose RF interfaces, WLANs, etc.), because they use modulation schemes (in these cases frequency shift keying) with constant RF envellope. For non-constant envellope modulation schemes like QPSK or 8PSK (e.g. IEEE801.11b or UMTS), you have to look at the peak power, not the average power. This is needed in these cases because a PA in compression would create too much adjacent channel leakage power. The Infineon device is fabricated in a 4V-25GHz silicon process, so for 29dBm the recommended supply voltage is 3.1V. Direct operation at two NiCd/NiMH cells is possible, because the supply voltage range starts at 1.9V. With this information we can calculate the optimum load impedance Z_{Lopt}. A nice program to do this is the AdLab tool ANPASS [1]. It uses the formula $R_{Lopt} \approx V_p^2/2P_{Wanted} \approx V_{CC}-V_{sat})^2/2P_{Wanted}$, which is pretty accurate for class-A operation (hints available on bubble help). There are some problems: Firstly we can only guess the saturation voltage, which should be close to app. 0.2V, because it's a low-voltage bipolar design. Secondly we operate in deep compression, so the class-A approximation is not valid. For instance for class-E [2] the voltage swing is not $2\cdot(V_{CC}-V_{sat})$ but app. $3.5\cdot(V_{CC}-V_{sat})$. For the class-A approximation and $V_{sat}=0.2V$ ANPASS delivers $R_{Lopt}=4.9\Omega$ for a single-ended PA and 19.6Ω for the balanced topology. This shows a clear advantage of the push-pull output, its impedance is already closer to 50Ω.

The result is a real value for the impedance (19.6Ω, so 9.8Ω for each side) which is not truly realistic with real world transistors and finite package inductances. So ANPASS delivers the correct value for an idealised PA. For compressed class-B operation a higher value of R_{Lopt} is a bit better for higher efficiency (say 11Ω, for class-E operation ANPASS delivers 5.64Ω for single-ended

Fig. 3. Calculating R_{Lopt} via ANPASS



☑ Q by dφ/dω

Q-Factor 0.20

Resistance R1 3.000 Ω

Element Q_L 100.00

Resistance R2 50.000 Ω

Element Q_C 100.00

Frequency fo 1.80G Hz

Bandwidth ≈ - Hz

v=V2/V1 -

20·log(v) - dB

Loss - dB

Q_{Btot} -

Supply Voltage V_{CC} 3.000 V

Saturation Voltage V_{sat} 200.00m V

Output Power P 800.00m W

Level 29.031 dBm

Io 571.43m A

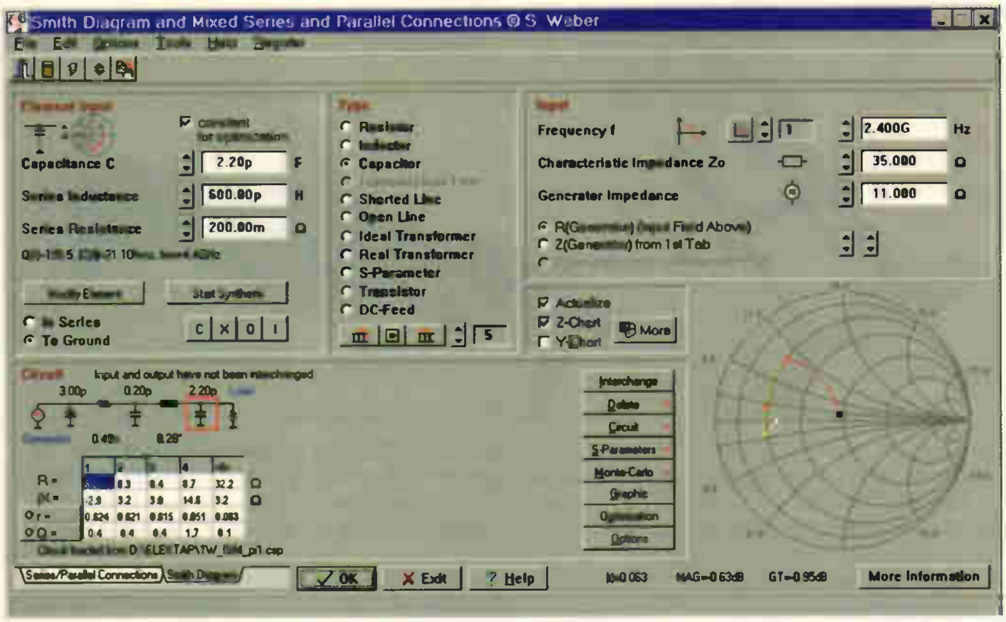
R_{Lopt1} 1.060 Ω

R_{Lopt3} 4.230 Ω

R_{Lopt2} 4.900 Ω

R_{Lopt4} 19.600 Ω

○ E6 Series (20%)
● E12 Series (10%)
○ E24 Series (5%)
○ E48 Series (2%)
○ E96 Series (1%)
☐ E-Series for Export



☑ constant for optimization

Capacitance C 2.20p F

Series Inductance 600.00p H

Series Resistance 200.00m Ω

○ In Series
● To Ground

○ Resistor
○ Inductor
● Capacitor
○ Shorted Line
○ Open Line
○ Ideal Transformer
○ Real Transformer
○ S-Parameter
○ Transistor
○ DC-Feed

Frequency f 2.400G Hz

Characteristic Impedance Zo 35.000 Ω

Generator Impedance 11.000 Ω

● R(Generator) (Input Field Above)
○ Z(Generator) from 1st Tab

☑ Actualize
☑ Z-Chart
☐ Y-Chart

Circuit: Input and output have not been interchanged

3.00p 0.20p 2.20p

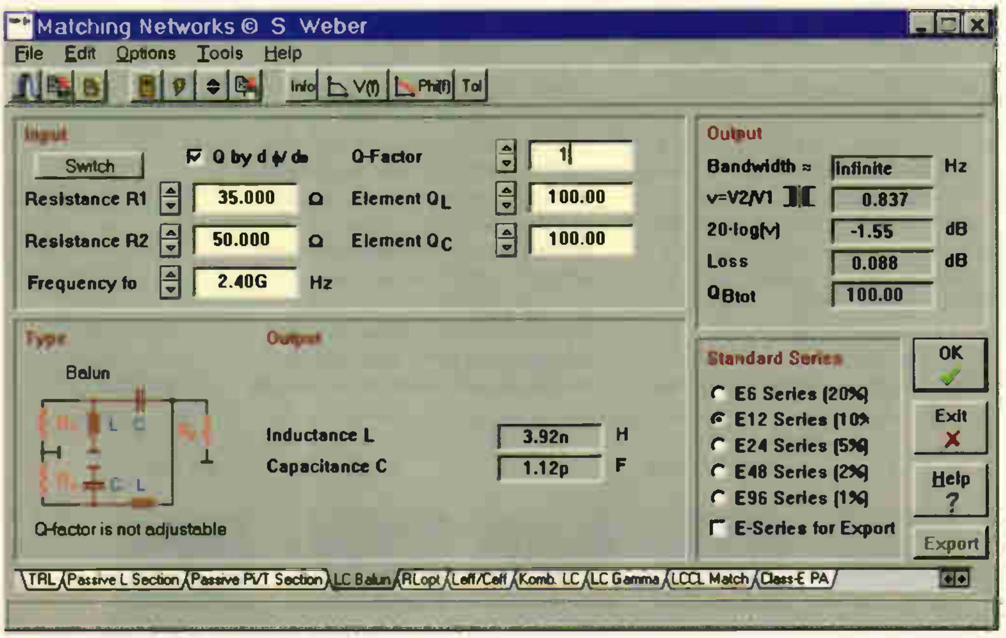
0.49λ 0.28"

	1	2	3	4	5	
R =		0.3	0.4	8.7	32.2	Ω
jX =	-2.9	3.2	3.8	14.8	3.2	Ω
r =	0.824	0.821	0.815	0.851	0.083	
Q =	0.4	0.4	0.4	1.7	0.1	

Circuit loaded from D:\ELEKTAP\TW_fall_p1.cap

k=0.063 MAG=-0.63dB GT=-0.95dB

Fig. 4. PA output modelling in CSMITH and the L-type pre-matching network to 35Ω. Note: The end capacitor has a series inductances of 0.5-0.6nH as a typical 0603 SMD component.



☑ Q by dφ/dω

Q-Factor 1

Resistance R1 35.000 Ω

Element Q_L 100.00

Resistance R2 50.000 Ω

Element Q_C 100.00

Frequency fo 2.40G Hz

Bandwidth ≈ infinite Hz

v=V2/V1 0.837

20·log(v) -1.55 dB

Loss 0.088 dB

Q_{Btot} 100.00

Inductance L 3.92n H

Capacitance C 1.12p F

Q-factor is not adjustable

○ E6 Series (20%)
● E12 Series (10%)
○ E24 Series (5%)
○ E48 Series (2%)
○ E96 Series (1%)
☐ E-Series for Export

Fig. 5. LC balun design using ANPASS.

configuration). Using another AdLab tool called CSMITH we can start with the corrected value as the generator impedance and we can add the transistor output capacitance (approx. 3pF with some series resistance representing losses in the silicon substrate) and the bond-wire inductance (app. 0.4-0.5nH and a small package capacitance) by hand. Note that CSMITH is able to use real elements with all their major parasitics like series resistors or inductances, also a frequency sweep with graphical output for gain, MAG, return loss, etc. is available.

What we need now is a match from the transistor output to the balun. Because we need a DC-feed, a L-type low-pass structure (high-impedance transmission line acting as a series-L followed by a shunt-C) is the easiest solution. In other situations a high-pass is a better choice, e.g. in the interstage match where a DC-break is needed or some compensation of the drop of the transistor gain at higher frequencies is needed.

A balun generally transforms a differential signal to a single-ended one (which is normally 50W) and vice versa. A standard LC balun can be designed using ANPASS. One open question is the intermediate balun input impedance. It's a good idea to take an intermediate impedance value (say 35W), so that the match is distributed over the first prematching network and the balun. This often gives the largest bandwidth and low tolerances. Other types of baluns are well-known (e.g. with transformers or $^1/_4$-transmission lines), but the LC all-pass is preferred here because it is very compact. Note, one balun capacitor could be merged with the shunt-C of the prematch.

The resulting circuit is very close to what we have achieved in the lab. Of course in reality some tweaking is always needed in 2GHz circuits due to component parasitics and modelling inaccuracies. Also the impedances at the harmonic frequencies are not unimportant due to large signal operation. This behaviour is known as harmonic matching, but it is not easy to get an advantage from this behaviour at a GHz power amplifier.

For higher output power levels the impedances become very low (e.g. typically 2Ω at GSM levels) and a single-step matching network would result in a small bandwidth, but more importantly in tolerance problems. In these cases you need a multi-step match. In principle such a matching network can be designed in the same manner using the Smith chart, although it is not easy to optimise both losses and bandwidth. The main problem is that in the Smith chart you normally calculate at one frequency, so you often don't get the bandwidth advantage of more complex circuit structures like Chebyshev filters. In CSMITH you can do such a design, because Monte-Carlo analysis, frequency sweeps and also optimisation (in conjunction with the general-purpose simulator APLAC [4]) are available.

Currently, we are only looking very roughly at the transistor. In fact, so far we only look at its saturation voltage, its current and voltage capabilities and its output capacitance. Of course other

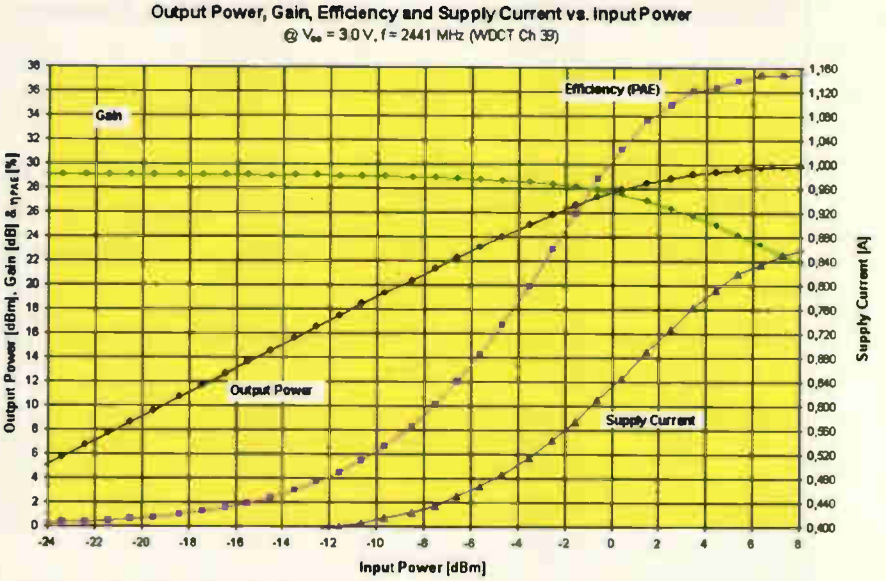


Fig. 6. Measurement results for the 29dMm Si PA

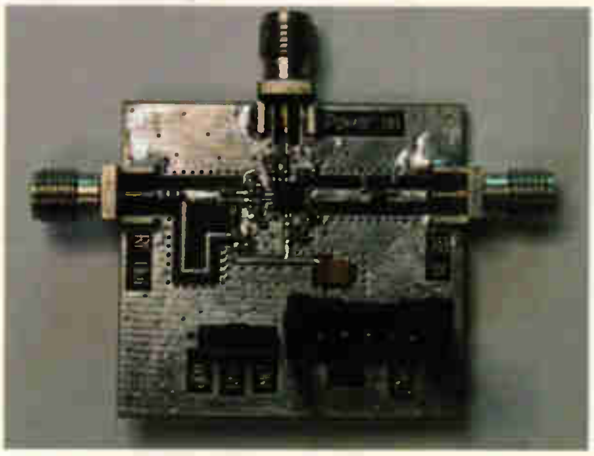


Fig. 7. The 2.4GHz PA board with the Infineon 2.4GHz-PA in VQFN20 package

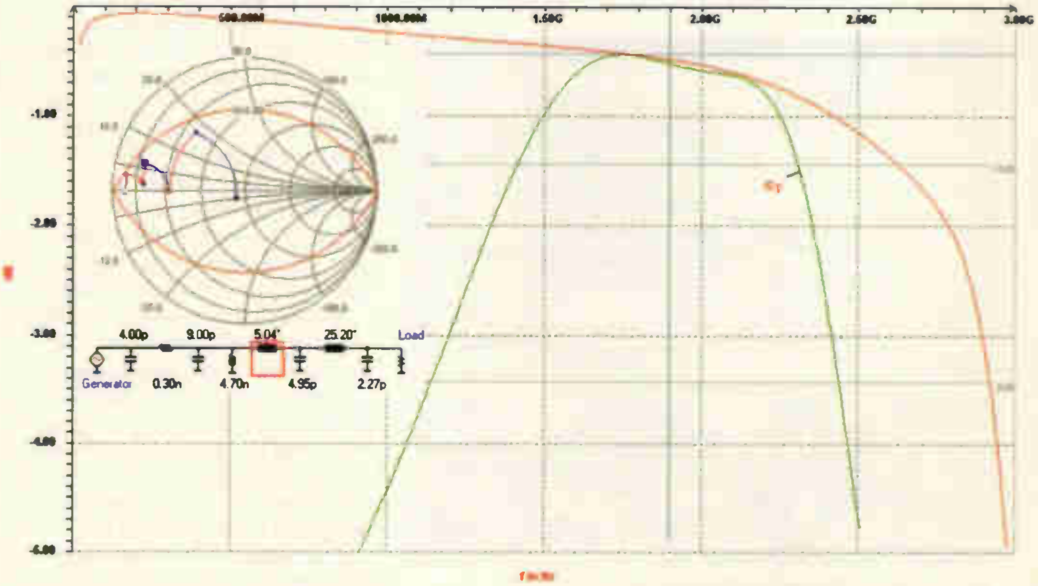
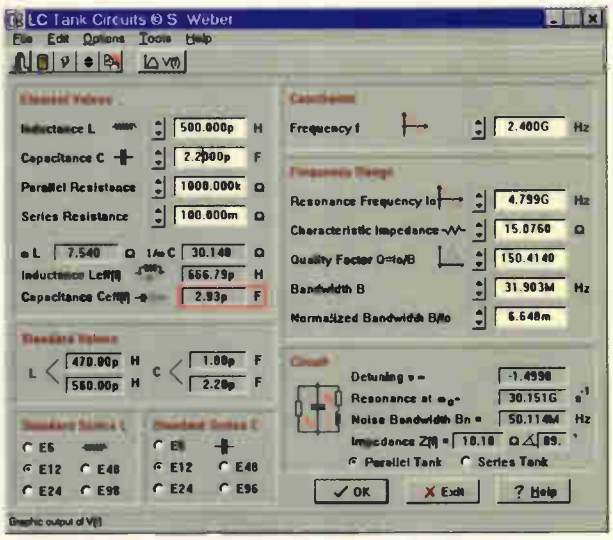


Fig. 8. CSMITH results of a 1.9 GHz 3-step matching network optimised for wide bandwidth. the MAG (upper curve) shows that the element losses increases at higher frequencies, so it's not easy to get a true flat response.

Topics	**Influence**	**Comments**
Transistor models	May have a large influence, especially on interstage matching!	Gummel-Poon may be sufficient for Si, but not in all cases. High current/low voltage region is critical, also quasi-saturation and breakdown!
Capacitances to substrate	Often a low influence (not for transistor or MOS-C capacitances)	This is different to low power/high impedance designs.
Series resistors	Medium influence. Look also at the on-chip MOS capacitances	Reduces gain
Series inductances	Large influence! Not only as feedback in BJT emitters stages	Changes frequency response
On-chip coils	Medium influence. A peak Q of 5..10 is realistic for Si technologies. Include the lines to the coil.	Modelling is not too difficult, but Q is limited for typical Si technologies
Package model	Strong influence due to series inductances	Not easy to model
Substrate model	Medium influence on bias and RF performance	Difficult to model, important for mixed mode designs
PCB and external components	Large influence	Grounding and crosstalk are difficult to model
Bypassing and biasing	Large influence on stability and linearity	Don't optimise only at the operation frequency

Table 1 : Summary of key factors in modelling for RF power amplifiers.

parameters such as feedback capacitance, transition frequency f_T, maximum frequency of oscillation f_{max}, maximum available gain MAG, stability factor k, current gain B, etc. are important - but not so much for the output match. Often a carefully chosen compromise is needed. For instance transistors with high f_T and f_{max} (like the new Silicon-Germanium technologies) have a high power gain G, which is advantageous for high PAE and getting a low number of RF stages. But these transistors tend to have lower breakdown voltages and might be less stable. As a rule of thumb the supply voltage should not exceed the transistors V_{CEO}, although breakdown behaviour also depends on the impedance at the transistor base (V_{CEO}< V_{CER}< V_{CES}). Your transistors should be stable at the operating frequency (k>1), so the MAG is a good indicator of the possible gain. If the device is not stable you need damping elements (e.g. series resistor at the base) or feedback (series or shunt feedback).



Inductance L: 500.000p H
Capacitance C: 2.2000p F
Parallel Resistance: 1000.000k Ω
Series Resistance: 100.000m Ω
ωL: 7.540 Ω
1/ωC: 30.140 Ω
Inductance Leff(f): 666.79p H
Capacitance Ceff(f): 2.93p F
L: 470.00p H / 560.00p H
C: 1.80p F / 2.20p F
Standard Series L: ○ E6 ● E12 ○ E24 ○ E48 ○ E96
Standard Series C: ○ E6 ● E12 ○ E24 ○ E48 ○ E96
Frequency f: 2.400G Hz
Resonance Frequency fo: 4.799G Hz
Characteristic Impedance: 15.0760 Ω
Quality Factor Q=fo/B: 150.4140
Bandwidth B: 31.903M Hz
Normalized Bandwidth B/fo: 6.648m
Detuning v = -1.4990
Resonance at ωo = 30.151G s⁻¹
Noise Bandwidth Bn = 50.114M Hz
Impedance Z(f) = 10.10 Ω ∠ 89. °
● Parallel Tank ○ Series Tank

Fig. 9. Effect of parasitic inductance on a 2.2pF SMD capacitor (LCFILT from ELEKTA Professional [5]). At 2.4 GHz the component acts as a 2.9pF cap, because we operate not so far from the self resonance frequency.

Not only the transistor is important but also all layout parasitics, like emitter-ground inductance, parasitics of SMD components and also on-chip parasitics [3]. Many chip designers think only the parasitic capacitances and series resistances are critical for their layout, but this is completely wrong for low-impedance RF circuits, such as PAs. Even small metal traces within the interstage match are critical. A typical 300μm metal trace will have an inductance of approx. 0.3nH and a series resistance of 0.5Ω. Note that at 2.4GHz the inductance corresponds to j4.5Ω, so the reactive part might influence the match and the frequency response seriously.

Most important is the ground inductance of the emitters (or sources for field-effect transistors) and in some cases (f>2GHz & P>2W) only chip vias (available in many GaAs or LDMOS technologies) or a balanced concept will help. For a GSM PA the AC peak-to-peak current is in the range of 4A, so even 100pH will cause a ripple of 2.26V_{pp} at 900MHz. This is a non-negligible part of the supply voltage and will reduce power gain dramatically and influences also PAE and stability. On the other hand some emitter inductance can help if the input impedances become to low (e.g. <1Ω), which will cause matching problems. The bipolar transistor input impedance is app. $Z_{in} \approx Z_E \cdot ß\ (f)$ with $Z_E \approx U_T/I_c + R_E + JwL_E$ and $ß(f) \approx f_T/jf$. For high power amplifiers this will become $Z_{in} \approx 2\pi fT \cdot L_E$. This is a nice result, because it is a real value which can be adjusted easily. Due to $P=I^2R$ the input power is proportional to L_E/f_T. Hence the power gain increases linearly with f_T/L_E. The other parameters are less important but base resistance rBB´ and feedback capacitance C_{BC} still have a strong influence, especially on stability factor k and isolation.

Careful biasing and supply bypassing is needed because any RF PA will not create trouble only at the operating frequency as especially at lower frequencies they often become unstable. In practice the transistor should 'see' no too extreme impedances at all its three terminals and over its entire active frequency range. Often damping resistances are necessary and can be part of the bias network. It is very interesting to see that bypassing with high-Q capacitors is in many frequency regions much worse compared to caps with lower Q, hence larger series resistors. The minimisation of any series inductance is very important and sometimes you need three or four capacitors with well-chosen values.

