Five-chip logic analyser

Super-regen receiver

Removing noise

New logic design aid

400Hz power inverter

Image portrayal

TV history

DSP or controller?

Recruitment ads start on page 170
WiNRADIO now brings you a complete choice in computer controlled radio scanning and reception.

With either the internal or external versions, you can couple all the power of the latest Windows PCs (not just the fraction that you can squeeze down an RS232 connection) to the latest synthesised receiver design techniques, and you'll get the ultimate in wide range, all mode programmable radio reception.

New external WiNRADIO™ (WR1000e and WR1500e) provide complete comms systems connecting either via the basic RS232 - or with an optional PCMCIA adapter, for high speed control. Power from existing 12v supplies, or our optional NiMH rechargeable 12v battery pack.

If you still want the ultimate receiver-in-a-PC with full DSP, then you need the WR3000-DSP with its hardware for real-time recording, signal conditioning and decoding applications. (This is available as an ISA card only).

Use WiNRADIO scanning PC comms receiver systems for...

- Broadcast
- Media monitoring
- Professional & amateur radio
- Fo0. sg,
- Bh0i,
- 6.0
- L
- N°’
- VisiTune™ spectrum tuning display

Your choice of virtual front panel

The DSP applet provided with the WR3000 spectrum monitor ISA card (£995+VAT) allows continuous control of audio bandwidth and other signal conditioning functions

Model No WR-1000 WR-1500
Construction WR-1000i/WR-1500i - Internal full length ISA cards WR-1000e/WR-1500e - external RS232/PCMCIA (optional)
Frequency range 0.5-1300 MHz 0.15-1500 MHz
Modes AM,SSB/CW,FM-N,FM-W AM,LSB,USB,CW,FM-N,FM-W
Tuning step size 100 Hz (5 Hz BFO) 100 Hz (10 Hz for SSB and CW)
IF bandwidths 6 kHz (AM/SSB), 17 kHz (FM-N), 270 kHz (FM-W) 2.5 kHz(SSB/CW), 9 kHz (AM) 17 kHz (FM-N), 270 kHz (FM-W)
Receiver type PLL-based triple-conv. superhet PLL-based triple-conv. superhet
Scanning speed 10 ch/sec (AM), 50 ch/sec (FM) 10 ch/sec (AM), 50 ch/sec (FM)
Audio output on card 200mW 200mW
Max on one motherboard 8 cards 8 cards
Dynamic range 65 dB 70 dB
IF shift (passband tuning) no ±2 kHz
DSP in hardware no - use optional DS software no
IRQ required no no
Spectrum Scope yes yes
Visitune yes yes
Published software API yes yes
Internal ISA cards £289 inc vat £399 inc vat
PCMCIA adapter (external) £389 inc vat £449 inc vat
PPS NiMH 12v battery pack & charger: £79 with ‘e’ series unit, otherwise: £69 inc.

Digital Suite Software
1. WEFAX / HF Fax
2. Packet Radio for HF and VHF
3. Aircraft Addressing and Reporting System (ACARS)
4. Audio Oscilloscope, real time Spectrum Analyzer with calibration cursors
5. Squelch-controlled AF Recorder
6. DTMF, CTSS decode and analyse £81.05 inc VAT

For your free info pack and software emulation demo disk contact Broadercasting Communication Systems
http://www.broadercasting.com FREEPHONE: 0800 0746 263
email: info@broadercasting.co.uk Fax: 01245 287057
Unit B, Chelford Court, Robjohns Road, Widford Industrial Estate, Chelmsford, Essex CM1 3AG

E&OE WiNRADIO and Visitune are trademarks of WiNRADIO Communications
CIRCLE NO. 101 ON REPLY CARD
COMMENT
Copyright, and the right to copy

NEWS
- EMP bullet detects land mines
- C&W pips BT in broadband race
- £7m for extreme-uv litho
- UK flat panels for video
- Java chips
- Morphing dashboard
- Euro dumping damage

PLDS/LOGIC ANALYSER
In-system programmable devices and free software have made plds cheap – provided you have a pc. To illustrate their power, Colin Attenborough describes a five-chip logic analyser using the simplest pld.