Some people say simulating RF power amps is nearly impossible, but this is not true. With careful modelling you can increase accuracy step-by-step. The remaining errors should by finally smaller then 1dB in output power and gain. To not overlook any aspect you should always ask yourself is what you calculate really close enough to reality. ■

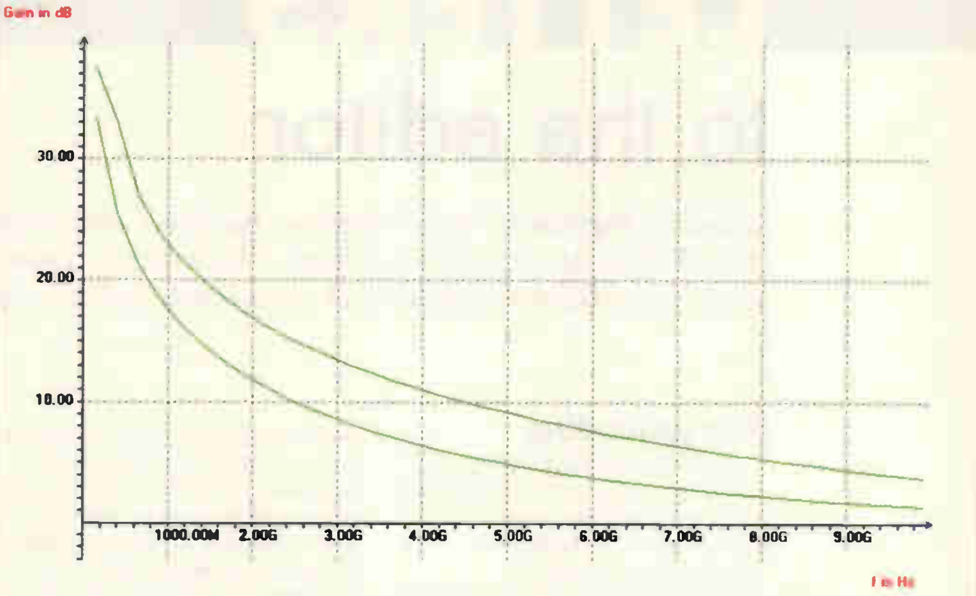


Fig. 10. MAG for a typical 2W 1.8GHz Si bipolar power transistor with (lower curve) and without 100pH emitter inductance (AdLab tool SPARAM showing MAG derived from S-parameter data from CSMITH)

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LETTERS
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e-mail j.lowe@cumulusmedia.co.uk using subject heading 'Letters'.

Star grounding

I cannot agree with Ian Darney "The star point concept is a thoroughly bad idea, and is based on a needless concern" (Letters, April 2002). Indeed, having worked in a Department of Arcs and Sparcs (Dept of Plasma Physics, Uni of Sydney) for a couple of decades I can report that not eliminating earth loops and other multiple earth paths (i.e. not adopting a star or tree like topology for earth) will most certainly result in some intractable interference problems in many circumstances.

Therein is part of the issue. Not everyone is wrangling small signals is such a hostile environment, but the intelligent approach to interference problems requires that one assess the nature and cause of the interference and deal with it appropriately. Generally speaking a branched/star/tree topology will result in far fewer interference problems that one with multiple electrically parallel earth paths.

Judging by Ian's description of the problems with valve radios I suggest that the problem was not caused by the star earth topology but primarily by other, bad wiring practices. The electrical topology of the star and the routing of sensitive wiring (away from hostile parts of the circuit) must take precedence over the physical shape of the star. My feeling is that the position of the star point could have been better chosen, although this can only be confirmed by proper measurement and experiment.

The physical layout of the wiring is important. The area enclosed by a signal wire and its earth should be as small as possible, otherwise the wires will act like a loop antenna and pick up all sorts of junk. They are prone to radiate as well, and in the RF bands the extra inductance will ruin your matching. For this reason some situations mandate the signal and earth wires (or power and return, for that matter) be twisted together as much as possible, or screened cable be used. This may even apply for some DC feeds, if the load current is pulsed for example. DC wiring can also act as a receiving antenna that funnels interference into shielded parts of a system.

Ian's description of "a set-up where there are several items of equipment" is altogether too sketchy to draw any but the vaguest conclusions. The nature of the set-up, how the equipment is wired internally and interconnected, the range of frequencies, voltages, and currents concerned, all impact on whether there is likely to be a problem with interference. Consider the following example of conducted interference in a real, well-shielded set-up.

In the Tokamak Lab in Plasma Physics there was a screened room (approximately 3 metres square) to shield the data taking and control equipment from the tokamak, which included several big sources of interference (like the main field current of about 20kA fed from a 2.5kV cap bank, and three 20kW RF sources). On a particular occasion a student was trying to view a signal of about 50mV by 50us on a CRO ('scope), which was triggered from a 50V (nom) 3us trigger pulse. The signal and the trigger pulse were routed diagonally across the screened room from the bulkhead where they entered the room, earths connected, to the CRO (in the opposite corner) through terminated RG58 co-axes. The signal showed a spurious pedestal of about 20mV amplitude and 20us duration, caused by some of the earth current of the trigger pulse running down the signal's co-ax shield.

Fitting an isolating pulse transformer at the CRO's trigger input cured the problem. We had electrically gone from a loop topology for the earths to a branched (star, tree) topology. Far from causing any intractable problems it cured one. Generally it was found that equipment used in the screened room had to have its earth through the power disconnected to kill earth loops, although that had some unpleasant effects on people who touched a chassis that was not otherwise earthed while it was plugged in. There have been numerous other instances such as a zapped PC, a magnetron that apparently consumed more power

Super Regen

I have been following the recent articles on super-regeneration by Eddie Insam with interest and his suggestion for an electronic tape measure using a Doppler module may well be a perfectly practical proposition. Indeed, under Recent Inventions, the November 1947 Wireless World describes something very similar.

A super-regenerative circuit is used both as a transmitter and receiver for short-range radar, the quench frequency being manually adjusted until it coincides with the time interval between an out-going pulse and the incoming echo from a distant target, coincidence occurring when the normal 'hiss' ceases in the valve circuit. A patent application, No. 581982, was filed by A.C. Cossor Ltd. and F.R.W. Stafford on December 30th, 1942 but there are is no information regarding actual performance.

Browsing through Wireless World, I have found a further article, namely, 'Super-Regenerative Receivers - a reassessment in the light of recent developments' by 'Cathode Ray' in the June 1946 edition that examines principles in some depth.

Certainly, the field of super-regeneration would seem to offer much scope for experimentation and applications are by no means confined to antiquity as some modern car alarm remotes utilise super-regenerative receivers.

J. Bubez
West Sussex U.K.

than it was fed, all caused by earth loops. I recall from my days as an appliance repairman that there were frequently problems with mains hum in cassette decks whose signal and mains earths were connected creating loops with the rest of the stereo system. Earth loops pose serious threats to signal integrity and even to equipment sometimes.

While Ian is not incorrect in his description of skin effect and its role in interference it is irrelevant for most audio applications because the skin depth in copper, for example, is greater than the diameter of most shielded cables over the audio band. This means that the interference punches right through the shield, through the inner signal conductor, and out the other side. The reason shielding still works in these circumstances is that the interfering signal induces (virtually) identical currents and voltages in both the earth and signal conductors, and these currents and voltages cancel. Both the interfering and signal currents will be distributed across the entire cross sectional area of the relevant conductors. Skin depth does not define a sharp cut-off anyway, it is an arbitrarily chosen depth at which the current density has dropped to a particular fraction of that near the surface, and in fact some portion of the current will flow through all areas of the conductor. Superconductors are another matter.

Ian may care to ponder the nature and purpose of the lump in the signal cable most PC monitors these days. It is a ferrite sleeve acting as a one turn common mode choke, and it is intended to suppress the effects of earth loops at high frequencies. I expect this is to reduce radiated interference rather than protect the monitor from interference. Whatever, the purpose is to break high frequency earth loops because they are a major cause of interference. Even in shielded systems earth loops can cause problems, partly because no shield is 100% effective at all frequencies, and the necessity to provide access for assembly and repair, and holes for connectors and feed-throughs, means that most shields have breaks in them.

It should be remembered that most power transformers provide very little isolation at high frequencies due to their high interwinding capacitance. Most mains filters and switched mode supplies include a common mode choke. It is possible a high frequency earth loop will be created through interwinding and other parasitic capacitances even when no hard earth connection exists, and the purpose of the common mode choke is the same, break the loop (or at least increase its impedance). Such chokes have little or no effect on differential mode interference (i.e. between Active and Neutral). Common mode chokes may (e.g. monitor signal cables) or may not (e.g. mains filters) include the earth conductor(s), depending on the nature of the particular interference they are intended to suppress.

There are other aspects of the topic that might need to be explained, but I've written enough about it for this forum. The branched or star topology is not a panacea for all interference problems, but it is a good starting point. It is not always easy to implement, but ignoring the principle is sure-fire recipe for "a set of intractable interference problems". Joe Carr knows his stuff, and I suggest that only the very clever should ignore his advice without seriously analysing why he might be wrong.

Phil Denniss
School of Physics
University of Sydney,
Australia

You can find more theorising on this subject in Ian Darney's article 'Designing for EMC' in this issue. – Ed.

More PCBs

Regarding the excellent article on 'Making single sided PCBs' by Cyril Bateman in the May issue, you can make a fairly decent prototype by printing the artwork out on standard paper, on a laser printer, reverse image, and then laying the artwork to the copper and using a normal household clothes iron to transfer the image (Hottest setting). Make sure you go over the whole artwork with the iron. Peel off the paper while its still hot, and you will have a reasonable quality artwork that needs to be gone over with a Dalo etch resist pen (This can take a while). Then just etch. I also have used Ruby automask and that 'Press'n'Peel' stuff. The Ruby was ok, but as all artworks had to be at 10 times size and the non editing quality of the process, I didn't think it was used anymore. As for the 'Press'n'Peel' ... Never again.

The easiest and quickest way is to use a laser printer with standard overhead transparency film, specifically for laser printers and use that in the UV exposure box. Double sided PCBs are made simply by taping the two sides of the artwork together, taping the UV sensitive PCB into this sandwich and then exposing both halves separately. Before I bought my UV box, I had kludged together one out of a standard light fitting and a UV tube.

B.Teleki
Newcastle-under-Lyme, U.K.

500Mhz sampling front end

You have probably received a fair number of comments from other readers concerning Mr Hickman's interesting and informative article in the June issue. Nevertheless, I thought I would write to you with an observation of my own.

With regard to producing shorter Gate 1 sampling pulses, I suspect that the avalanche pulse generator employed has already reached the limit of its capability in this direction. Some improvement might be indeed be achieved by using a shorter delay line, L1, and a transistor having a higher transition frequency than the BFR91. Unfortunately, this will inevitably be at the expense of pulse amplitude, since most commonly available low cost transistors with higher transition frequencies also tend to have lower avalanche voltages. Therefore, it might be worth considering an alternative method of generating shorter sampling pulses.

The method I have in mind is a variation on the theme of the classic step recovery diode (SRD) impulse generator. However, instead of employing an SRD - which is an unusual device that readers are unlikely to find in the majority of mainstream electronic component distributors' catalogues - try using an inexpensive and readily available PIN switching diode. With suitable biasing some short lifetime epitaxial PIN diodes exhibit behaviour very like that of SRD's. For example, Agilent Technologies' HSMP-3820 PIN diode or similar would probably make a suitable candidate for experimentation. In principle it should be possible to generate sampling pulses, having sufficient amplitude, of around 300ps or less using this method.

Douglas R Taylor
By email

CIRCUITIDEAS

Ozoniser

In hot and damp climates, fungus and mould can develop in all places but mainly in books. Ozone (O_3) is a powerful oxidizer that kills micro organisms and bad smells in the air.

The quartz bulb inside any mercury vapour lamp emits strong ultra-violet light which energy is enough for the reaction $3O_2 \leftrightarrow 2O_3$. This circuit is a driver and timer for a 220VAC 125W mercury lamp powered by a 120VAC mains source. The ballast in series with the lamp operates as a current source so the output is not reduced appreciably when operating at 120VAC but a voltage doubler is needed to start the plasma inside the bulb.

Pressing S1 starts the lamp and powers the timer that sends pulses generated by Q2 to trigger Q1 continuously. After the time selected by P1, IC1 output goes high and Q3 shuts down the pulses, cutting the power.

I use this ioniser when leaving for work to avoid any exposure of UV rays, harmful to eyes and skin, and ozone that burns the lungs.

The outside glass bulb must be broken to expose the quartz bulb and trigger connection inside (a wire with a 80kΩ resistor, R2). I installed the bulb inside a piece of plastic tube with tinfoil glued in the inner wall and put a fan in the bottom to disperse the ozone in the room like a fountain.

Be sure to open the windows when you came home again.

Tiaraju Vasconcellos Wagner
Brazil

Fact: most circuit ideas sent to *Electronics World* get published

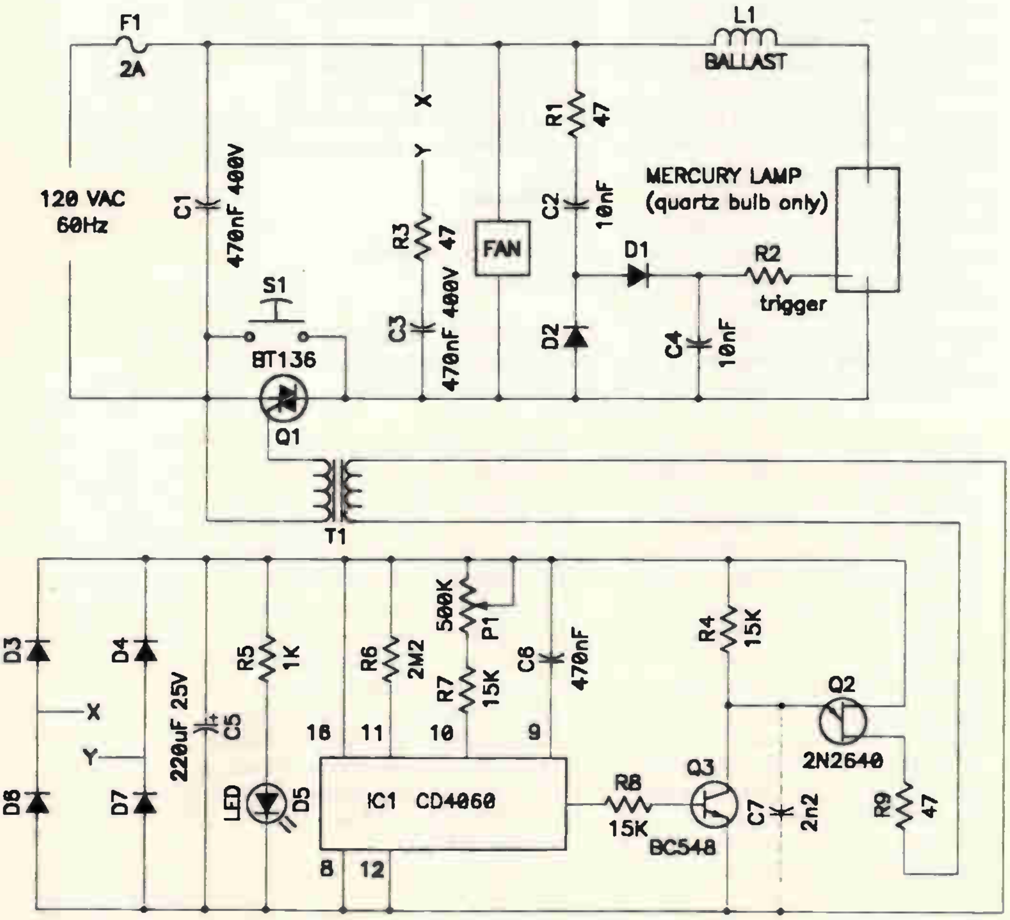
The best circuit ideas are ones that save time or money, or stimulate the thought process. This includes the odd solution looking for a problem – provided it has a degree of ingenuity.

Your submissions are judged mainly on their originality and usefulness. Interesting modifications to existing circuits are strong contenders too – provided that you clearly acknowledge the circuit you have modified.

Never send us anything that you believe has been published before though. Don't forget to say why you think your idea is worthy.

Clear hand-written notes on paper are a minimum requirement: disks with separate drawing and text files in a popular form are best – but please label the disk clearly.

Send your ideas to:
Jackie Lowe, Highbury Business Communications, Anne Boleyn House, 9-13 Ewell Road, Cheam, Surrey SM3 8BZ



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Operation of valve portable radios from the mains

There have been many circuits published for the operation of "picnic case portables" from either battery inverters or from mains power supplies. Most of these suffer from either safety problems if mains operated, or interference problems if of the battery driven inverter type.

This circuit overcomes these problems and is intended to operate any battery set from a mains supply in safety and without interference.

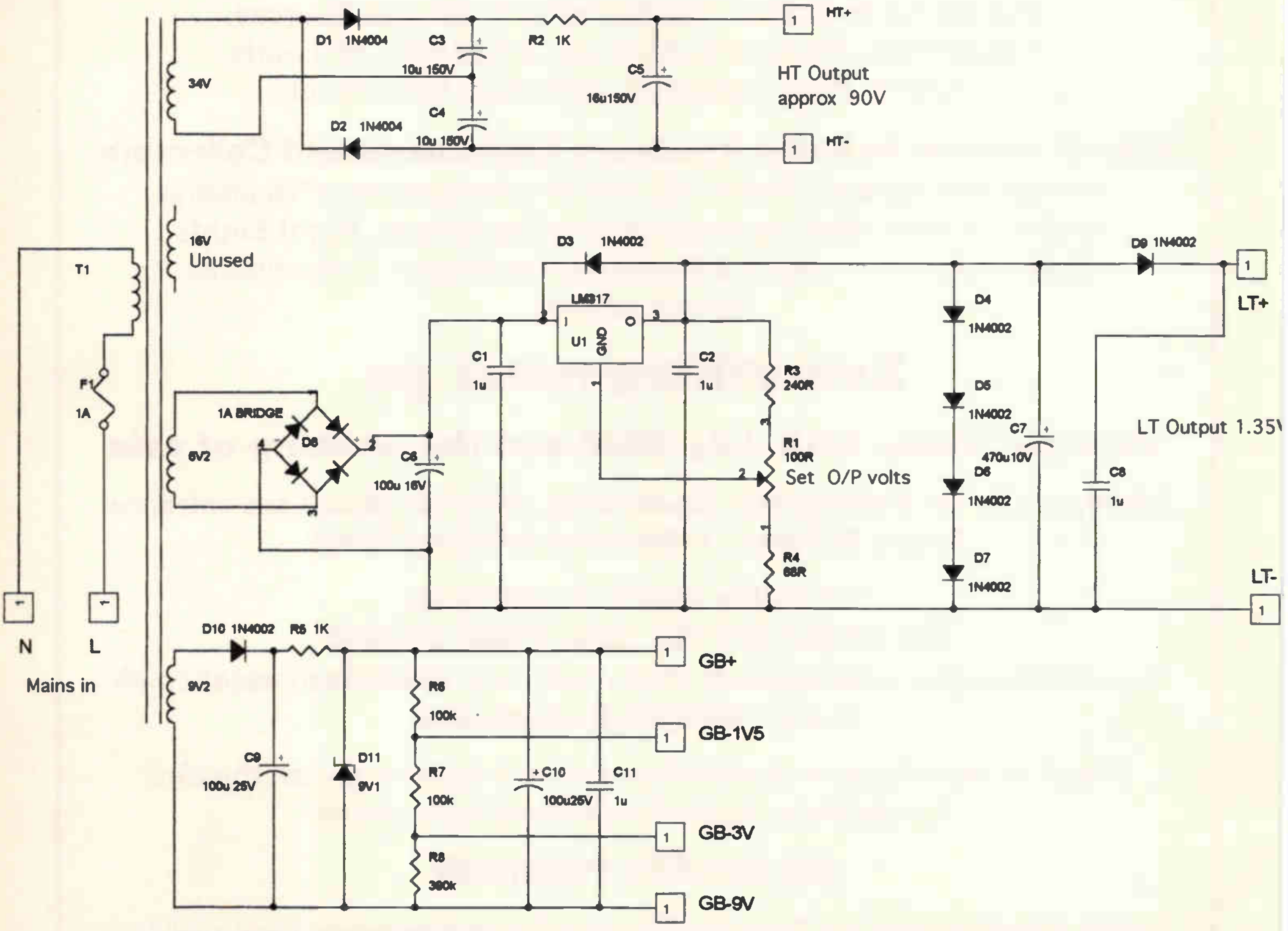
The heart of the circuit is a mains transformer from a video recorder. These transformers are double insulated as most recorders are not connected to mains earth and have several secondary windings ranging from about 4 to 40 volts.

The voltages of the various windings should be measured and one giving about 4 to 6 volts selected for the valve heaters. The higher voltage windings should be series connected to make up about 1/3rd the required HT voltage. This is then voltage doubled and smoothed for the HT supply. The HT current being low (10-15mA) means that this rectifier connection will give nearly 2.8 times the secondary RMS voltage. This voltage is not critical as in practice it varied widely as the HT battery discharged. Simple capacitive smoothing is all that is required. Voltages up to 150V can be obtained in this manner, The smoothing resistor R2 can also be adjusted for voltage setting.

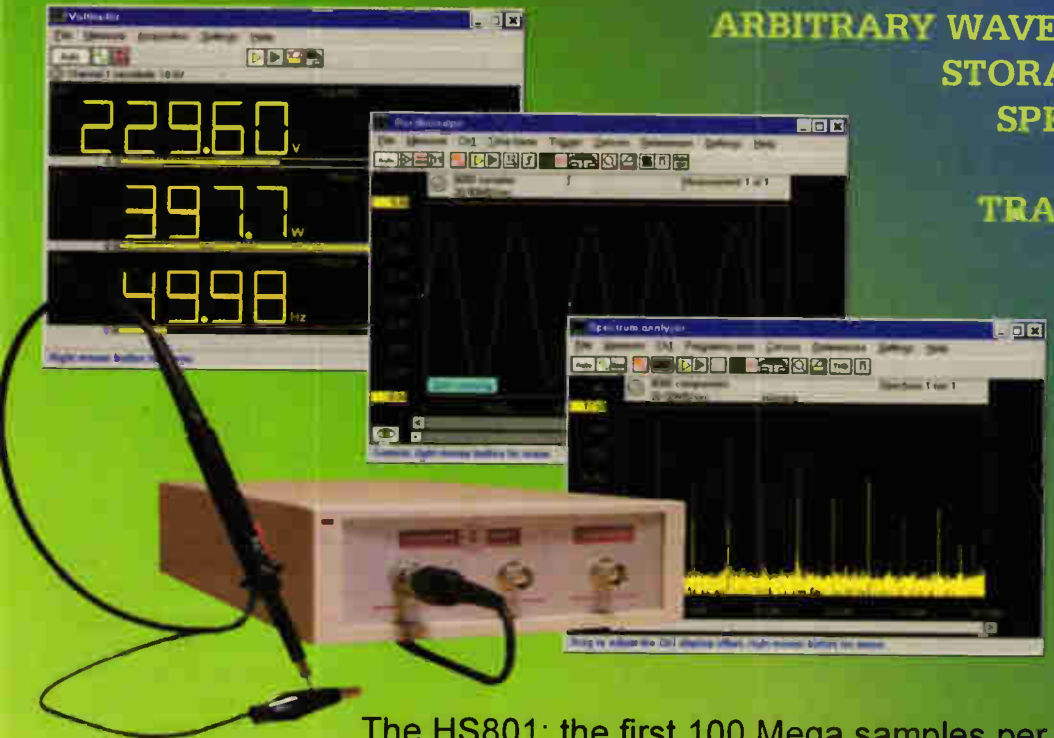
The LT circuit requires much more care, in terms of voltage control and hum level; an LM317 adjustable regulator is used. This device will only operate down to 1.3 volts, so a diode is connected in series with the output so it operates at 2.1 volts out, 1.4volts at the filaments. For older sets with 2-volt filaments the diode is omitted. The reverse diode across the regulator is to discharge the output capacitor at switch off. A string of four 1N4002 diodes can be fitted across the output to act as a crowbar in the event of the regulator going short. The unit should have the filament voltage pot set using a dummy load. With good valves this should be 1.3 to 1.35 volts for long life; with older valves that have possibly been overrun it is permissible to increase the voltage to 1.45V to achieve acceptable performance. R4 can be adjusted to give the required setting range on the pot R1.

For very old battery receivers that require a grid bias supply one of the spare windings is shown utilised for this purpose. The resistor chain R6,7,8 is adjusted for the required output voltage tappings.

Ed Dinning
Newcastle



GB circuit if required for older sets



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STORAGE OSCILLOSCOPE-
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Reliabity

The HS801: the first 100 Mega samples per second measuring instrument that consists of a MOST (Multimeter, Oscilloscope, Spectrum analyzer and Transient recorder) and an AWG (Arbitrary Waveform Generator). This new MOST portable and compact measuring instrument can solve almost every measurement problem. With the integrated AWG you can generate every signal you want.

- The versatile software has a user-defined toolbar with which over 50 instrument settings quick and easy can be accessed. An intelligent auto setup allows the inexperienced user to perform measurements immediately. Through the use of a setting file, the user has the possibility to save an instrument setup and recall it at a later moment. The setup time of the instrument is hereby reduced to a minimum.

- When a quick indication of the input signal is required, a simple click on the auto setup button will immediately give a good overview of the signal. The auto setup function ensures a proper setup of the time base, the trigger levels and the input sensitivities.

- The sophisticated cursor read outs have 21 possible read outs. Besides the usual read outs, like voltage and time, also quantities like rise time and frequency are displayed.

- Measured signals and instrument settings can be saved on disk. This enables the creation of a library of measured signals. Text balloons can be added to a signal, for special comments.

- The (colour) print outs can be supplied with three common text lines (e.g. company info) and three lines with measurement specific information.

- The HS801 has an 8 bit resolution and a maximum sampling speed of 100 MHz. The input range is 0.1 volt full scale to 80 volt full scale. The record length is 32K/64K samples. The AWG has a 10 bit resolution and a sample speed of 25 MHz. The HS801 is connected to the parallel printer port of a computer.

- The minimum system requirement is a PC with a 486 processor and 8 Mbyte RAM available. The software runs in Windows 3.xx / 95 / 98 or Windows NT / 2000 / XP and DOS 3.3 or higher.

- TiePie engineering (UK), 28 Stephenson Road, Industrial Estate, St. Ives,
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  Tel: 01480-460028; Fax: 01480-460340

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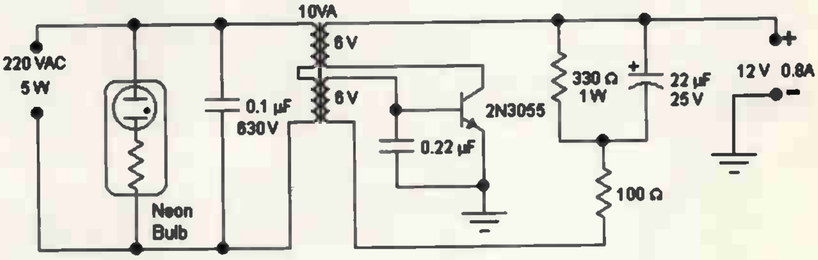
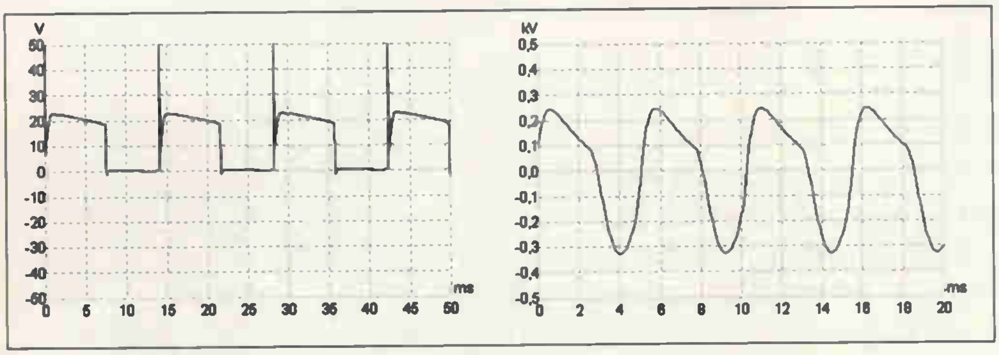
COMPUTER CONTROLLED MEASURING INSTRUMENT

5W Inverter



This inverter has been designed with readily available components. The transformer is a standard 10VA mains transformer with two 6V windings connected as shown in the schematic. Its purpose is to provide a suitable voltage for all those mains battery chargers that surround us: mobile phones, electric razors, generic battery chargers and even for a 5W electronic neon lamp. Frequency of operation is between 70 and 190Hz depending on the load. The frequency is not quite the mains frequency but is good enough to supply the intended loads. A small neon light at the output gives an indication of the presence of a dangerous voltage. The circuit will withstand temporary shorts and battery reversals. Some switching chargers require an initial peak current that might look like a short to the inverter. In this case it is necessary to disconnect and reconnect the load until it works. A fuse rated at 2.5A is a useful addition. Reverse one of the windings if the circuit does not oscillate.

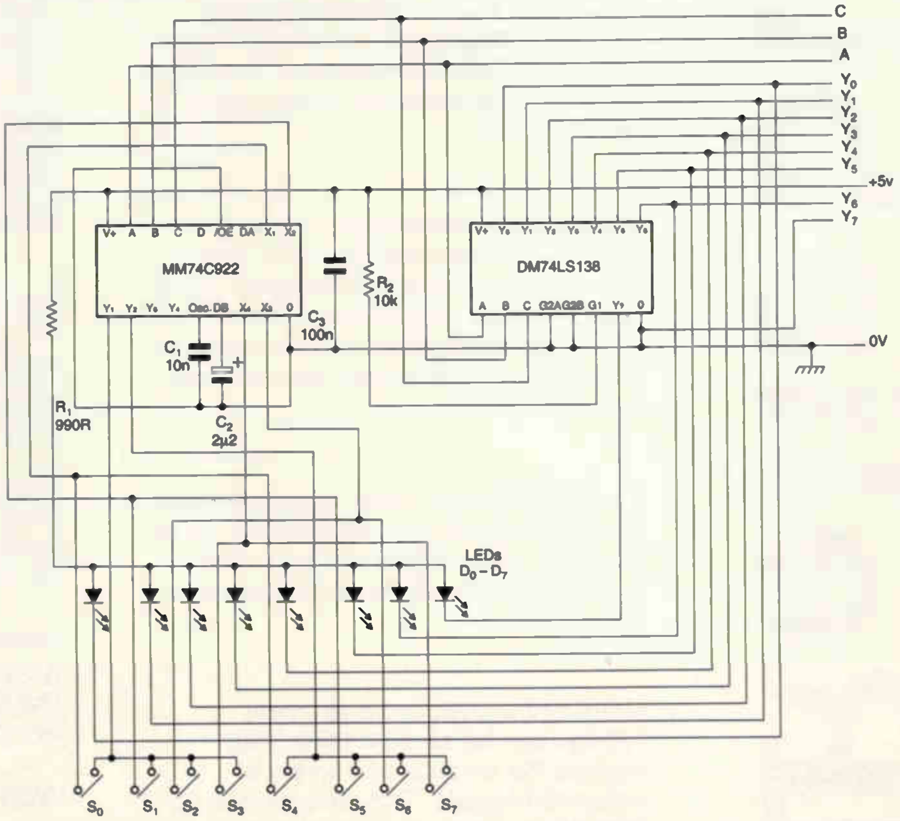


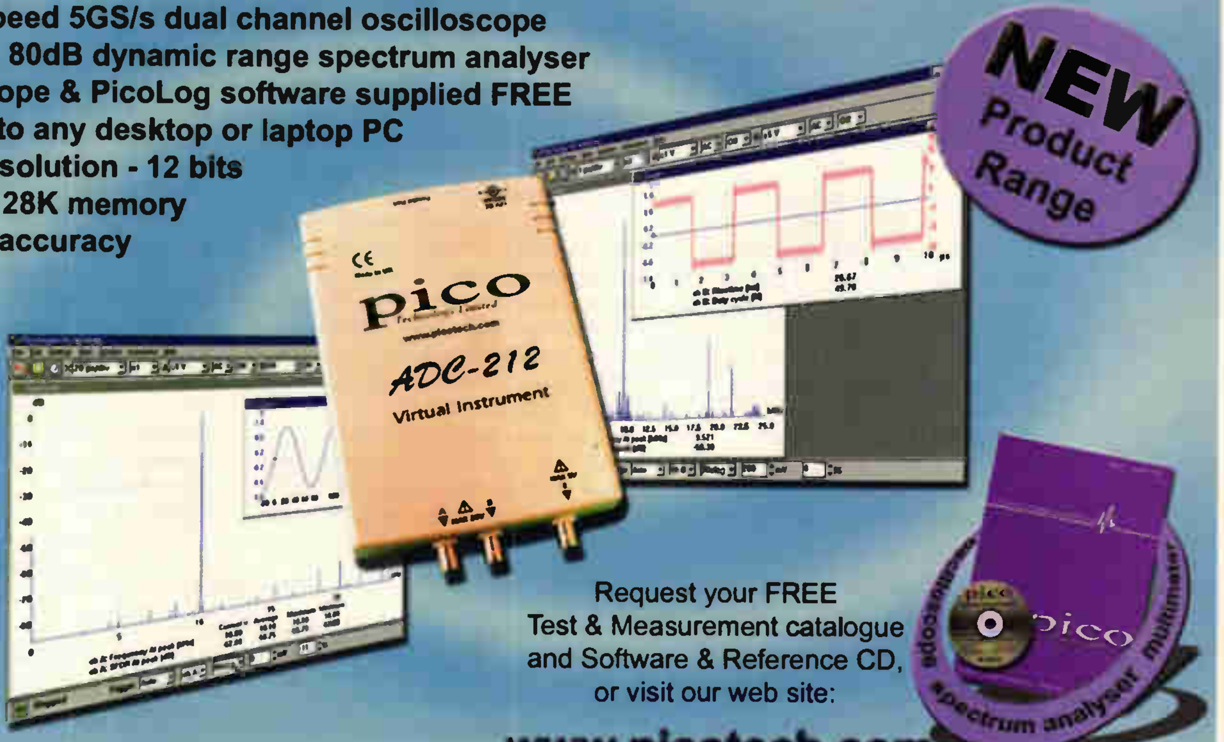
D. Di Mario
Milan

Standalone button latch

The conventional way of entering commands from a keyboard employs a scanning encoder occasions when a simple latching circuit is required, independent of complex processors. For two buttons, a pair of cross-coupled NAND gates offers a straightforward solution, but when selection is to be made from any one of say eight buttons, clearly a more versatile method is called for. It is possible to employ a counter, whose clock is stopped when the desired number is reached, but this turns out to be rather messy as it requires a gate for each button. A better method is to use the MM74C922, which is a hexadecimal keyboard encoder with built-in latches, as well as debouncing. To achieve the desired aim of eight illuminated buttons in one row, some rearrangement is necessary and a 3-to-8-line decoder such as a DM74LS138 needs to be added, as illustrated in Fig. 1. The encoder scans the eight momentary push-button switches S0 to S7, using an internal clock of about 6kHz set by C1, though an external clock of up to 10kHz can be applied to pin 5 instead. The debounce time is some 22ms, determined by the value of C2 = 2p2 shown. The decoder sends one and only one of its eight outputs Y0 to Y7 into the low state, and the sinking current is sufficient to illuminate the respective LED. Push-buttons with built-in LEDs are very effective here, and only one current-limiting resistor (R1) is required. Another point to note is that the binary output ABC from the hex-encoder is also available for commands, depending on whether the circuit to be driven wants 8-line or 3-line inputs. In the latter format this circuit has been made up as a sub-board that conveniently mounts behind front panels, with a five-wire ribbon cable (0V, 5V, A, B, C) to the main PCB. The 8-line (Y0 to Y7) version needs a total of ten wires; as it turns out, the same PCB layout can be used, with either a 5-way or a 10-way connector being fitted during the assembly process.

C. J. D. Catto
Cambridge

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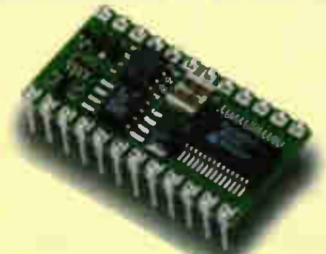
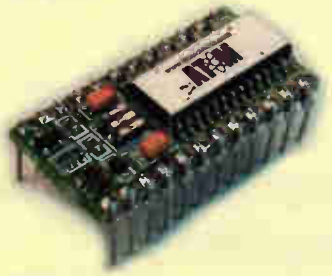





BASICMICRO
BASIC

Timer for battery chargers

Many devices with NiCd or other types of rechargeable cell specify a time for charging. This is usually several hours and it is very easy to put a battery on charge and then forget about it.

This circuit was developed at the request of my son who was given a rechargeable strimmer at Christmas that required a charge of 8 hours.

On operating the 'On/Start' switch the output is live for a preset period of from 2 to 12 hours, after which it is off. Timing is reset by switching 'On/Start' off and then on.

The delay is provided by the ICM7242 Timer/Counter chip, which is connected as a monostable and triggered by switch-on. The Timer drives a TLP3063 optical isolator triac with zero crossing turn-on. A PNP transistor, BC212L, buffers the output of the timer as its maximum sink current is 3mA and the optical isolator needs about 5mA. The optical isolator, in turn, controls the gate of a TIC 226M triac. The maximum current for the TLP3063 is 100mA and this current is possibly sufficient for battery chargers up to about 20 watts, but having a larger triac makes the unit more versatile. For example it could be used to switch a light off in the house when unattended.

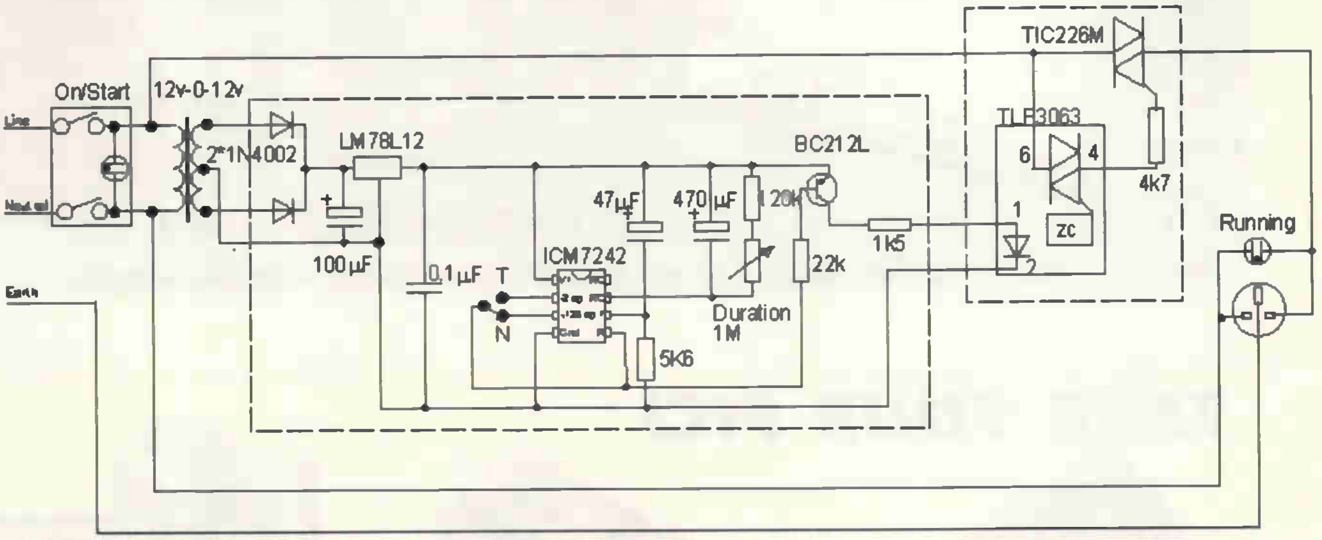
A jumper allows timing and switching functions to be tested over a short interval (20 secs to 2 mins).

By simply changing the value of the 470μF capacitor the delay range may be altered.

The low-voltage components were mounted on one PCB and the two triacs on another, with only the led drive connecting the two. The output connector is a panel mounting 13A socket (RS part number 847-455), with the 'running' neon indicating when that socket is live. The unit is housed in a 150x90x55mm box.

The timer chip, optical isolator and triac are available from RS (parts numbers 264-793, 261-0211 and 649-403) and their Application Notes may be downloaded from the RS site. Other components came from Maplin.

Tony Meacock
Norwich



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Signal Wizard 1.6 (formerly RTDF) is a unique real-time audio-bandwidth digital filter system with infinitely adjustable characteristics – all available at the click of a button. It uses a DSP unit that runs the filter and a friendly Windows-based interface that allows you to design and download any kind of filter you like, all within seconds. You don't need to know about filter maths, DSP or analogue filter design – all you need to know is what kind of filter you want. With Signal Wizard you can do more than specify the gain of the frequency response – you can also specify the phase of any frequency, with a resolution of one hundred thousandth of a degree! If you don't want to bother with phase, Signal Wizard will design with total phase-free distortion, no matter how complex or sharp the filter is. You are not limited to the design tool interface either - you can also import frequency responses as text files, specifying just magnitude or magnitude and phase. Once you are happy with the design, just download the filter and run it in real-time. Low-pass, High-pass, multiple-band or arbitrary are all possible.

Signal Wizard 1.6- Key features

- Runs under Windows 95, 98, Me, 2000, NT and XP.
- Multiple pass, stop or arbitrary filters.
- Import mode for arbitrary frequency response.
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- Deconvolution (inverse) or flipped filter options.
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- Eleven sample rates from 48kHz down to 3kHz.
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System includes:

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- Signal Wizard 1.6 CD.
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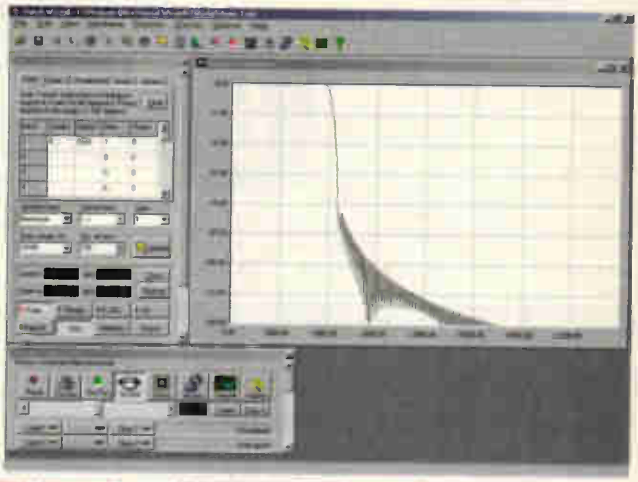

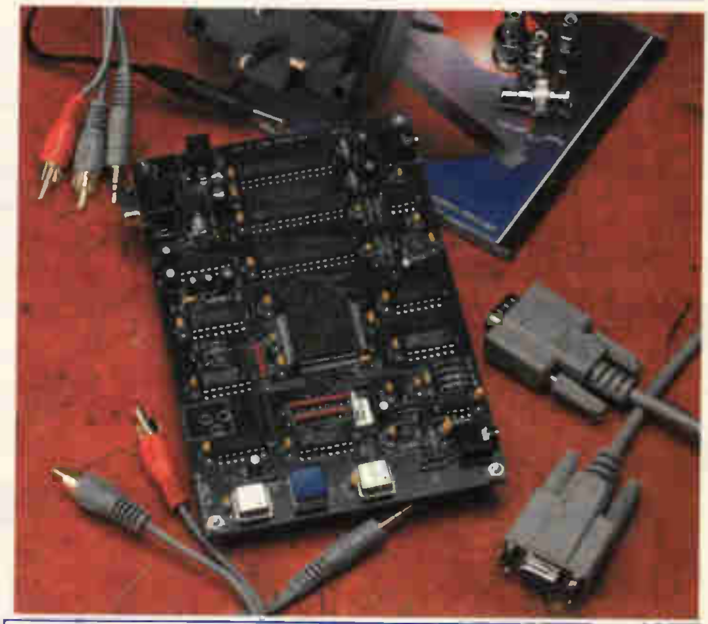

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The **TELEBOX** is an attractive fully cased mains powered unit, containing **all** electronics ready to plug into a host of video monitors or AV equipment which are fitted with a composite video or SCART input. The composite video output will also plug directly into most video recorders, allowing reception of TV **channels not normally receivable on most television receivers*** (TELEBOX MB). Push button controls on the front panel allow reception of 8 fully tuneable 'off air' **UHF** colour television channels. **TELEBOX MB** covers virtually all television frequencies VHF and **UHF including the HYPERBAND** as **used by most cable TV operators**. Ideal for **desktop computer video systems** & PIP (picture in picture) setups. For complete compatibility - even for monitors without sound - an integral 4 watt audio amplifier and low level Hi Fi audio output are provided as standard. Brand new - fully guaranteed.

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

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2 " **TOSHIBA** MK6409MAV 6.1Gb laptop (12.7 mm H) *New*	£98.00
2 " **TOSHIBA** MK1814GAV 18 Gb laptop (12 mm H) *New*	£149.95
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Order as LK33 ***ONLY £79.00 or 2 for £149.00*** *(B)*

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Wordperfect 6 for DOS supplied on 3 " disks with manual	£24.95

shipping charges for software is code B

SOLID STATE LASERS

Visible red, 670nm laser diode assembly. Unit runs from 5 V DC at approx 50 mA. Originally made for continuous use in industrial barcode scanners, the laser is mounted in a removable solid aluminium block, which functions as a heatsink and rigid optical mount. Dims of block are 50 w x 50 d x 15 h mm. Integral features include over temperature shutdown, current control, laser OK ouput, and gated TTL ON / OFF. Many uses for experimental optics, comms & lightshows etc. Supplied complete with data sheet.

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TEST EQUIPMENT & SPECIAL INTEREST ITEMS

Unless marked NEW, items in this section are pre owned.

MITSUBUSHI FA3445ETKL 14 Ind. spec SVGA monitors	£245
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FARNELL AP3080 0-30V DC @ 80 Amps, bench Suppy	£1850
KINGSHILL CZ403/1 0-50V @ DC 200 Amps - NEW	£3950
1kW to 400 kW - 400 Hz 3 phase power sources - ex stock	£POA
IBM 8230 Type 1, Token ring base unit dnver	£760
Wayne Kerr RA200 Audio frequency response analyser	£2500
INFODEC 1U, 24 port, RJ45 network patchpanels. #TH93	£49
3COM 16670 12 Port Ethemet hub - RJ45 connectors #LD97	£69
3COM 16671 24 Port Ethemet hub - RJ45 connectors	£89
3COM 16700 8 Port Ethemet hub - RJ45 connectors NEW	£39
IBM 53F5501 Token Ring ICS 20 port lobe modules	£POA
IBM MAU Token ring distribution panel 8228-23-5050N	£45
AIM 501 Low distortion Oscillator 9Hz to 330Khz, IEEE I/O	£550
ALLGON 8360.11805-1880 MHz hybrid power combiners	£250
Trend DSA 274 Data Analyser with G703(2M) 64 i/o	£POA
Marconi 6310 Programmable 2 to 22 GHz sweep generator	£4500
Marconi 2022C 10KHz-1GHz RF signal generator	£1550
HP1650B Logic Analyser	£3750
HP3781A Pattem generator & **HP3782A** Error Detector	£POA
HP6621A Dual Programmable GPIB PSU 0-7 V 160 watts	£1800
HP6264 Rack mount variable 0-20V @ 20A metered PSU	£475
HP54121A DC to 22 GHz four channel test set	£POA
HP8130A opt 020 300 MHz pulse generator, GPIB etc	£7900
HP A1, A0 8 pen HPGL high speed drum plotters - from	£550
HP DRAFTMASTER 1 8 pen high speed plotter	£750
EG+G Brookdeal 95035C Precision lock in amp	£1800
Keithley 590 CV capacitor / voltage analyser	£POA
Racal ICR40 dual 40 channel voice recorder system	£3750
Fiskers 45KVA 3 ph On Line UPS - New batteries	£4500
Emerson AP130 2.5KVA industrial spec.UPS	£1499
Mann Tally MT645 High speed line printer	£2200
Intel SBC 486/133SE Multibus 486 system. 8Mb Ram	£945

HP6030A 0-200V DC @ 17 Amps bench power supply	£1950
Intel SBC 486/125C08 Enhanced Multibus (MSA) **New**	£1150
Nikon HFX-11 (Ephiphot) exposure control unit	£1450
PHILIPS PM5518 pro. TV signal generator	£1250
Motorola VME Bus Boards & Components List. SAE / CALL	£POA
Trio 0-18 vdc linear, metered 30 amp bench PSU. **New**	£550
Fujitsu M3041R 600 LPM high speed band printer	£1950
Fujitsu M3041D 600 LPM printer with network interface	£1250
Siemens K4400 64Kb to 140Mb demux analyser	£2950
Perkin Elmer 299B Infrared spectrophotometer	£500
Perkin Elmer 597 Infrared spectrophotometer	£3500
VG Electronics 1035 TELETEXT Decoding Margin Meter	£3250
LightBand 60 output high spec 2u rack mount Video VDA's	£495
Sekonic SD 150H 18 channel digital Hybrid chart recorder	£1995
B&K 2633 Microphone pre amp	£300
Taylor Hobson Tallysurf amplifier / recorder	£750
ADC SS200 Carbon dioxide gas detector / monitor	£1450
BBC AM20/3 PPM Meter (Emest Tumer) + drive electronics	£75
ANRITSU 9654A Optical DC-2.5G/b waveform monitor	£5650
ANRITSU ML93A optical power meter	£990
ANRITSU Fibre optic characteristic test set	£POA
R&S FTDZ Dual sound unit	£650
R&S SBUF-E1 Vision modulator	£775
WILTRON 6630B 12.4 / 20GHz RF sweep generator	£5750
TEK 2445 150 MHz 4 trace oscilloscope	£1250
TEK 2465 300 Mhz 300 MHz oscilloscope rack mount	£1955
TEK TDS380 400Mhz digital realtime + disk drive, **FFT** etc	£2900
TEK TDS524A 500Mhz digital realtime + colour display etc	£5100
HP3585A Opt 907 20Hz to 40 Mhz spectrum analyser	£3950
PHILIPS PW1730/10 60KV XRAY generator & accessories	£POA
VARIACS - Large range from stock - call or see our website	
CLAUDE LYONS 12A 240V single phase auto. volt. regs	£325
CLAUDE LYONS 100A 240/415V 3 phase auto. volt. regs	£2900

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NEWPRODUCTS

Please quote *Electronics World* when seeking further information

19in. rack-mount monitor drawers

APW Standard Products has introduced the Cyberview family of rack-mounted interface devices for use in its IMserv & Paramount server cabinets and any other 19in practice equipment. The 1U drawers take up the minimum possible vertical rack space and, when flipped up, the screen sits in front of the verticals. An 1U flip-up monitor drawer houses a15in or 17in TFT/LCD active matrix colour display panel. Suitable for all cabinets from 650 to 1000mm deep, the displays feature a wide viewing angle with resolutions up to 1280 x 1024. Also available are 1U keyboard/display drawers, giving an 84-key keyboard with trackball and a 15in. display. These units can also integrate an 8-port KVM switch, which, when tiered, is stackable to 64-way.

APW
Tel: 01895 237123
www.apw.com

IC maps Gigabit Ethernet into SDH network

Transwitch has introduced a device for full-duplex mapping of Ethernet traffic into the SONET/SDH transport network. The EtherMap-3 supports eight 10/100 Ethernet ports or one Gigabit Ethernet port to deliver a broad range of both SONET/SDH and Ethernet processing functionality. By incorporating both the new standardised link layer framing protocols GFP (Generic Framing Procedure), LAPS (Link Access Procedure for SDH) and LAPF (Link Address Procedure Framed-mode) and the new virtual concatenation (VC) standards, the IC will allow designs to implement private line Ethernet transport and Transparent LAN services in the wide area network. The device incorporates an Ethernet Media Access Control (MAC) function, a buffering strategy, 84-channel VT/TU (Virtual Tributary / Tributary Unit) mapping, VC-3/VC-4 mapping and virtual concatenation.

Transwitch
Tel: 01256 882158
www.transwitch.com

Inductors offer low current resistance

Pulse has introduced a series of inductors for DC-to-DC power supplies that offer both a low direct current resistance (DCR) rating and wide inductance range. Available with inductances from 0.4 to 6.2μH and current ratings from 9 to 73A, the components provide DCR ranges from 0.38 to 1.44mΩ. This allows power loss ratings to be kept to a minimum, 0.16 to 2.25W, placing the inductors among the most efficient on the market.

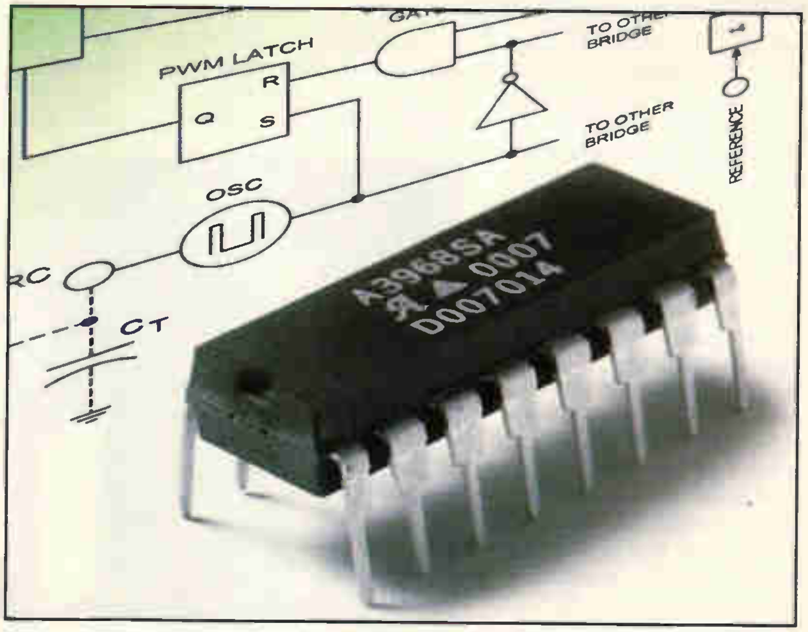
Pulse
Tel: 0033 84350448
www.pulseeng.com

Memory is bank-switchable

IDT has added to its family of bank-switchable dual-port memory with device speeds up to 200MHz and densities up to 9Mbits. Unlike traditional 9Mbit dual-port devices that rely on multiple internal die, these devices are available in a single configuration. The 36-bit and 18-bit devices feature selectable 3.3/2.5V I/O operations, with the

Motor driver ICs with brake function

Allegro Microsystems has a range of dual full-bridge PWM motor driver integrated circuits featuring a brake function. Each device is designed to control two DC motors bi-directionally and includes two H-bridges capable of continuous output currents of ±650mA and operating voltages to 30V. Motor winding current can be controlled by internal fixed-frequency, pulse-width-modulated (PWM) current-control circuitry. The peak load current limit is set by the user's selection of a reference voltage and current-sensing resistors. The fixed frequency pulse duration is set by a user-selected external RC timing network.The capacitor in the RC timing network also determines a user-selectable blanking window that prevents false triggering of the PWM current-control circuitry during switching transitions. Two package styles are available: the A3968SA is supplied in a 16-pin dual-inline plastic package, while the A3968SLE is supplied in a 16-lead plastic SOIC package with copper heatsink tabs.



Allegro Microsystems
Tel: 0033 4505 12359
www.allegromicro.com

3.3V options supporting speeds up to 200MHz and the 2.5V options supporting speeds up to 166MHz. The bank-switchable devices are organised into 64 banks within a common memory array, surrounded by multiplexing circuitry to allow each bank to be accessed by either port. The devices are capable of supporting frequencies up to 200MHz on buses of various widths, frequencies and voltage levels. The dual ports feature separate, independent clocks on each port to support communication between busses running at different frequencies, even with the two ports set at different voltage levels.

IDT
Tel: 01372 366112
www.idt.com

Watch out for miniature crystal

Fox Electronics is offering a miniature watch crystal that measures 7.0 x1.5mm with a profile of 1.4mm for real time clock (RTC) applications. With a frequency of 32.768kHz, the new FSX327 is optimised for a 12.5pF load capacitance. Frequency tolerance is ±20 PPM at 25°C and frequency stability is –0.035 ±0.01 PPM over –40 to +85°C. Turnover temperature range is +20 to +30°C operating temperature is -40 to +85°C, and storage temperature is –55 to +125°C. Minimum insulation resistance is 500MΩ at 100 VDC and maximum equivalent series resistance is 65kΩ.

Fox Electronics
www.foxonline.com

Voltage reference with 50ppm/°C drift

Texas Instruments has introduced a family of low-dropout, series-mode CMOS voltage references offering accuracy of 0.2%, a SOT23-3 package size, and 50ppm/Cmax drift. Power consumption is 50μA (max). The REF30xx family features 1.25V, 2.048V, 2.5V, 3.3V and 4.096V output voltages. The devices are able to source up to 25mA of output current and provide a supply range up to 5.5V. The references do not require a load capacitor, and are stable with any capacitive load. Unloaded, the devices can be operated on a supply within 1mV of output voltage.

Texas Instruments
Tel: 0049 8161 80 33 11
www.ti.com

WCDMA test for adjacent channel leakage

Rohde & Schwarz is offering firmware for its SMIQ03HD signal generator and FSU spectrum analyser to support ACLR (adjacent channel leakage ratio) measurements of WCDMA signals. According to the supplier, with power amplifiers, adjacent channel leakage must be low, especially on the downlink, For a single-carrier WCDMA signal, the signal generator features ACLR of +77dB in the adjacent channel and +82dB in the alternate channel. Compared to previously available performance . that means 7dB more dynamic range and besides SCPA's (single-carrier power amplifiers), producers of basestations are making increasing use of MCPA's (multicarrier power amplifiers) for up to four channels.

Rhode & Schwarz
Tel: 01252 818888
www.rsuk.rohde-schwarz.com

STS-3/STM-1 transceiver with 311MHz clock

TDK Semiconductor is offering a SONET/SDH line interface unit which operates at 155.52Mbit/s (STS-3 or STM-1) rates and provides a synchronized clock for backplanes operating at 311MHz speeds. The 78P2254 interfaces to a 75Ω coaxial cable using CMI coding and provides all necessary transmit and receive circuitry to interface to a digital framer.

TDK Semiconductor
Tel: 020 8443 7061
www.tdksemiconductor.com

FPGA is a live system power-up

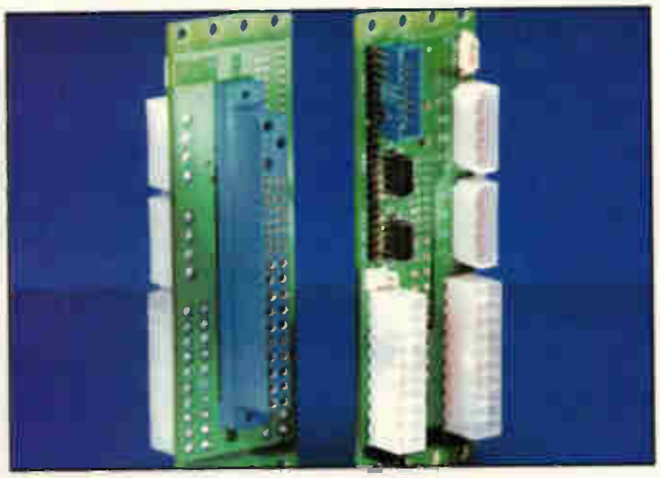
Actel has announced availability of a "live-at-power-up" 72,000-gate anti-fuse FPGA for radiation-intensive applications, such as low-Earth orbiting satellites and deep space probes.

The RTSX-S family uses hardened latches, which the firm says eliminates the need for software-based triple module redundancy (TMR) and maximises the total number of logic gates available to the designer. The RTSX-S devices offer total ionising dose

P47 Power backplane

Schroff has expanded its range of power backplanes with P47 connections for Compact PCI systems. The backplane supports the connection of up to four power supply units in parallel, with separable fault signals FAL# (Fail) and DEG# (derating of outputs). This allows for a higher-level monitoring unit to carry out logical operations on the signals before they are forwarded to the CPU. This can be used for studying the monitoring of redundant power supplies in high-availability systems at prototype stage. The System Management Bus as specified in PICMG 2.09 is integrated on the board, so with the definable geographical address of each slot, information on the status of each power supply in the system can be monitored at a higher level.

Schroff
Tel: 01442 240474
www.schroff.co.uk



performance in excess of 100Krad; inherent single-event latchup immunity; greater than 63Mev-cm²/mg single-event upset performance; and hot-swap compliant I/Os and cold-sparing capabilities. The family ranges in density from 32,000 to 72,000 typical gates (16,000 to 36,000 Asic gates).

Actel
Tel: 01276 803399
www.actel.com

DC-DC converter has 10.5mm profile

Acal Power Solutions has introduced a family of 10W DC-DC converters manufactured by IBEK of Switzerland and packaged in a 2 x 1in metal case measuring only 10.5mm high. The converters are available with input voltage ranges of 9 to 18, 18 to 36 or 36 to 75V DC with output voltages of 3.3, 5, ±5, 12, ±12, 15 or ±15V DC. Typical output voltage noise at 20MHz bandwidth is only 60mV p-p. Continuous no-load and short-circuit protection are provided as standard and a shut-down function is available as an option.

Acal Power Solutions
Tel: 01252 858727
www.acalelec.co.uk

Audio playback DAC with SACD interface

Analog Devices has introduced a single-chip stereo digital audio playback design which comprises a multi-bit sigma-delta modulator, digital interpolation filters and a continuous-time differential current output DAC. The audio DAC includes a separate Super Audio CD (SACD) bit-stream and external digital filter interface. The AD1955 supports a 24-bit, 192kHz sample rate and provides 123dB of dynamic range using its mono mode and is fully compatible with all known DVD audio formats, said the supplier. The 5V chip also is backwards compatible, supporting 50/15μs digital de-emphasis intended for "redbook" compact discs, as well as de-emphasis at 32 and 48kHz sample rates. It has a 120dB specified signal-to-noise ratio and 120dB of dynamic range (both not muted at a 48kHz sample rate, A-weighted stereo).

Analog Devices
Tel: 01932 266000
www.analog.com

Smartcard goes remote with IDC termination

Targeting applications such as set top boxes and digital encryption, board-mount smartcard connectors with IDC termination from Tyco Electronics are designed to allow for the smartcard slot to be located remotely from the main board. The smartcard connector features a ribbon cable with strain relief, various cable lengths and versions offering 8 and 16 contacts.

Tyco
Tel: 020 8954 2356
www.tycoelectronics.com

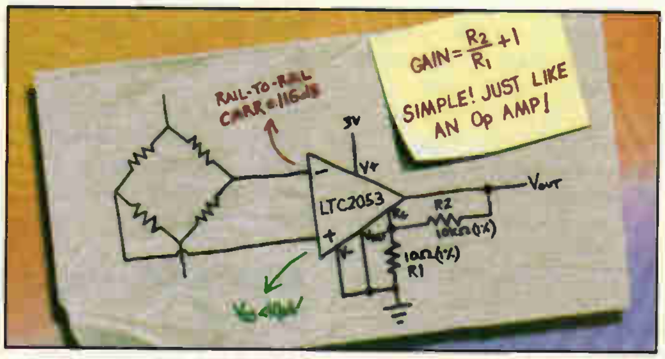
Dual cathode varactor of 15pF capacitance

For applications needing close tuner diode matching, Zetex has introduced dual common cathode hyperabrupt varactors. Two devices, the ZMDC831BTA and ZMDC832BTA offer high tolerance CV characteristics, low leakage and an accordingly low phase noise performance. Nominal capacitances for the 831B and832B are respectively just 15pF and 22pF for a reverse bias voltage of 2V and a frequency of 1MHz. Reverse voltage leakage current is typically as low as 0.2nA. A maximum footprint of 2.2mm by 2.2mm is required by the component's SOT323 outline. Typical applications for the ZMDC dual varactors include voltage controlled oscillators and tuned phase lock loop circuits.

Zetex
Tel: 0161 622 4444
www.zetex.com

Instrumentation amp on a 2.7V supply

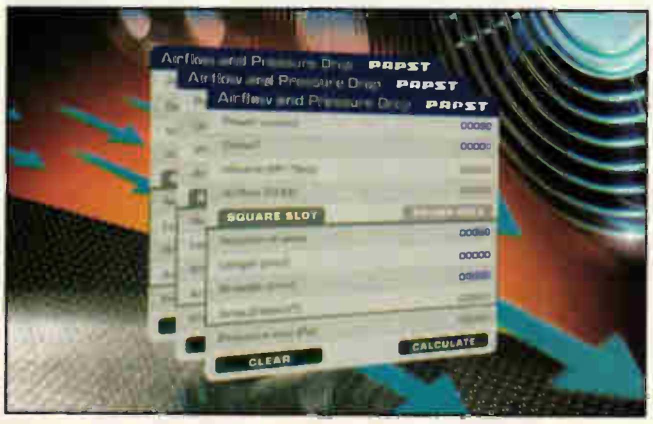
Linear Technology has introduced the LTC2053, a zero-drift instrumentation amplifier that features rail-to-rail input and output, works on a single 3V supply and is available in the tiny MSOP-8 package. It has a maximum of 10μV offset voltage, a 50nV/°C offset drift and a high common mode rejection ratio of 116dB, which is gain independent. According to the supplier, this level of DC accuracy exceeds the precision specifications of instrumentation amps that until now have been only available in the bigger DIP and SO packages and require dual supplies to operate.



Linear Technology
Tel: 01276 677676
www.linear-tech.com

Fans look cool on the web

Fan specialist Papst has added product specifying tools to its web site. Working alongside the existing pressure and airflow unit converter tools, the Airflow and Pressure Drop Calculators are designed to help engineers specify the company's fans. The objective of this tool is to obtain an initial estimate of what airflow a fan needs to produce, and to deduce what back pressure the fan must overcome to eradicate excessive heat from a system. To establish what back pressure the fan needs to overcome to deliver the required flow rate, the user then enters details of the relevant aperture size. By clicking on 'calculate' the result is displayed as a value in m² and is the total available open area for air to travel through.



Papst
Tel: 01264 333388
www.papstpic.com

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You can handle desk-top cases

OKW has introduced a range of aluminium desk-top cases with ergonomic carry handles. The uniMET range is suitable for housing test and measurement devices, communications equipment, machine controllers, network peripherals and medical technology. Three standard case sizes are offered: 85x230x190, 85x250x260mm and 120x350x260mm. The handle mechanism is robust and can be indexed at 30° intervals. The range includes a die-cast front bezel, located on the folded aluminium case body. The case is painted in mid grey RAL 7040 (bezel) and light grey RAL 7035 (body). Anodised aluminium front panels are available as accessories and include trims to hide the fixing screws.

OKW
Tel: 01489 583858
www.okw.com

Power resistors in a chip

Welwyn Components is finding applications for its ranges of standard and custom surface mount resistors in the design of DC-DC converters, where the drive efficiency is placing heavy demands on the specifications of components such as chip resistors. The thick film PWC series (Pulse Withstanding Chip), is available in four standard sizes from 0805 to 2512, it offers a resistance range from 1R0 to 10MΩ, tolerance to 0.5 per cent and typical TCR of 100ppm/°C. Its special design permits an enhanced power rating (1.5W at 70°C for 2512) and higher Limiting Element Voltage (500 for 2512). The PCR series of precision chip resistors offers any resistance value within a specified range of 10R to 1MΩ, at a tolerance of 0.1% and TCR of 50ppm/°C.

Welwyn Components
Tel: 01489 583858
www.welwyn-tt.co.uk

Dual-port comms RAM is 9Mbit

Cypress Semiconductor is offering a 9Mbit dual-port RAM. The CY7C0853V provides 9Mbit of synchronous, pipelined dual-ported memory capable of buffering large packets of data between two independent clock domains. Configured as a 256k x 36-bit wide device, it provides up to 9.6Gbit/s of bandwidth and allows for interface to wide busses. Unlike alternative bank-switchable devices this is a true dual-port, providing simultaneous read and write access to any cell in its memory array from either of its two ports. In addition, the two ports may operate at independent clock speeds, allowing complete decoupling of the devices being interfaced. The devices are available in a 172-pin BGA package at up to 133MHz.

Cypress Semiconductor
Tel: 01707 378799
www.cypress.com

Testing ADSL loop in the field

The LX100 from Yokogawa Martron is a portable test tool for the field troubleshooting of ADSL services over copper cable. The unit displays test data required for effective troubleshooting, including attenuation, noise, TDR measurements, burst noise waveform and complex impedance. Applications include verifying the signal/noise margin necessary for ADSL services, determining the locations of loading coils and bridge taps, estimating the source of crosstalk noise and burst noise, and impedance measurement. It can measure noise down to low levels (–140dBm/Hz), and will carry out measurements on attenuation levels of up to 100dB. There is an auto test mode and the instrument is fitted with a PC compatible PCMCIA memory card slot.

Yokogawa Martron
Tel: 01494 459200
www.martron.co.uk

Frequency translator has low jitter

Vectron has introduced a low jitter frequency translator designed for clock smoothing applications. The FX-700 is a crystal-based frequency translator that provides output frequency ranges from 1kHz to 77.76MHz, with a supply voltage that can be either 3.3V or 5V. The device is hermetically sealed in a 16-pad ceramic SMD package, measuring 5 x 7.5 x 2.0mm. Possible applications include SONET/SDH/ATM, WDM, digital cross connect, GSM and CDMA basestations.

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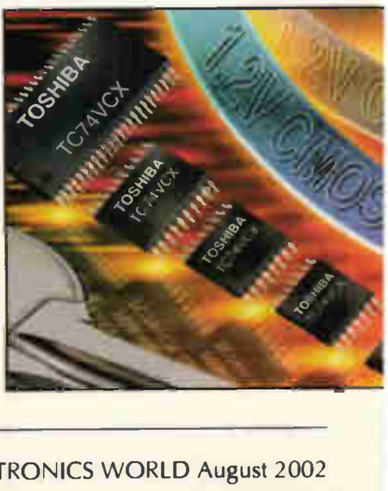

Controller for Pentium 4

Semtech has announced the SC1474 dual-phase power supply controller to supply both V(core) and VID voltages for the mobile Intel Pentium 4 processors. It delivers the 0.600V to 1.750V core voltage at up to 40A, and the 1.2V, 300mA VID power.The core voltage is set by a 5-bit DAC accurate to 0.85 per cent. The dynamic current-sharing feature automatically balances the average current in each phase, eliminating hot spots caused by mismatched trace impedance and component tolerance variations, said the firm. A linear regulator controller delivers the 1.2V, 300mA power.

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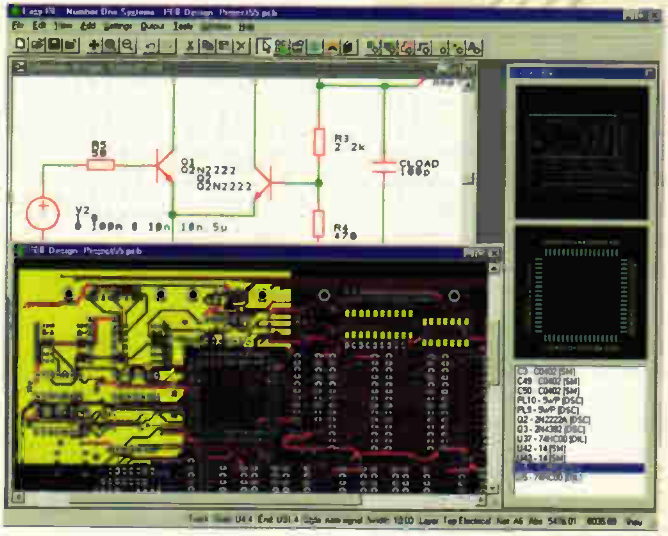

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operates down to 1.2V. Package options include industry-standard 56-, 48-, 20-, 16- and 14-pin TSSOP, while devices are also available in the newer US16 and US20 package styles, which are claimed to have footprints up to 30% smaller than equivalent TVSOP and TTSOP packages. The family offers standard logic functions, such as basic gates, bus buffers, bus transceivers, latches and flip-flops. Over-voltage-tolerant inputs and outputs allow the parts to operate as an interface between different supply voltages in the same system, says the supplier, In addition, each device incorporates a power-down-protected I/O structure that means signals can be applied to any I/O pin during both normal operation and power-down modes. Toshiba, along with Fairchild Semiconductor and ON Semiconductor, is a member of the Logic Alliance. (www.LvLAlliance.com)

Toshiba
Tel: 01276 694730
www.toshiba-europe.com

Secure controller has USB interface

Atmel is sampling the AVR-based secure flash microcontroller which has a USB full-speed interface The AT90SC6464C-USB is built around the firm's AVR 8-bit Risc processor, with 64kbytes of on-chip flash memory and 64kbytes of EEPROM. The USB V1.1 full speed interface (12Mbit/s) gives it a direct high-speed connection to PC or Internet appliance using e-Token or smartcard support, said the company. Examples include electronic signature, user authentication, transfers of large amounts of secure data, high-security financial transactions and access keys for secure software.

Atmel
www.atmel.com

F-class power Mosfets for fast switching

IXYS has announced the availability of two power Mosfet dies designed for very fast switching applications. The IXFD 12N50F is rated at 12A (DC) and 500V and its R(DS)cc is less than 0.4Ω. The specifications of the higher voltage rated IXFD 6N100F are 1000V, 6A(DC) and 1.9Ω R(DS)on. Both chip types are available for prototyping in either the TO-247 through-hole package or surface mountable TO-268 packages. ■

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Part 1: Capacitors, Inductors, and the Electronic Atom.

Nigel Cook

An Electronic Universe

Inability to explain fundamental concepts to a wide audience leads to a severe problem in communication: to being regarded as a 'technician' who hides ignorance behind jargon. The ability to design circuits, but inability to explain everything, causes a frustrating lack of self-confidence for engineers in the boardroom. Jargon without clear explanation leads to shunning by a society which doesn't appreciate mere description of crucially important phenomena, e.g., 'capacitance' and 'inductance', and who want proper underlying explanations. So electronics, as jargon-dominated trivia, is being left out of newspapers and TV, despite the increasingly important reliance of society and science upon electronics.

History

A century ago, 'electronics' was the name of the latest and most prestigious science. But the researchers ended up in chaos, with Ampere's original theory of 'current' finally culminating in the calculated typical 1 mm/s flow of drifting 'electrons', versus Heaviside's 300,000 km/s transverse electromagnetic (TEM) energy wave (whose exact speed, like the local speed of light in a medium, is determined solely by the dielectric insulating material, such as air or plastic, between the conductors, not by the nature of the conductors themselves). This particle-versus-wave problem was not a new problem; it had its roots originally in 1680 when Christian Huygens proposed that light is waves, in direct opposition to Isaac Newton's particle theory. Eventually, in 1927, Niels Bohr invented a 'correspondence principle' to suppress critics by accepting 'particle-wave duality', permitting whichever calculation was appropriate for the problem in hand. Consequently, explanations became submerged by semi-empirical equations, while experimental electronics applications flourished.

It is obvious that even if the entire mass of the cable was electrons, they would carry negligible kinetic energy travelling at 1 mm/s (since the kinetic energy equation is E = _ mv^2). Hence, a 1 mm/s electron current cannot be the predominant mechanism of energy transfer. Ivor Catt (b. 1935) started developing TEM wave-based explanations with David Walton and Malcolm Davidson in May 1976, and published them between 1978-88 as *Wireless World* articles, which unfortunately were produced in an abstruse manner (absurdly rejecting electric current and displacement current out of hand using Ockham's razor, without including a proper replacement theory or using the new facts which they established to produce an understanding of the unanswered problems in science).

Continuity of electric current in a circuit: a Science Fiction Story

Once upon a time, everyone grasped the basic law of electric currents that currents only flow in complete circuits. It was a simple theory, which was consistent with the known facts.

Sadly, it was a misleading and false theory, because the electric current cannot know if there is a break in the wire at one point until it arrives there, travelling at the speed of light for the dielectric.

Whenever any cable is connected to a power source, the power source will deliver power to the cable, because it has no way of telling whether there is an open circuit or a load at the other end. Only when the electric energy arrives at a break, is the circuit proven open. In the intervening period, electric energy flows at 300,000km/s as if there is no break. So electric current will flow in an open circuit.

It is important to stop at this stage, and carefully examine what happens in the cable that has been carrying electric energy towards the unconnected (open circuit) wire ends of the cable. First, the cable itself acquires an electric charge (like a pair of capacitor plates connected to a power source). Due to the electric charge, an electric field occurs between the wires of the cable. Second, when the electric energy arrives at the break in the circuit, it has no place to go except to bounce back, which it does, always at the speed of light.

When we close the switch and energy goes off into the open-ended cable at the speed of light for the dielectric between the wires, not knowing that an open circuit exists at the end of the cable:

(1) Ohm's Law is violated because, in his equation $V = IR$, R is the circuit resistance, which is infinity if there is an open circuit.

(2) Kirchhoff's First Law is violated since the law says electric current requires a complete circuit.

Both these problems arise because these old Laws assume instantaneous action at a distance, i.e., that the electricity knows whether or not it faces an open circuit before it even sets off at the speed of light when the switch is closed! Ivor Catt's research in computer circuits disproved such nonsense.

Oliver Heaviside around 1875 corrected Ohm's Law by adding to resistance the term Z, which is the impedance of the dielectric used in the cable. If there is nothing between the wires in the cable, Z is the impedance of the fabric of free space (vacuum), 377 ohms.

The corrected version of Ohm's law reads: $V = I(R+Z)$. If there is no resistance, Ohm's law becomes $V= IZ$. Hence, any 377 volt source will initially send a 1 amp electromagnetic pulse (EMP or transverse electromagnetic wave, TEM wave, depending on preference) travelling at 300,000km/s (if the dielectric is vacuum), into a pair of wires it is connected to, regardless of whether there is a load or an open-circuit at the other end.

A consideration of what happens when the 1 amp of energy reaches the open circuit and reflects back, is the basis for the ingenious calculation (below) by Catt, Davidson, and Walton. This proves that "a capacitor is a transmission line", i.e., that electric current as presently taught in electronics and physics, is an old deception which needs replacement by the new theory presented below.

In the Dec 1978 issue of *Wireless World*, p 51, Ivor Catt, Malcolm Davidson and Dr. David S. Walton produced the most original and brilliant theoretical calculation in electronics since Maxwell's day: they calculated the real mechanism of charging of a pair of wires (open ended power transmission line) through a resistor by 300,000 km/s energy being delivered to it, with the energy bouncing back and forth as it charged up, giving a mathematical formula exactly the same as that empirically found for a charging capacitor. We hereby set out clearly their basic mathematical proof of "a capacitor is a transmission line" and that 'static' electricity is indeed in constant c speed motion:

1. Because the pair of open ended wires being charged up through resistor R are in open circuit, their impedance is that of free space, $Z = 377\Omega$.
2. When the switch is closed sending energy at potential V volts through the resistor into the wires, the voltage of the energy in the wires is $VZ/(R+Z)$, which will move at the speed of light for the dielectric (air, vacuum, plastic, or whatever) between the wires.
3. When the energy arrives at the open or loose ends of the wires, it will bounce back at the same speed, colliding with more incoming energy which is continuously arriving at potential $VZ/(R+Z)$. This adds to the incoming energy potential (since electric fields are scalar, direction does not matter in voltage contributions). This gives the pair of wires $2VZ/(R+Z)$ volts.
4. If the length of the wires is x, and the speed of light c, then the number of 2-way passes of the light speed energy in the wires in time t will be simply: $n = ct/(2x)$.
5. Each additional reflection at each end of the wires, continues to increase the voltage potential from the existing potential, although due to the difference between R and Z the increase will be by decreasing amounts, since the differential increase on the n number 2-way pass will be: $2[(R-Z)/(R+Z)]n.[VR/(R+Z)]$.
6. Summing (with a geometric series) all the contributions from n reflective passes of the energy up and down the wire while energy is being put in continuously with potential $VZ/(R+Z)$, gives a total voltage in the wires of $V[1-\{(R-Z)/(R+Z)\}]n$.
7. In the simple case, R is much larger than Z, so that $R >> Z$.
8. Since $R >> Z$, it follows that as n becomes very large (as it will do very, very quickly, since the speed of the energy is nearly 300,000,000m/s), the voltage formula reduces to simply: $V[1-e^{(-2nZ/R)}]$.
9. Since we have shown (in step 4 above) $n = ct/(2x)$, the voltage at time t is $V[1-e^{\{-ctZ/(xR)\}}]$.
10. The term in the exponent above, $cZ/x = 1/C$, where C is capacitance of the pair of wires, so we arrive at the standard result for a charging capacitor: $V[1-e^{\{-t/(RC)\}}]$.

Hence Catt, Davidson and Walton discovered the correct mechanism of electricity, proving that both 'static' and current are continuous 300,000km/s electromagnetic energy flows and showing that the traditional exponential charging formula for a capacitor is merely an approximation to the numerous small steps of bouncing 300,000km/s TEM wave energy which actually occur in the real physical process.

All 'Static' Charge is Oscillating 300,000km/s Standing Waves of Electromagnetic Energy

1. " Energy can only enter a capacitor at the speed of light."
2. "Once inside, there is no mechanism for the energy current to slow down below the speed of light."
3. "The steady electrostatically charged capacitor is indistinguishable from the reciprocating, dynamic model."
4. "The dynamic model is necessary to explain the new feature to be explained, the charging and discharging of a capacitor and serves all the purposes previously served by the steady, static model."

(I. Catt, Electromagnetism 1, Westfields Press, St. Albans, 1994, p 5).

In addition to this proof that the capacitor is a transmission line, the same thing was done for the inductor, treating it as square-shape for simplicity of calculation, with a lot of maths solved by a computer program by Ivor Catt and Michael S. Gibson. The basic concept is a bit like the charging capacitor, but there is cross talk between the adjacent windings of the inductor coil so that: "The inductor is a time-delay and energy trap. A voltage step enters and travels back and forth through the device, with gradual trapping of energy inside." The computer iteration solution gave a lot of small steps which shows that the correct (experimentally known) exponential induction curve is just an approximation to the c speed energy flow physical mechanism and was the proof that was published by Catt and Gibson in Proc. IEEE, vol. 75 (1987), p 849.

Ivor Catt also did the analysis for a simple oscillator circuit, containing a capacitor and inductor. Traditionally, the circuit is analysed by equating the potential (voltage) across the capacitor with that across the inductor: $v = (1/C)\int i\,dt \quad -L\,di/dt$ where C is capacitance and L is inductance. (These terms come from Maxwell's "displacement current" formula for a capacitor, i = C.dv/dt, and the Faraday equation for self-inductance by a coil of wire or inductor, v = -L.di/dt.) Differentiating gives an accelerating current equation, d2i/dt2 = -i/(LC). This is then solved as a case of simple harmonic motion, giving the sine wave voltage variation curve. sin (ωt), where ω2 = 1/(LC).

The problem with this traditional analysis is that, as Catt states, it: "assumes that when current is switched into the inductor, it appears instantaneously at all points in the inductor; the use of the single, lumped quantity L implies this. Similarly, it is assumed that the electric charge density at all points in the capacitor is the same… Work on high-speed logic systems led to a reappraisal of the conventional analysis." Ivor Catt's reappraisal of the oscillator circuit on the basis of real c speed energy flow, shows that the conventional sine wave solution is only an approximation to the reality, which is a large series of small steps due to c speed energy reflections in the circuit, in which the capacitor behaves as an open-circuit transmission line, while the inductor behaves as a short-circuited transmission line. Catt showed that the underlying mechanism is that the bigger the values of the capacitor or inductor, the smaller is each bouncing pulse of current between the capacitor and inductor, so more time elapses while the capacitor charges and discharges, thereby reducing the 'resonant frequency' of the circuit. Catt published the full mathematical proof in Proc. IEEE, vol. 71 (1983), p 772.

Experimental Proof from the Discharge of a Charged Cable into an Oscilloscope:

"A one metre section of 50Ω coaxial cable was charged up to a steady 10 volts via a 1 MΩ resistor, then suddenly discharged into a long piece of coax. A 5–volt pulse 2 metres wide was found to travel off at the speed of light for the dielectric. The voltage was half of what one would expect. It appears that after the switch was closed, some energy must have started off to the left, away from the now closed switch; bounced off the open circuit, and then returned all the way back to the switch and beyond."

"This paradox is understandable if one postulates that a steady charged capacitor is not steady at all; it contains energy, half of it travelling to the right at the speed of light, and the other half travelling to the left at the speed of light. Now it becomes obvious that when the switches are closed, the rightwards-travelling energy will exit first, immediately followed by the leftwards-travelling energy after it has bounced off the open circuit. Any apparently steady field is a combination of two energy currents travelling in opposite directions at the speed of light."

(I. Catt, Electromagnetism 1, Westfields Press, St. Albans, 1994, pp 13-14, condensed here.)

The Nature of the Electron as Derived from Catt's Results

The above experimental proof, conducted by Ivor Catt when working out the theory of mutual inductance (cross-talk) in computer circuits while at Motorola, Phoenix, in the 1960s, leads to the question of what happens to the magnetic fields from each opposing component of the c speed energy oscillating in the capacitor plates. The answer is that the magnetic fields are vectors which curl in one direction around the direction of the energy flows and since there is equal energy flow in each possible direction in 'static' electricity, the magnetic fields from each equal and opposite energy flow cancel each other out exactly, while the scalar electric fields simply add up.

It is interesting to consider what we mean by 'cancel out'. Do the two components of the magnetic field magically dematerialise energy by disappearing (thereby breaking the law of conservation of energy)? Or is the cancellation just a superposition of fields that cannot be measured by a compass needle for the reason that the compass needle is equally pulled in two opposite directions?

The answer can be found by calculating the total electric energy of a capacitor, and seeing whether this is the complete energy, or whether the total input energy shows that there is also an unobserved magnetic field present in all 'static' electric charge. The capacitance of a pair of wires is C = Q/V, where Q is electric charge on either conductor (each conductor having equal and opposite charge), and V is the potential difference (voltage) between the charged wires. The electric energy stored in a capacitor is E = (1/2)CV2, whereas the magnetic energy is E = (1/2)LI2, where L is the self-inductance of a 2-wire power cable.

[Since electromagnetic energy in a capacitor has half its energy in magnetic energy and half in electric field, $E = (1/2)CV^2 = (1/2)LI^2$, so $CV^2 = LI^2$, which upon employing Ohm's law as Z = V/I proves that $Z = (L/C)^{1/2}$, and $L = CZ^2$. These very useful results also apply to a transmission line since "a capacitor is a transmission line".]

The problem is that when we measure the energy going into the capacitor, we only usually measure the electric energy, not both electric and magnetic energy. even though every wire carrying a new energy flow has a measurable corresponding magnetic field around it. If we measure the electric plus magnetic energy supplied to the capacitor, it is $E = CV^2$, exactly double the electric field energy in the charged capacitor! Hence, half the energy in the capacitor must be present in unobservable magnetic fields with opposing curls from each equal and opposite 300,000km/s energy flow.

This factor of (1/2) difference also occurs when comparing the equation for kinetic energy, $E = (1/2)mv^2$, with Einstein's total energy equation for mass, $E = mc^2$. This analogy between electromagnetic energy in capacitors and energy in general physics is not a coincidence. By reduction of the previous capacitor situation down to a unit charge, we see that every apparently 'static' charge in the universe is, in effect, a charged capacitor plate with electromagnetic energy oscillating in all directions at speed c. From this, we see that the individual electron is, as Catt's experiment proves, "a standing wave of energy" (Catt, private correspondence). Furthermore, Catt in a January 1986 *Wireless World* article points out that a standing wave (sine wave) is a "camouflaged circle".

From this, I argue the nature of an electron using Catt's findings: an electron, as a unit charge, is a pulse of pure electromagnetic energy going around in a tiny circle (due to the inverse-square nature of gravity becoming very great on a tiny distance scale), so the electromagnetic energy is bent into a circular orbit due to its own mass, $m = E/c^2$ (from $E = mc^2$). Remember, light has no 'rest mass' because light is never at rest, but light does have transit mass. We thus find that the electron is a spinning electromagnetic 'black hole' of radius $R = 2Gm/c^2 = 2GE/c^4$. Since the effective gravity of a loop can be calculated on the basis that the entire mass of the loop is located in its centre. See Newton's Principia for an ingenious geometric proof of this (Newton proved that the gravity of the Earth can be calculated correctly by treating the mass as all being located at the centre).

This model of the electron has a spherically symmetric electric field at large distances compared to the electron radius R, since the electric field lines are scalars radiating outwards equally in all directions at right angles to the loop at each point on the loop, but it has an asymmetric magnetic field due to the fact that the magnetic field loops around each point on the electron loop, creating a toroid or ring doughnut-shaped magnetic field which at long distances is a dipole magnet, hence the known magnetic moment of the electron. The spinning of the electron ring at speed c explains the spin of the electron as utilised in quantum mechanics to explain the anomalous Zeeman effect (spectral line splitting when the emitting atoms are in a magnetic field). The reason why most atoms are non-magnetic is the Pauli exclusion principle, which forces every electron in the atom's electron shells to have an opposite spin compared to its neighbours. This results in the magnetic fields normally cancelling each other in the sense of producing an unobservable net magnetic field, although orbital variations in the electron shells orbitals of some elements do produce a slight net magnetic field due to the asymmetry of a small proportion of electrons in the material. This effect produces our magnets.

Problems in original *Wireless World* presentation

The lack of application of Catt, Davidson and Walton's work from electronics to general science (including derivation of Maxwell's equations, quantum mechanics, fundamental particle physics, relativity, mechanisms of fundamental forces and their inter-relationships, etc.), led them into a wilderness of suppression - akin to the famed Aristarchus of Samos who discovered the solar system theory in Ancient Greece, but was ridiculed and suppressed for nearly two thousand years until the theory was developed in detail by people who appreciated its value. It is important to note that some of the inferences of Catt, Davidson and Walton were misleading in matter of detail. For example, they disastrously asserted (December 1980) that there is "no electric current", while what they actually prove is that energy is normally propagated by transverse electromagnetic mechanism, not by electron drift, and that capacitors charge, store energy and discharge at the speed of light, with no mechanism for the stored energy to slow down below that speed therefore proving that apparently static electrons have in fact speed-of-light oscillating speed and are TEM waves. Although this is correct, and proves that static charge or normal electrical energy transfer does not comprise of 1 mm/s electron drift, it does not disprove the existence of electric currents in other circumstances, and electrons can be lost from a circuit due to electron emission and chemical reactions, so a drift current can in fact actually exist, although as Catt, Davidson and Walton assert, electric current is not the mechanism of energy transfer in electricity. This 1 mm/s electric current is to the 300,000 km/s TEM wave of electron spin and orbit at 90 degrees to each other, what the 1 m/s mild air breeze is to the 500 m/s air molecule bombardment speed.

The real issue is whether the concept of electric current, as the number of Coulombs of electric charge passing a point in a circuit each second, is really applicable to mains AC power supply, where the net drift of electrons is zero! Clearly this calculation and the whole concept in such a situation is in serious error and we should be careful not to apply the concept of 'electric current' or its calculation in Coulombs/second to mains AC electricity, since applying such a scalar equation to a vector situation where the resultant is zero will evidently give a completely false answer. What we must do instead is to refer to mains AC as 'electric power' not 'electric current', and measure the electric power in Watts (Joules/second of energy). It is important that this is not obvious: it is an analogy to the situation in physics where 'weight' and 'mass' were not distinguished for centuries and even Cavendish, when first determining the mass of the earth, called his experiment "Weighing the Earth". Today, students are banned from doing this because the important distinction between weight (which is force) and mass (which is matter) is finally appreciated. We should therefore not belittle Catt, Davidson, and Walton for dismissing the 1 mm/s 'electric current' from situations where it is not applicable!

In regard to the original dismissal of "displacement current" by Catt, Davidson, and Walton, they failed to distinguish that what they were dismissing was Maxwell's physical interpretation of displacement current, not Maxwell's mathematical equation of it. Subsequently, Professor D.A. Bell, writing in the August 1979 issue of Wireless World, headed his article "No Radio Without Displacement Current", and showed that radio transmission involves the mathematical equation for current being equivalent to the rate of change of electric field (multiplied by the appropriate electromagnetic constant), i.e., so-called displacement current. The general problem with Catt, Davidson, and Walton's research presentation was the lack of careful restriction of their discoveries to the area in which they were proven to be valid. If they had carefully stated that they were only dismissing electric current where electrical energy flow in transmission lines and capacitors was concerned, they would have avoided producing confusion in their ignorant readers and would have avoided giving the scientific world an excuse to argue that their discoveries were incompatible with well-established facts such as electron motion in vacuum TV picture tubes which implies an electron drift current in the cathode supply wires due to electron loss.

Part 2, 'The Electronic Big Bang', will be published later.

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Keyboard input for PIC projects

For many PIC microcontroller based projects one of the design problems that needs to be resolved is how to input commands or set up information to a PIC program.

Wiring a few links to a spare port of the microcontroller that is read on reset, or a few switches that are scanned when the PIC software is running may be sufficient. However, a low cost alternative is to use a standard PC keyboard. These keyboards cost only a few pounds and it is an input device that we are all familiar with. As a bonus there are three LEDs that can be controlled by the PIC program to show program status.

Within the article all data generated by the keyboard is given in hexadecimal 'NN'h form to distinguish between data and key characters such as function key F1. The PIC keyboard software was written for the 16F877 microcontroller but should work with most PIC microcontrollers, however only the 16F87x and 16C74 family has the built in serial port used for testing.

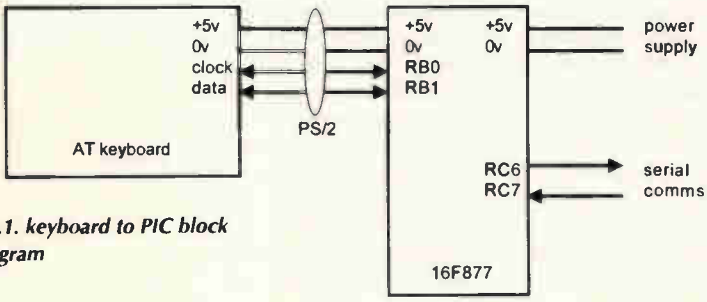


Fig.1. keyboard to PIC block diagram

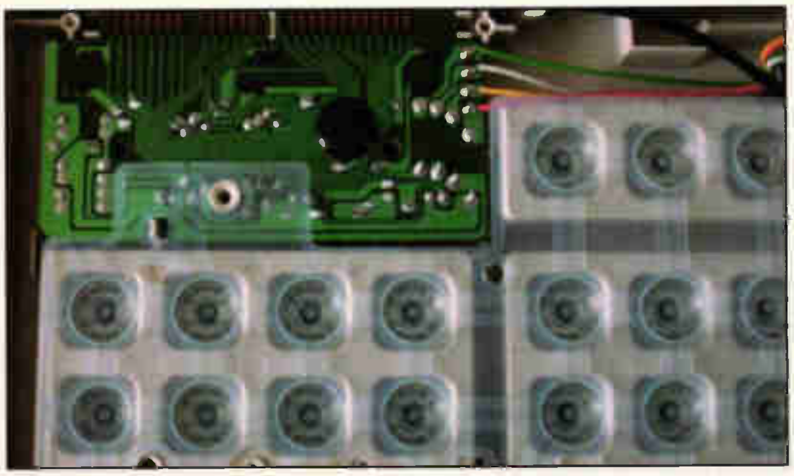


Fig. 2. Picture of keyboard viewed from underneath showing pcb and clear rubber mat.

AT keyboard

All current PCs are supplied with an AT style keyboard that have a PS/2 type connector. The keyboard was designed by IBM to be software configurable so that there is no need to manufacture different keyboards for different countries’. Only the key tops need changing between countries not the keyboard circuit. This software flexibility allows keys to be added. For example, recent addition of the Euro currency key (¤), and some keyboards now include dedicated internet browser keys.

Keyboard internals

Internally these low cost AT keyboards consist of the keys sitting on a moulded clear rubber mat, this mat is placed on top of two plastic sheets with conductive circuit tracks printed on them. This conductive pattern is a 22 by 6 matrix where pressing down a key will make the connection between the two layers at a unique intersection. The keyboard controller continually scans this matrix and determines which key position has been pressed and sends this data to the PC.

The keyboard controller board is a small single-sided printed circuit board consisting of a surface mount controller (hidden under black protective coating), a few discrete components, 18 wire links and the three keyboard LEDs. Figure 2 shows the keyboard viewed from underneath, for clarity the two conductive sheets have been removed but they connect to the edge connector at the top of the printed circuit board.

Power supply

The keyboard will work off a 5-volt supply, so the same supply can power both the PIC circuit and keyboard. However the electrical characteristics sticker on the base of my 'Ever Green Touch' keyboard (manufactured in China) states that it requires 5V at 170mA.

It is hard to imagine that a single customised controller chip requires all this power so I measured the current and found that it was only 8mA, and with all three LEDs on the keyboard consumed a total of 20mA. This is many times what the PIC microcontroller consumes, but if you are considering a battery powered application, then the current the keyboard requires will need to be taken into account.

Keyboard controller

The original keyboard design had a single chip microprocessor, but now a customised controller chip is used. This keyboard controller chip takes care of all keyboard matrix scanning, key de-bouncing and communications with the computer, and has an internal buffer if the keystroke data cannot be sent immediately. The PC motherboard decodes the data received from the keyboard via the PS/2 port using interrupt IRQ1.

The one thing that these keyboards do not generate is ASCII values. With a typical AT keyboard having more than 101 keys, a single byte could not store codes for all the individual keys, plus these keys along with shift, control, or alt, etc. Also for some functions there is no ASCII equivalent, for example 'page up', 'page down', 'insert', 'home', etc.

When the keyboard controller finds that a key is being pressed or released it will send this keystroke information, known as scan codes, to the PIC microcontroller. There are two different types of scan codes - make codes and break codes.

make code

A make code is sent whenever a key is pressed or held down. Each key, including 'shift', 'control' and 'alt', sends a specific code when pressed. Cursor control keys, 'delete', 'page up', 'page down', 'ins', 'home' and 'end', send extended make codes. The make code is preceded by 'E0'h to indicate an extended code. The only exception is the 'pause' key that starts with a unique 'E1'h byte.

break code

A break code is sent when a key is released. The break code is the make code preceded by 'F0'h byte. For extended keys the break code has an 'E0'h preceding the 'F0'h and make code value. The only exception is the 'pause' key as it does not have a break code and does not auto-repeat when held down.

key code

Every key is assigned its own unique code so that the host computer processing the information from the keyboard can determine exactly what happened to which key simply by looking at the scan codes received. There is no direct relationship between the scan code generated by a particular key and the character printed on the key top.

The set of make and break codes for each key comprises a scan code set. There are three standard scan code sets - numbered 1, 2, and 3 - stored within the keyboard controller. Scan code set 1 is retained for compatibility for older IBM XT computers. Scan set 3 is very similar to the set 2 but the extended codes are different. Scan code set 2 is the default for all AT keyboards and all scan codes discussed here are from this set.

scan code

If, for example, you press 'shift' and 'A' then both keys will generate their own scan codes, the 'A' scan code value is not changed if a shift or control key is also pressed. Pressing the letter 'A' generates '1C'h make code and when released the break code is 'F0'h, '1C'h.

Pressing 'shift' and 'A' keys will generate the following scan codes :

The make code for the 'shift' key is sent '12'h.
The make code for the 'A' key is sent '1C'h.
The break code for the 'A' key is sent 'F0'h, '1C'h.
The break code for the 'shift' key is sent 'F0'h,'12'h.

Fig. 3. Summary of commands that can be sent to keyboard controller.

command	description
'ED'h (LEDs)	keyboard responds with ACK and waits for a data byte.
'EE'h (echo)	keyboard responds with echo code ('EE'h).
'F2'h (identity)	keyboard responds with ACK and two ID bytes ('83'h,'AB'h).
'F3'h (typematic)	changes delay and key auto-repeat rate.
'F4'h (enable)	clears keyboard buffer and starts scanning, returns ACK.
'F5'h (disable)	resets keyboard, disables key scanning, returns ACK.
'F0'h (scan code set)	responds with ACK, then waits for which scan code set to use.
'F0'h ('00'h)	responds with ACK, and sends scan code set in use.
'FF'h (reset)	reset keyboard and run power on test.

Fig. 4. Possible keyboard controller response codes.

command	description
'00'h (error)	keyboard buffer has overflowed.
'AA'h (result)	self test passed.
'EE'h (echo)	keyboard responds to 'EE'h echo command.
'FA'h (acknowledge)	command or data received correctly.
'FE'h (error)	improper command, or data not received correctly.

Fig. 5. 'FA'h command keyboard LED data byte.

data	num	caps	scroll
0	off	off	off
1	off	off	on
2	on	off	off
3	on	off	on
4	off	on	off
5	off	on	on
6	on	on	off
7	on	on	on

If the right shift was pressed then the make code is '59'h and break code is 'F0'h, '59'h.

By analysing these scan codes the PC software can determine which key was pressed. By looking at the shift keystroke the software can distinguish between upper and lower case.

Keyboard commands

The main purpose of the keyboard is to accept typed data and send this information to the host computer, however there are several commands that can be sent to the keyboard controller. **Figure 3** shows some of the more common keyboard commands. There are other commands that can be used to change make or break codes for individual keys, but the commands given here are the most useful. The possible keyboard response to these keyboard commands is given in **Fig. 4**.

Keyboard self test

When the keyboard is first powered up it runs a self-diagnostic test, this test primarily looks for keys that are 'stuck' down. All the LEDs on the keyboard will also briefly switch on and off as part of this self test. When the keyboard is plugged into a PC you may be forgiven for thinking that this was part of the PC start-up sequence as it happens around the same time as the PC is powering up and

Fig. 6. Auto repeat data byte

xDDRRRRR
where -
x - not used.
DD - repeat delay (00 = 250 millisec, 11 = 1 sec).
RRRRR - repeat rate (00000 = 30 cps, 11111 = 2 cps).

also running diagnostic tests.

After running the self-test the keyboard processor sends 'AA'h byte if everything is working correctly. If the keyboard processor finds a fault it will send 'FE'h byte. If the keyboard reports a fault then the PC BIOS will display 'Keyboard error or no keyboard present' followed by the less than useful message 'Press F1 to continue' (!).

'ED' keyboard LED command

The keyboard processor does not switch the 'Num Lock', 'Caps Lock', and 'Scroll Lock' LEDs whenever the appropriate key is pressed. Control of these LEDs is done by the host computer sending LED on/off commands to the keyboard processor. The keyboard LEDs and the corresponding keys are independent of each other.

To tell the keyboard which LED to turn on or off, send command 'ED'h and wait for the keyboard to respond with acknowledge byte ('FA'h). Then send the binary number '00000ABC' where the 'A' bit is the state of the 'Caps Lock' LED, 'B' is the state of the 'Num Lock' LED, and 'C' is the state of the 'Scroll Lock' LED. Logic '1' is LED on, '0' for LED off. The keyboard will then respond (again) with 'FA'h indicating that it has successfully received the information.

The most significant five bits in the byte containing the LED information must be zero. If any of those bits is set then the keyboard processor will respond with 'FE'h (error) and wait for a properly formatted byte. There are no mechanisms for asking the keyboard controller the status of these LEDs, if you are using the LEDs and need to know which are on or off then the PIC program will need to store this information.

'EE'h echo test

As the name suggests this command echoes back the command value. It can be used as a quick test to make sure that the keyboard is connected and working.

'F0' set scan code command

If you want to change to a different scan code set, send 'F0'h command byte to the keyboard. The keyboard processor will respond with 'FA'h (acknowledge). Then send '01'h, '02'h, or '03'h for scan code sets 1, 2, or 3. When the new scan code is received the keyboard will again reply with 'FA'h.

To find out which scan code set is currently being used by the keyboard send '00'h instead of a new scan code set number. The keyboard will then respond with scan code number '01'h, '02'h (default) or '03'h.

All the scan codes presented here are those actually generated by the keyboard. When the keyboard is plugged into the PC the BIOS may translate some of these scan codes for compatibility reasons. Consequently a PC program may report slightly different scan codes for some keys.

'F2'h device identity command

The keyboard will respond to this command with 'FA'h (acknowledge) followed by the keyboard device type numbers 'AB'h,'83'h. When the keyboard is plugged into a PC the computer needs to know what type of device is connected to which PS/2 port. Other PS/2 devices can also be connected, such as a PS/2 mouse, which will respond with ID number '00'h,'00'h.

'FF'h keyboard test command

If the keyboard is wired to the same 5-volt supply as the PIC, then it is possible that the self test result will appear before the PIC microcontroller has initialised, particularly if the PIC power up timer is enabled. If the keyboard is already powered then sending command byte 'FF'h will force the keyboard to reset and run the self-test. This command is acknowledged by the keyboard ('FA'h) before the self test is executed. Alternatively use the 'F2'h command to get the keyboard device id number.

Typematic

When you press and hold down a key on the keyboard that key becomes typematic. This means the keyboard will keep sending that key's make code until the key is released. The typematic delay is a short delay between the sending of the first and second make scan code. Typematic rate is how many characters per second will appear after this initial typematic delay. The typematic delay can range from 0.25 second to 1 second and the typematic rate can range from 2 characters per second (cps) to 30 cps.

'F3'h set keyboard repeat rate

These typematic values can be changed using the 'F3'h command (set auto repeat rate), send 'F3'h and the keyboard will respond with 'FA'h byte, then the keyboard waits for the data byte that specifies the auto-repeat delay and rate.

With the exception of the 'pause' key, all keys will auto repeat. The default delay is 500ms and the auto repeat

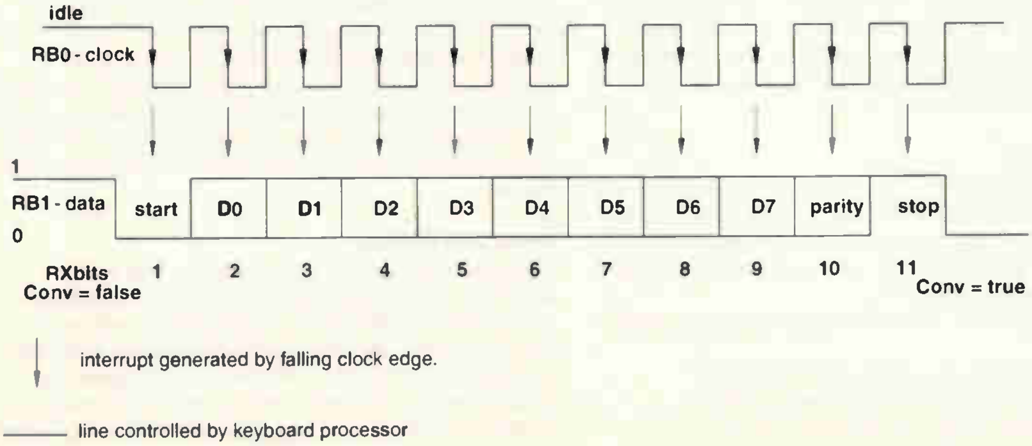


Fig. 7. Serial data sent from keyboard to PIC, data is read on the falling clock edge.

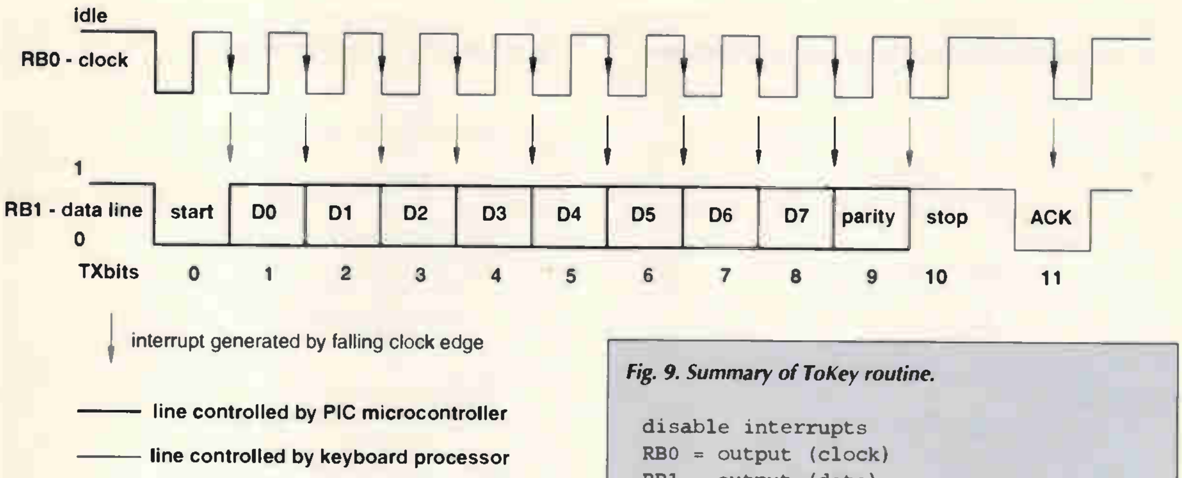


Fig. 8. Sending commands to the keyboard, data is set on the falling clock edge and read by the keyboard on the rising clock edge.

default is 10 characters per second. It is unlikely that these default values will need to be changed, but there may be circumstances where longer delays are needed to allow the PIC to process information between key presses.

Keyboard serial data

The AT keyboard transmission protocol is a serial format, with one line providing the data and the other line providing the clock. The data length is 11 bits with one start bit (logic 0), 8 data bits (lsb first), odd parity bit and a stop bit (logic 1). The clock rate is approximately 10 to 30kHz and varies from keyboard to keyboard.

The communications protocol is bi-directional, but as there are only two lines the handshaking between keyboard and PIC is more complicated. Unusually the keyboard generates the clock irrespective of the direction of data flow. The keyboard communications protocol is a strange mix with elements of both synchronous (separate data and clock) and asynchronous (start/stop bits) data transmission.

Both the keyboard clock and data lines are open collector outputs and require pull-up resistors to +5V. The PIC microcontroller has internal pull-up resistors on Port B which are enabled in the 'iniPIC' routine, if the keyboard is connected to another port then external pull-up resistors will be needed.

How the code works

The keyboard clock signal is connected to RB0 and used to generate an interrupt on the falling edge. The keyboard data line is connected to PIC port RB1. Running the iniPIC routine initialises the various register options, sets the timer prescaler and initialises the variables. In program keybd.asm, the serial communication port is initialised.

TimerOverflow is the T0IF flag of the 8-bit timer 0, this flag is set whenever the timer has counted up to 255 and starts counting again at 0. This flag is used to indicate a timeout and various counts are then automatically cleared. Without this, if the received data becomes corrupt and the RXbits count is wrong, then all following data will be decoded incorrectly. An alternative method if the timer is being used within the application program is to use the watchdog timer.

Variables TXbits and RXbits are counters indicating which bit in the serial keyboard data is being sent or received. The Conv flag is set whenever the data had been received from the keyboard. ReceiveDataFlag is the serial communication RCIF flag that is set whenever data is received from the PC via the serial port (keybd.asm only). This value is stored in variable TX and the ToKey routine is called.

Fig. 9. Summary of ToKey routine.

```
disable interrupts
RB0 = output (clock)
RB1 = output (data)

TXbits = 1
RB0 = input
RB1 = output

while TimerOverflow = false
// waiting for timer overflow
loop

parity = 1
enable interrupts
return
```

Receiving data from keyboard

The keyboard will transmit data to the PIC microcontroller as soon as a key is pressed if both the clock and data lines are high, as this indicates idle status. If the clock line is held low by the PIC microcontroller then the keyboard cannot send and the keyboard controller will buffer the keystroke data.

Variable RXbits keeps track of which bit is being received, as RXbits is incremented on each interrupt. Variable keywork stores the bit pattern of the data received from the keyboard. This is achieved by setting the carry flag according to the logic status of the data at port RB1, then using the rotate right PIC instruction to shift the carry bit

Fig. 10. Summary of main program loop for keybd.asm.

```
call iniPIC
loop
  if conv = true then
    call FromKey
  if TimerOverflow = true then
  begin
    if TXbits = 0 then
    begin // not sending data
      RXbits = 0
      Keydata = 0
      TimerOverflow = false
    end
  end
; serial communications
  if ReceiveDataFlag = true then
  begin
    TX = ReceivedData
    call ToKey
  end
goto loop
```

Fig. 11. Summary of main program loop for keybd1.asm.

```
call iniPIC
loop
  if conv = true then
  begin
    if keydata = ‘A’ then
    begin
      send LED command (‘ED’h)
      wait for ack (‘FA’h)
      send LED on (b‘00000111’)
    end
    if keydata = ‘B’ then
    begin
      send LED command (‘ED’h)
      wait for ack (‘FA’h)
      send LED off (b‘00000000’)
    end
  end
  if TimerOverflow = true then
  begin
    if TXbits = 0 then
    begin // not sending data
      RXbits = 0
      Keydata = 0
      TimerOverflow = false
    end
  end
goto loop
```

Fig. 12. summary of interrupt routine.

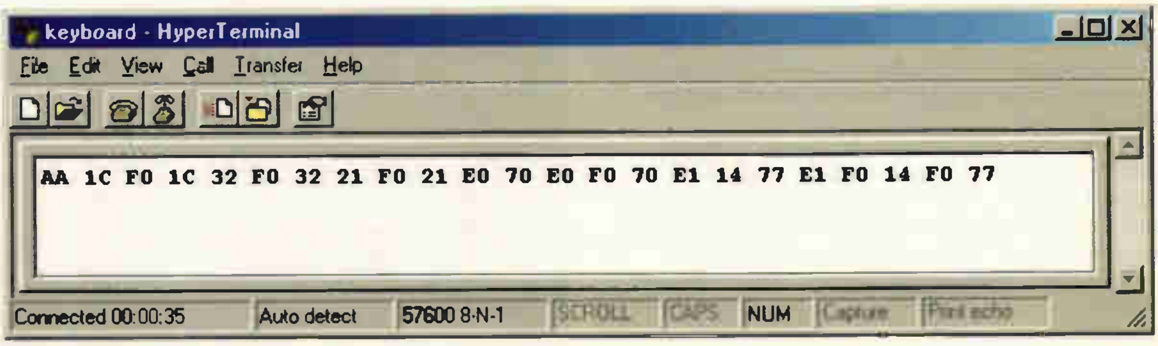
```
if TXbits > 0 then
begin
  if TXbits < 9 then
  begin
    if TX[TXbits] = true then
    begin
      RB1 = ‘1’  // output
      invert parity bit
    end
    else
    begin
      RB1 = ‘0’  // output
    end
  end
  if TXbits = 9 then
    output parity
  if TXbits = 10 then
  begin
    make RB1 an input
    RB1 = ‘1’  // stop bit
  end
  TXbits = TXbits +1
  if TXbits = 12 then
    TXbits = 0
end
else
begin
      RXbits = RXbits + 1
      if RXbits = 11 then
      begin
     keydata = keywork
     Conv = true
     RXbits = 0
     keywork = 0
      end
      else
      begin
             if RXbits = 10 then
       exit  // do nothing
  end
  else
  begin
    if RB1 = true then
      keywork = keywork + ‘1’
    else
      keywork = keywork + ‘0’
  end
end
timer0 = 0 ; clear timer 0
```

into the keywork variable. If RXbits = 10 this indicates the PIC is processing the parity bit, however this bit is ignored by the PIC program. On receiving RXbit = 11 (stop bit) the Conv flag is set indicating the end of data. Setting this flag causes the routine FromKey to be called from the main program loop. FromKey routine clears the Conv (convert) flag and sends the received keyboard data (contained in variable char) to the PrntHex (print hex) routine in the keydb.asm code.

This PrntHex routine converts the binary data into the ASCII suitable for display. Adding 48 to a binary decimal number converts that number to its ASCII text equivalent, if the number is greater than 9 then adding 55 will convert the hexadecimal number into an ASCII character. The PrntHex routine then calls the SendPC routine. This routine waits for the TXIF flag to be set, this indicates that the serial communications TXREG (transmitter register) is empty. TXREG register is loaded with the char data and this data is automatically transmitted via the serial port to the PC. These routines are not required in keybd1.asm.

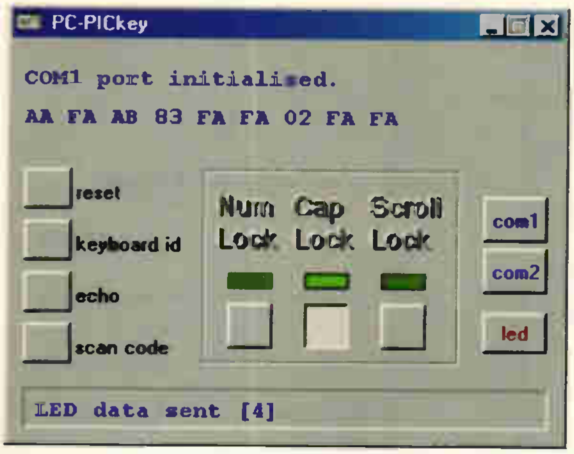
Sending data to the keyboard

When the PIC microcontroller needs to send data to the keyboard, the routine ToKey is called. ToKey sets the clock



```
AA 1C F0 1C 32 F0 32 21 F0 21 E0 70 E0 F0 70 E1 14 77 E1 F0 14 F0 77
```

Fig. 13. HyperTerminal screen showing the scan codes when A, B, C, insert, and pause keys are pressed on the keyboard.



```
COM1 port initialised.
AA FA AB 83 FA FA 02 FA FA

LED data sent [4]
```

Fig. 14. Windows PC screen showing various command options and response received from the keyboard.

line low for 60 milliseconds using timer 0. Bringing the clock line low prevents the keyboard from transmitting data. While the data line is held low the clock line is set to input and the keyboard will start generating a clock signal.

To make a port pin an output a '0' is sent to the TRISB (data direction register), a '1' sets that relevant port pin to an input. Data to be transmitted is output on the clock interrupt and read by the keyboard on the rising clock edge.

PIC software

Sending the scan codes to the PC is a useful demonstration (and functional test) of the keyboard to PIC connection. It allows specific keyboard scan codes to be verified but it is of very limited application.

The main function of this software is to use the keyboard as an input device to a PIC microcontroller. Rather than send the scan code to the PC, the scan value should be checked for various scan codes and appropriate data values modified within the PIC application program.

Assembler listing keybd1.asm shows a simple method of reading the keyboard scan codes and if specific keys are pressed, then the keyboard LEDs are turned on or off. The program looks for the letter 'A' (scan code '1C'h), when this is pressed all the LEDs are switched on (variable led determines which LEDs are switched on). When the letter 'B' is pressed (scan code '32'h) all the LEDs are switched off. All other key presses are ignored. These keyboard keys and which LEDs are activated can be changed, or values changed when specific keys are pressed.

Testing the interface

When the PIC is programmed with the keybd.asm code any

Fig.15. Keyboard alpha numeric scan codes.

key	make	break
A	'1C'h	'F0'h, '1C'h
B	'32'h	'F0'h, '32'h
C	'21'h	'F0'h, '21'h
D	'23'h	'F0'h, '23'h
E	'24'h	'F0'h, '24'h
F	'2B'h	'F0'h, '2B'h
G	'34'h	'F0'h, '34'h
H	'33'h	'F0'h, '33'h
I	'43'h	'F0'h, '43'h
J	'3B'h	'F0'h, '3B'h
K	'42'h	'F0'h, '42'h
L	'4B'h	'F0'h, '4B'h
M	'3A'h	'F0'h, '3A'h
N	'31'h	'F0'h, '31'h
O	'44'h	'F0'h, '44'h
P	'4D'h	'F0'h, '4D'h
Q	'15'h	'F0'h, '15'h
R	'2D'h	'F0'h, '2D'h
S	'1B'h	'F0'h, '1B'h
T	'2C'h	'F0'h, '2C'h
U	'3C'h	'F0'h, '3C'h
V	'2A'h	'F0'h, '2A'h
W	'1D'h	'F0'h, '1D'h
X	'22'h	'F0'h, '22'h
Y	'35'h	'F0'h, '35'h
Z	'1A'h	'F0'h, '1A'h
`	'0E'h	'F0'h, '0E'h
1	'16'h	'F0'h, '16'h
2	'1E'h	'F0'h, '1E'h
3	'26'h	'F0'h, '26'h
4	'25'h	'F0'h, '25'h
5	'2E'h	'F0'h, '2E'h
6	'36'h	'F0'h, '36'h
7	'3D'h	'F0'h, '3D'h
8	'3E'h	'F0'h, '3E'h
9	'46'h	'F0'h, '46'h
0	'45'h	'F0'h, '45'h

Fig. 16. Keyboard scan codes.

key	make	break
Esc	'76'h	'F0'h, '76'h
-	'4E'h	'F0'h, '4E'h
=	'55'h	'F0'h, '55'h
back space	'66'h	'F0'h, '66'h
[	'54'h	'F0'h, '54'h
]	'5B'h	'F0'h, '5B'h
;	'4C'h	'F0'h, '4C'h
@	'52'h	'F0'h, '52'h
#	'5D'h	'F0'h, '5D'h
enter	'5A'h	'F0'h, '5A'h
,	'41'h	'F0'h, '41'h
.	'49'h	'F0'h, '49'h
/	'4A'h	'F0'h, '4A'h
tab	'0D'h	'F0'h, '0D'h
Caps Lock	'58'h	'F0'h, '58'h
left shift	'12'h	'F0'h, '12'h
left control	'14'h	'F0'h, '14'h
left windows	'E0'h, '12'h, 'E0'h, '1F	'E0'h, 'F0'h, '1F'h, 'E0'h, 'F0'h,'12'h
left alt	'11'h	'F0'h, '11'h
space	'29'h	'F0'h, '29'h
alt gr	'E0'h, '11'h	'E0'h, 'F0'h, '11'h
right windows	'E0'h, '12'h, 'E0'h, '27'h	'E0'h, 'F0'h, '27'h, 'E0'h, 'F0'h,'12'h
right control	'E0'h, '12'h, 'E0'h, '2F'h	'E0'h, 'F0'h, '2F'h, 'E0'h, 'F0'h,'12'h
right shift	'59'h	'F0'h, '59'h
Print Screen	'E0'h, '12'h, 'E0'h, '7C'h	'E0'h, 'F0'h, '7C'h, 'E0'h, 'F0'h, '12'h
Scroll Lock	'7E'h	'F0'h, '7E'h
Pause	'E1'h, '14'h, '77'h, 'E1'h, 'F0'h, '14'h, 'F0'h, '77'h	none
Insert	'E0'h, '70'h	'E0'h, 'F0'h, '70'h
Home	'E0'h, '6C'h	'E0'h, 'F0'h, '6C'h
Page Up	'E0'h, '7D'h	'E0'h, 'F0'h, '7D'h
Delete	'E0'h, '71'h	'E0'h, 'F0'h, '71'h
End	'E0'h, '69'h	'E0'h, 'F0'h, '69'h
Page Down	'E0'h, '7A'h	'E0'h, 'F0'h, '7A'h
Up arrow	'E0'h, '75'h	'E0'h, 'F0'h, '75'h
Left arrow	'E0'h, '6B'h	'E0'h, 'F0'h, '6B'h
Down arrow	'E0'h, '72'h	'E0'h, 'F0'h, '72'h
Right arrow	'E0'h, '74'h	'E0'h, 'F0'h, '74'h

Fig. 17. Keyboard function key scan codes.

key	make	break
F1	'05'h	'F0'h, '05'h
F2	'06'h	'F0'h, '06'h
F3	'04'h	'F0'h, '04'h
F4	'0C'h	'F0'h, '0C'h
F5	'03'h	'F0'h, '03'h
F6	'0B'h	'F0'h, '0B'h
F7	'83'h	'F0'h, '83'h
F8	'0A'h	'F0'h, '0A'h
F9	'01'h	'F0'h, '01'h
F10	'09'h	'F0'h, '09'h
F11	'78'h	'F0'h, '78'h
F12	'07'h	'F0'h, '07'h

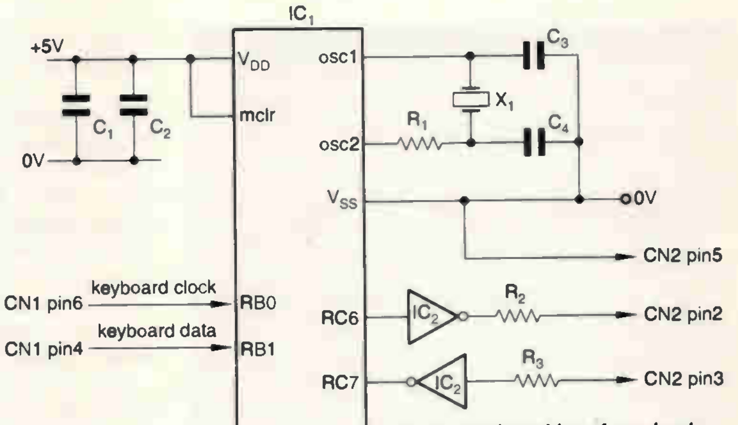


Fig. 19. Keyboard interface circuit diagram.

Fig. 18. Keyboard key pad scan codes.

key	make	break
Num Lock	'77'h	'F0'h, '77'h
/	'E0'h,'4A'h	'E0'h, 'F0'h, '4A'h
*	'7C'h	'F0'h, '7C'h
-	'7B'h	'F0'h, '7B'h
+	'79'h	'F0'h, '79'h
Enter	'E0'h,'5A'h	'E0'h, 'F0'h, '5A'h
.	'71'h	'F0'h, '71'h
0	'70'h	'F0'h, '70'h
1	'69'h	'F0'h, '69'h
2	'72'h	'F0'h, '72'h
3	'7A'h	'F0'h, '7A'h
4	'6B'h	'F0'h, '6B'h
5	'73'h	'F0'h, '73'h
6	'74'h	'F0'h, '74'h
7	'6C'h	'F0'h, '6C'h
8	'75'h	'F0'h, '75'h
9	'7D'h	'F0'h, '7D'h

Fig. 20. Components required for keyboard interface.

IC1	PIC 16F877
IC2*	74LS14
C1	10mF
C2	1nF
C3, 4	15pF
R1, 2*, 3*	470W
X1	20MHz crystal
CN1	6 pin mini DIN (PS/2)
CN2*	9 pin 'D' serial data

* optional

make and break scan codes will be sent as ASCII characters to the PIC serial port. This requires the 74LS14 and two resistors to be fitted. A suitable three-wire serial cable to connect the PIC to the PC's serial port will need to be made.

The Windows Hilgraeve HyperTerminal (supplied with Windows) program can be used to view these keyboard generated scan codes as they are transmitted by the PIC software as text. The program properties should be set up as follows - direct to com, speed as 57600 baud, 8 bits, no parity, no flow control and one stop bit.

Figure 13 is a HyperTerminal screen showing the self test passed byte followed by the scan codes for letters A (make code = '1C'h, break code = 'F0'h, '1C'h), B (make code = '32'h', break code = 'F0'h, '32'h), C (make code = '21'h, break code = 'F0'h, '21'h).

Followed by the extended scan codes generated when pressing the insert key (make code = 'E0'h, '70'h, break code = 'E0'h, 'F0'h, '70'h) and eight byte extended code when the pause key was pressed (make code = 'E1'h, '14'h, '77'h, 'E1'h, ' F0'h, '14'h, 'F0'h, '77'h, no break code).

Figure 14 shows an interactive Windows program displaying the keyboard response to various commands sent to the keyboard from the PC via the serial communications port. The four buttons (reset, keyboard id, echo, and scan code) when pressed will send that particular command to the keyboard and the keyboard's responces can be seen. The three LEDs can be switched on or off and when the button marked 'LED' is pressed this command is sent to the keyboard and the appropriate LEDs should be lit on the keyboard.

Fig. 21. Power interface wiring list.

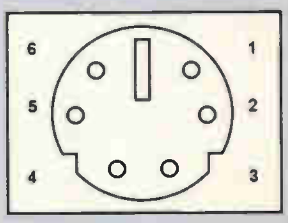
+5v	PIC pin 1 (mclr)
+5v	PIC pin 11
+5v	PIC pin 32
+5v	IC2 pin 14
+5v	CN1 pin 2
0v	PIC pin 12
0v	PIC pin 31
0V	IC2 pin 7
0v	CN1 pin 5

Fig. 22. '9' pin serial communications link.

R2 - CN2 pin 2 (tx)
R3 - CN2 pin 3 (rx)
0v - CN2 pin 5 (gnd)

Fig. 23. Wiring of the keyboard 6 pin mini-DIN PS/2 socket - viewed from the solder side.

pin 1 - no connection
pin 2 - +5v
pin 3 - no connection
pin 4 - PIC RB1 (data)
pin 5 - 0v
pin 6 - PIC RB0 (clock)



The 'AA'h is the result of the keyboard self test, 'FA'h is the command acknowledgement for the device identity request. The keyboard responds with device type 'AB'h and '83'h'. The two 'FA'h bytes are acknowledgement of the scan code query command and keyboard processor responds with scan set 2. The final two 'FA'h are for the LED command acknowledge. The program will also show any make or break codes if any keys are pressed on the keyboard. This Windows program (two versions are available, one for Windows 95/98/ME and the other for Windows XP) and the two PIC assembler source code programs (keybd.asm and keybd1.asm) will be available from EW – just email j.lowe@cumulusmedia.co.uk stating which one you'd like.

Construction

The PIC circuit can be built using strip board, the 20MHz crystal can should be connected to 0V for correct operation. The two inverters and series current limiting resistor are for the optional PC serial communications. They are not necessary for the keyboard connection. The PIC expects to interface to a serial line driver which in operation would invert the data, as a serial driver IC is not used then the data has to be inverted.

Care is needed when wiring the PS/2 socket – particularly for the power connection. Remember to observe the keyboard self test when the keyboard is plugged into the socket. All the LEDs should briefly flash if the wiring is correct. If not then disconnect the power supply and check the wiring. ■

Acknowledgements

My thanks to Andrew Thomas for help with the PIC programming.

PIC is a registered trademark of Microchip Technology Incorporated, USA.

Windows is a registered trademark of Microsoft Corporation.

Assembler listings

```
 ; keybd.asm
 ; PIC AT-keyboard reader
 ; Written by Roger Thomas
 ; MPASM 23 January 2002

  __config H'0F02'

 TMR0   EQU H'01' ; timer0
 STATUSEQU H'03' ; register
 C      EQU H'00' ; carry flag
 Z      EQU H'02' ; zero flag
 RP0    EQU H'05' ; page bit
 PORTB  EQU H'06' ; port B
 RB1    EQU H'01' ; keybd data
 INTCONEQU H'0B' ; register
 IRQ_RB0        EQU H'01' ;
interrupt
 T0IF   EQU H'02' ; timer0
 IRQ_ENEQU H'07' ; irq
 OPT_REG        EQU H'01' ;
register
 TRISB  EQU H'06' ; port B
 PIR1   EQU H'0C' ; peripheral
 RCIF   EQU H'05' ; serial comm
 RCSTA  EQU H'18' ; serial comm
 RCREG  EQU H'1A' ; serial comm
 TXSTA  EQU H'18' ; serial comm
 SPBRG  EQU H'19' ; serial comm
 TEMP   EQU H'20' ; irq handler
 IRQW   EQU H'2A' ; irq handler
 IRQS   EQU H'2B' ; irq handler
 IRQSTKEQU H'2C' ; irq handler
 CHAR   EQU H'2D' ; output
 RXBITSEQU H'2E' ; bit count
 TXBITSEQU H'2F' ; bit count
 KEYDATA        EQU H'30' ; keybd
calc
 KEYWORK        EQU H'31' ; keybd
calc
 TX     EQU H'32' ; transmit
 PARITYEQU H'33' ; keyboard
 FLAGS  EQU H'34'
 CONV   EQU H'00'

        ORG 0
        goto MAIN

      ORG 4   ; interrupt
      MOVWF   IRQW
      SWAPF   STATUS,W
      BCF     STATUS,RP0
      MOVWF   IRQS
      MOVF    TEMP,W
      MOVWF   IRQSTK
      CALL    IRQ
      MOVF    IRQSTK,W
      MOVWF   TEMP
      SWAPF   IRQS,W
      MOVWF   STATUS
      SWAPF   IRQW,F
      SWAPF   IRQW,W
      RETFIE

MAIN  CALL    INIPIC
LOOP  BTFSS   FLAGS,CONV
      GOTO    MAIN1
; if conv = true then
      CALL    FROMKEY
MAIN1 BTFSS   INTCON,T0IF
      GOTO    MAIN2
; if T0IF = true then
      MOVF    TXBITS,W
      SUBLW   D'00'
      BTFSS   STATUS,Z
      GOTO    MAIN2
; if TXBITS = 0 then
      CLRF    RXBITS
      CLRF    KEYDATA
      BCF     INTCON,T0IF

MAIN2 BTFSS   PIR1,RCIF
      GOTO    MAIN3
; if RCIF = true then
      MOVF    RCREG,W
      MOVWF   TX
      CALL    TOKEY
MAIN3 GOTO    LOOP

IRQ   MOVF    TXBITS,W
      BTFSC   STATUS,Z
      GOTO    IRQ6
; if TXBITS = true then
; begin
      MOVF    TXBITS,W
      SUBLW   D'09'
      BTFSS   STATUS,Z
      GOTO    IRQ1
      MOVF    PARITY,W
      MOVWF   TX
IRQ1  MOVF    TXBITS,W
      SUBLW   D'10'
      BTFSS   STATUS,Z
      GOTO    IRQ2
      MOVLW   D'255'
      BSF     STATUS,RP0
      MOVWF   TRISB
      BCF     STATUS,RP0
      GOTO    IRQ4
IRQ2  RRF     TX,F
      BTFSS   STATUS,C
      GOTO    IRQ3
      BSF     PORTB,RB1
      COMF    PARITY,F
      GOTO    IRQ4
IRQ3  BCF     PORTB,RB1
IRQ4  INCF    TXBITS,F
; end
      MOVF    TXBITS,W
      SUBLW   D'12'
      BTFSS   STATUS,Z
      GOTO    IRQ5
; if TXBITS = 12 then
      CLRF    TXBITS
IRQ5  GOTO    IRQEND
IRQ6  INCF    RXBITS,F
      MOVF    RXBITS,W
      SUBLW   D'11'
      BTFSS   STATUS,Z
      GOTO    IRQ7
; if RXbits = 11 then
; keydata = keywork
      MOVF    KEYWORK,W
      MOVWF   KEYDATA
      BSF     FLAGS,CONV
      CLRF    RXBITS
      CLRF    KEYWORK
; end
      GOTO    IRQEND
IRQ7  MOVF    RXBITS,W
      SUBLW   D'10'
      BTFSS   STATUS,Z
      GOTO    IRQ8
```

```
        GOTO    IRQEND
; if RXbits = 10 then
IRQ8    BTFSS   PORTB,RB1
        GOTO    IRQ9
; if RB1 = true then
        BSF     STATUS,C
        RRF     KEYWORK,F
        GOTO    IRQEND
IRQ9    BCF     STATUS,C
        RRF     KEYWORK,F
IRQENDBCF       INTCON,IRQ_RB0
        CLRF    TMR0
        RETURN

FROMKEY         BCF     FLAGS,CONV
        CALL    PRNTHEX
        MOVLW   D'32' ; space
        MOVWF   CHAR
        CALL    SENDPC
        RETURN

TOKEY   BCF     INTCON,IRQ_EN
        BTFSC   INTCON,IRQ_EN
        GOTO    TOKEY
        MOVLW   H'00'
        MOVWF   PORTB
        MOVLW   D'252'
        BSF     STATUS,RP0
        MOVWF   TRISB
        BCF     STATUS,RP0
        BCF     INTCON,T0IF
; while T0IF = false
WHILE1BTFSC     INTCON,T0IF
        GOTO    LOOP1
        GOTO    WHILE1
LOOP1   BCF     INTCON,T0IF
        MOVLW   H'01'
        MOVWF   TXBITS
        MOVLW   D'253'
        BSF     STATUS,RP0
        MOVWF   TRISB
        BCF     STATUS,RP0
        MOVLW   H'01'
        MOVWF   PARITY
; irq_rb0=false
        BCF     INTCON,IRQ_RB0
        BSF     INTCON,IRQ_EN
        RETURN

PRNTHEX         MOVF    KEYDATA,W
        MOVWF   CHAR
; char div 16
        BCF     STATUS,C
        RRF     CHAR,F
        BCF     STATUS,C
        RRF     CHAR,F
        BCF     STATUS,C
        RRF     CHAR,F
        BCF     STATUS,C
        RRF     CHAR,F
        MOVF    CHAR,W
        SUBLW   D'09'
        BTFSC   STATUS,C
        GOTO    PHEX1
```

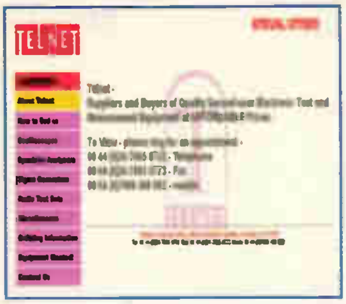
```
; if char > 9 then
; char=char+55
        MOVF    CHAR,W
        ADDLW   D'55'
        MOVWF   CHAR
        GOTO    PHEX2
; else
; char=char+48
PHEX1   MOVF    CHAR,W
        ADDLW   D'48'
        MOVWF   CHAR
PHEX2   CALL    SENDPC
; char=KEYDATA and 15
        MOVF    KEYDATA,W
        ANDLW   D'15'
        MOVWF   CHAR
        MOVF    CHAR,W
        SUBLW   D'09'
        BTFSC   STATUS,C
        GOTO    PHEX3
; if char > 9 then
; char=char+55
        MOVF    CHAR,W
        ADDLW   D'55'
        MOVWF   CHAR
        GOTO    PHEX4
; else
; char=char+48
PHEX3   MOVF    CHAR,W
        ADDLW   D'48'
        MOVWF   CHAR
PHEX4   CALL    SENDPC
        RETURN

SENDPCBTFSS     PIR1,4 ; TXIF
        GOTO    SENDPC
        MOVF    CHAR,W
        MOVWF   H'19'   ; TXREG
        RETURN

INIPICCLRF      TXBITS    ; =0
        CLRF    RXBITS    ; =0
        CLRF    KEYDATA   ; =0
        MOVLW   D'196'
        MOVWF   TMR0
        BCF     FLAGS,CONV
        MOVLW   H'03'
        BSF     STATUS,RP0
        MOVWF   TRISB
        BSF     TXSTA,2   ; BRGH
        BCF     STATUS,RP0
; SPBRG = 20  57600 baud
        MOVLW   H'14'
        BSF     STATUS,RP0
        MOVWF   SPBRG
        BCF     TXSTA,6   ; TX9
        BCF     STATUS,RP0
        BCF     RCSTA,6   ; RX9
        BSF     RCSTA,4   ; CREN
        BSF     STATUS,RP0
        BSF     TXSTA,5   ; TXEN
        BCF     TXSTA,4   ; SYNC
        BCF     STATUS,RP0
        BSF     RCSTA,7   ; SPEN
```

```
        BSF     STATUS,RP0
        BCF     OPT_REG,7 ; RBPU
        BCF     OPT_REG,6 ; INTEDG
        BCF     OPT_REG,5 ; T0CS
        BCF     OPT_REG,3 ; PSA
        BSF     OPT_REG,0 ; PS0
        BCF     OPT_REG,1 ; PS1
        BSF     OPT_REG,2 ; PS2
        BCF     STATUS,RP0
; enable RB0 interrupts
        BCF     INTCON,IRQ_RB0
        BSF     INTCON,4
        BSF     INTCON,IRQ_EN
        RETURN
        END
 ; keybd1.asm
; PIC AT-keyboard reader
; LED demo
; Written by Roger Thomas
; MPASM 23 January 2002

 __config H'0F02'

TMR0  EQU H'01' ; timer0
STATUSEQU H'03' ; register
C     EQU H'00' ; carry flag
Z     EQU H'02' ; zero flag
RP0   EQU H'05' ; page bit
PORTB EQU H'06' ; port B
RB1   EQU H'01' ; keybd data
INTCONEQU H'0B' ; register
IRQ_RB0       EQU H'01' ;
interrupt
T0IF  EQU H'02' ; timer0
IRQ_ENEQU H'07' ; irq
OPT_REG       EQU H'01' ;
register
TRISB EQU H'06' ; port B
TEMP  EQU H'20' ; irq handler
IRQW  EQU H'2A' ; irq handler
IRQS  EQU H'2B' ; irq handler
IRQSTKEQU H'2C' ; irq handler
RXBITSEQU H'2E' ; bit count
TXBITSEQU H'2F' ; bit count
KEYDATA       EQU H'30' ; keybd
calc
KEYWORK       EQU H'31' ; keybd
calc
TX    EQU H'32' ; transmit
PARITYEQU H'33' ; keyboard
FLAGS EQU H'34'
LEDS  EQU H'35' ; leds on
CONV  EQU H'00'
ACK   EQU H'01' ; 'FA'h

        ORG 0
        goto MAIN

        ORG 4   ; interrupt
        MOVWF   IRQW
        SWAPF   STATUS,W
        BCF     STATUS,RP0
        MOVWF   IRQS
        MOVF    TEMP,W
```

```
      MOVWF   IRQSTK
      CALL    IRQ
      MOVF    IRQSTK,W
      MOVWF   TEMP
      SWAPF   IRQS,W
      MOVWF   STATUS
      SWAPF   IRQW,F
      SWAPF   IRQW,W
      RETFIE

MAIN  CALL    INIPIC
LOOP  BTFSS   FLAGS,CONV
      GOTO    MAIN1
      BCF     FLAGS,CONV
      MOVF    KEYDATA,W
      SUBLW   H'1C'
      BTFSS   STATUS,Z
      GOTO    MAIN4
      MOVLW   H'ED'
      MOVWF   TX
      CALL    TOKEY
      BSF     FLAGS,ACK
      MOVLW   H'07'
      MOVWF   LEDS
      GOTO    MAIN1
MAIN4 BTFSS   FLAGS,ACK
      GOTO    MAIN5
      MOVF    KEYDATA,W
      SUBLW   H'FA'
      BTFSS   STATUS,Z
      GOTO    MAIN5
      MOVF    LEDS,W
      MOVWF   TX
      CALL    TOKEY
      BCF     FLAGS,ACK
      CLRF    LEDS
MAIN5 MOVF    KEYDATA,W
      SUBLW   H'32'
      BTFSS   STATUS,Z
      GOTO    MAIN1
      MOVLW   H'ED'
      MOVWF   TX
      CALL    TOKEY
      BSF     FLAGS,ACK
      CLRF    LEDS

MAIN1 BTFSS   INTCON,T0IF
      GOTO    LOOP
      MOVF    TXBITS,W
      SUBLW   D'00'
      BTFSS   STATUS,Z
      GOTO    LOOP
; if TXBITS = 0 then
      CLRF    RXBITS
      CLRF    KEYDATA
      BCF     INTCON,T0IF
      GOTO    LOOP

IRQ   MOVF    TXBITS,W
      BTFSC   STATUS,Z
      GOTO    IRQ6
; if TXBITS = true then
; begin
      MOVF    TXBITS,W
```

```
      SUBLW   D'09'
      BTFSS   STATUS,Z
      GOTO    IRQ1
      MOVF    PARITY,W
      MOVWF   TX
IRQ1  MOVF    TXBITS,W
      SUBLW   D'10'
      BTFSS   STATUS,Z
      GOTO    IRQ2
      MOVLW   D'255'
      BSF     STATUS,RP0
      MOVWF   TRISB
      BCF     STATUS,RP0
      GOTO    IRQ4
IRQ2  RRF     TX,F
      BTFSS   STATUS,C
      GOTO    IRQ3
      BSF     PORTB,RB1
      COMF    PARITY,F
      GOTO    IRQ4
IRQ3  BCF     PORTB,RB1
IRQ4  INCF    TXBITS,F
; end
      MOVF    TXBITS,W
      SUBLW   D'12'
      BTFSS   STATUS,Z
      GOTO    IRQ5
; if TXBITS = 12 then
      CLRF    TXBITS
IRQ5  GOTO    IRQEND
IRQ6  INCF    RXBITS,F
      MOVF    RXBITS,W
      SUBLW   D'11'
      BTFSS   STATUS,Z
      GOTO    IRQ7
; if RXbits = 11 then
; keydata = keywork
      MOVF    KEYWORK,W
      MOVWF   KEYDATA
      BSF     FLAGS,CONV
      CLRF    RXBITS
      CLRF    KEYWORK
; end
      GOTO    IRQEND
IRQ7  MOVF    RXBITS,W
      SUBLW   D'10'
      BTFSS   STATUS,Z
      GOTO    IRQ8
; if RXbits = 10 then
      GOTO    IRQEND
IRQ8  BTFSS   PORTB,RB1
      GOTO    IRQ9
; if RB1 = true then
      BSF     STATUS,C
      RRF     KEYWORK,F
      GOTO    IRQEND
IRQ9  BCF     STATUS,C
      RRF     KEYWORK,F
IRQENDBCF     INTCON,IRQ_RB0
      CLRF    TMR0
      RETURN

TOKEY BCF     INTCON,IRQ_EN
      BTFSC   INTCON,IRQ_EN
```

```
      GOTO    TOKEY
      MOVLW   H'00'
      MOVWF   PORTB
      MOVLW   D'252'
      BSF     STATUS,RP0
      MOVWF   TRISB
      BCF     STATUS,RP0
      BCF     INTCON,T0IF
; while T0IF = false
WHILE1BTFSC   INTCON,T0IF
      GOTO    LOOP1
      GOTO    WHILE1
LOOP1 BCF     INTCON,T0IF
      MOVLW   H'01'
      MOVWF   TXBITS
      MOVLW   D'253'
      BSF     STATUS,RP0
      MOVWF   TRISB
      BCF     STATUS,RP0
      MOVLW   H'01'
      MOVWF   PARITY
; irq_rb0=false
      BCF     INTCON,IRQ_RB0
      BSF     INTCON,IRQ_EN
      RETURN

INIPICCLRF    TXBITS      ; =0
      CLRF    RXBITS      ; =0
      CLRF    KEYDATA     ; =0
      MOVLW   D'196'
      MOVWF   TMR0
      BCF     FLAGS,CONV
      MOVLW   H'03'
      BSF     STATUS,RP0
      MOVWF   TRISB
      BCF     OPT_REG,7 ; RBPU
      BCF     OPT_REG,6 ; INTEDG
      BCF     OPT_REG,5 ; T0CS
      BCF     OPT_REG,3 ; PSA
      BSF     OPT_REG,0 ; PS0
      BCF     OPT_REG,1 ; PS1
      BSF     OPT_REG,2 ; PS2
      BCF     STATUS,RP0
; enable RB0 interrupts
      BCF     INTCON,IRQ_RB0
      BSF     INTCON,4
      BSF     INTCON,IRQ_EN
      RETURN
      END
```



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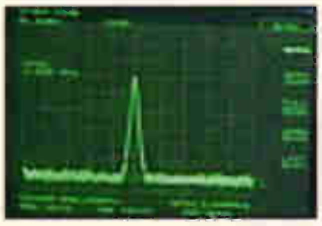

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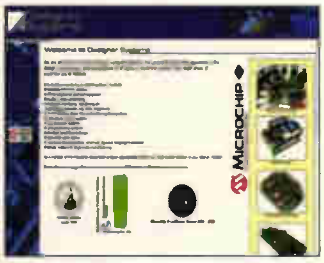

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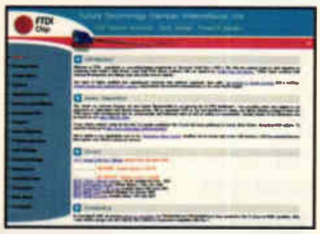

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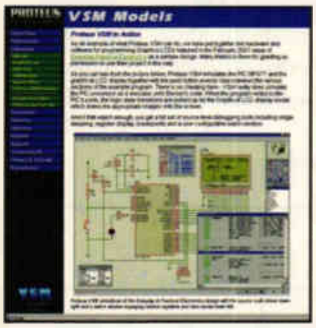

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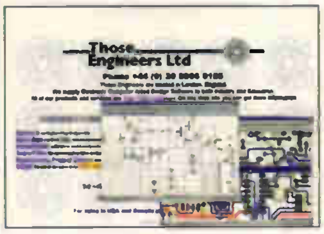

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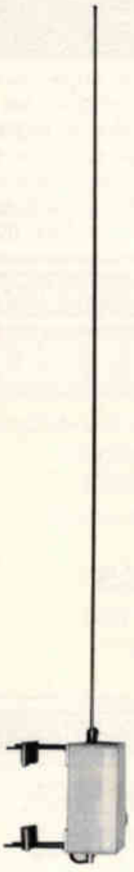

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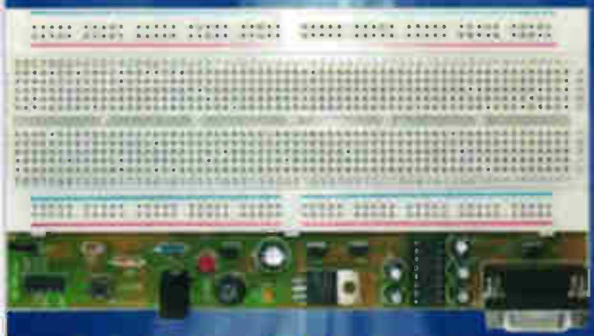


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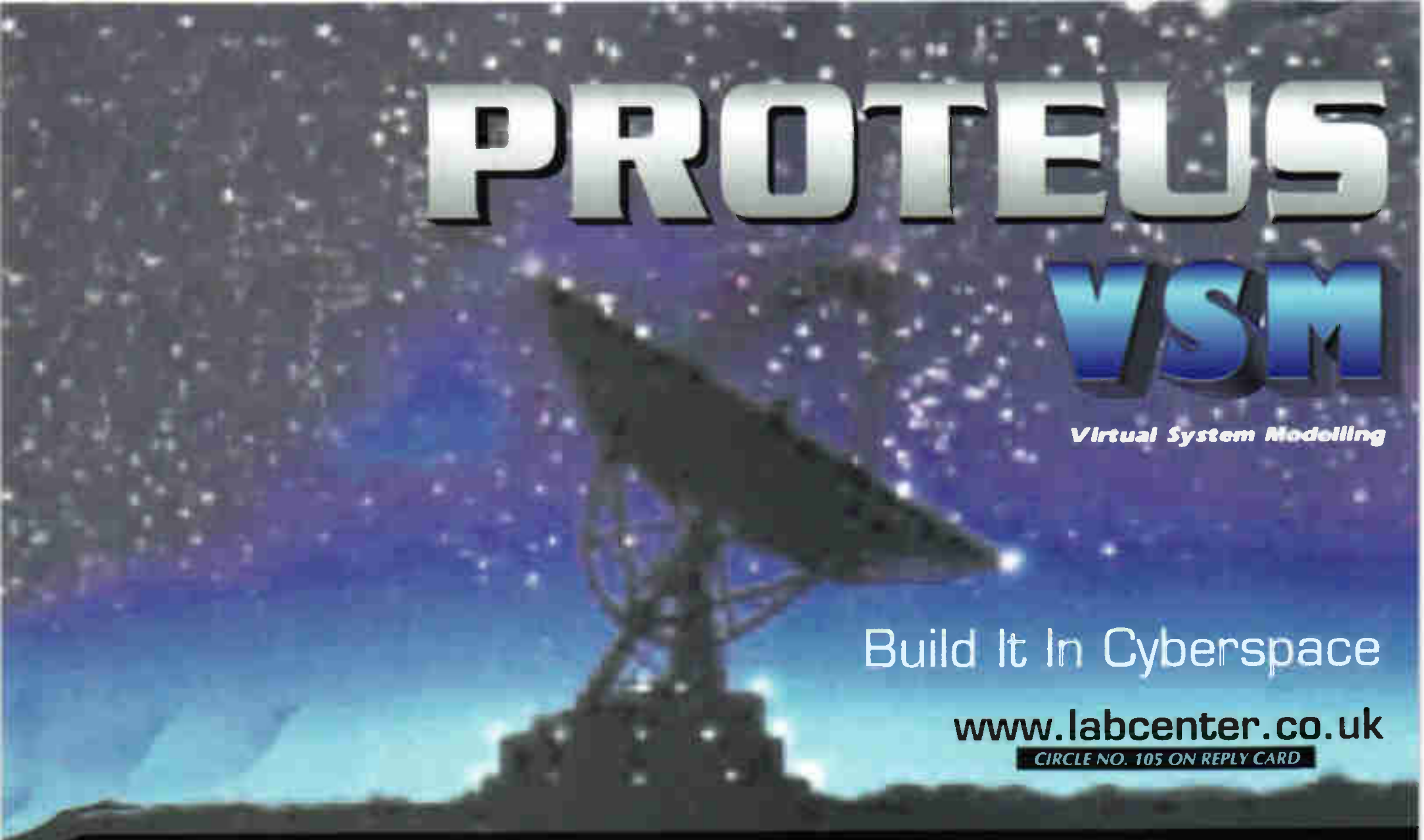

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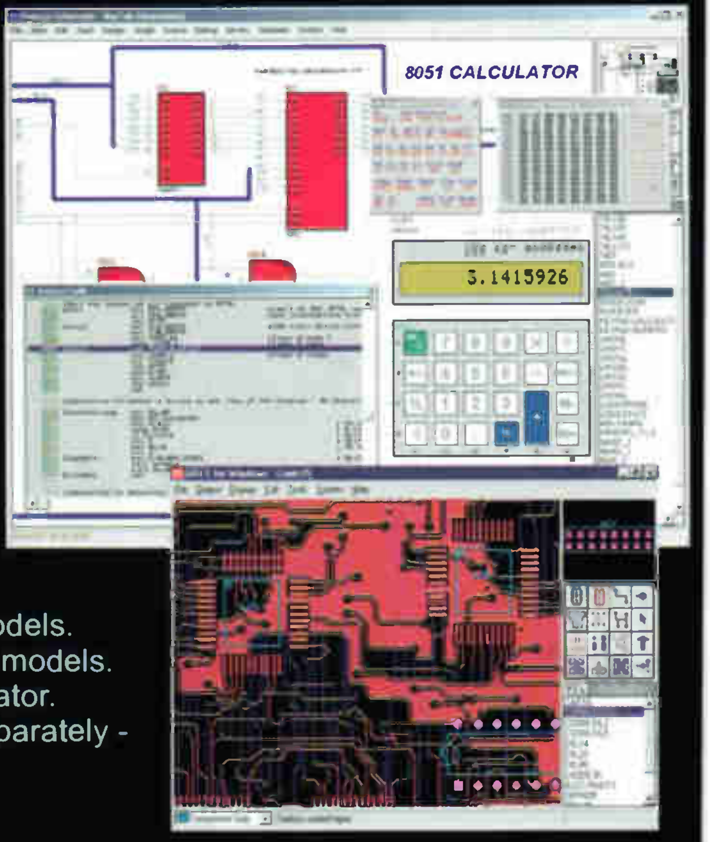

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