LETTERS
50W from a 3.6W mains adaptor? Students’ lots
Digital audio far from perfect
Have you seen a microwave fuse?
Wideband fet amplifier
Windows commentary

HANSD ON INTERNET
Cyril Batemen reveals three clearing houses for data sheets and application notes – all accessible via the net, free of charge. And there’s design information for those interested in temperature measurement.

CIRCUIT IDEAS
- Chopper-stabilised bridge amplifier
- Set/reset and bistable flip-flops
- Simple linear sawtooth
- Lf signal rectifier
- Medium-power inverting driver
- Capacitance bridge

400HZ 1KW INVERTER
Paul Bennett’s three-phase power inverter uses high-frequency switching to avoid the bulky, expensive inductive components.

KNOW NOISE
Joe Carr looks at noise from the viewpoint of the receiver designer.

SUPER-REGEN OR SUPER-REPLACEMENT?
Performance in a receiver usually goes hand-in-hand with complexity.
Ian Hickman describes an exception.

NEW PRODUCTS
New product outlines, presented by Phil Darrington.

SPEAKERS’ CORNER
This month, John Watkinson looks into the basket – the chassis part of an electromagnetic loudspeaker.

IMAGE PORTRAYAL
Technologies for image portrayal in computer graphics, film and television were once very different, but digital electronics is causing them to converge, as John Watkinson explains.

DIGITAL VISIONS
Don McLean has new evidence to show that Baird’s television system was better than we were led to believe.

DSP VERSUS THE MICROCONTROLLER
DSPs at the bottom end of the market are finding themselves used in ever increasing applications, but how will they compete against the likes of Risc and microcontrollers? Steve Bush finds out.

How can the Internet help you solve your thermal management problems? Find out on page 109.

NEW LOGIC
David Warren-Smith’s rethink of Boolean algebra fills in the gaps, making it even more useful to digital designers.

March issue on sale 4 February
COVENTRY CV3 2SF.

Telnet, 8 Cavans Way, Binley Industrial Estate, Add carriage and VAT to all goods.

Telnet

8922 BGH G.S.M. Test

£4995

9(,)

CMTA94 GSM Radio Comms Analysers

£7500

CM15 54 Radio Comms Service monitor (0.4 to 1000MHz)

£6250

All equipment is used - with 30 days guarantee.

4000 MHz - 4 channels -

Teledyne 2467B

£8500

Wandel & Goltermann

PFJ-8 Error & jiter test set (£all options fitted)

£12500

PCM4 PCM Channel measurement set £POA

Hewlett Packard

8642A

High Performance R/F Synthesiser - 0.1 to 1050MHz

£8500

Textronix 2467B

400MHz - 4 channels - high writing speed oscilloscope

£8500

Oscilloscopes

Beckman 9020 - 20MHz - Dual channel

£1150

Hewlett Packard 54504A - 20MHz - Digitising

£1050

Hewlett Packard 54505A - 50MHz - Digitising

£1050

Hewlett Packard 54505B - 100MHz - Digitising

£1250

Hiashi V520/22V202V2010305755/55V550V5650

from £125

Hiashi 1054A - 0.1 to 10MHz - 4 channel

£7500

waveform 2520 - 20MHz - Dual channel D.S.O. (new)

£450

Kicoset COS 5100 - 100MHz - Dual channel

£650

Lecky 9545A - 20MHz/50120V D.S.O. 2 channel

£2250

Meguro MS1040A - 20MHz - Dual channel

£450

Philips 3205/5 - 20MHz - Dual channel

£450

Philips PM 3255 - 50MHz - Dual channel

£1250

Philips 3260A - 40MHz - D.S.O. channel

£1250

Panasonic VPS741A - 100MHz - Dual channel

£1750

Tektronix 460 - 50MHz - Dual channel

£395

Tektronix 465 - 100MHz - Dual channel

£395

Teletronics 4130 - 60MHz (with A.S. storage)

£350

Tektronix 470/473A - 200MHz/250MHz

from £450

Tektronix 486 - 100MHz - D.S.O.

£850

Tektronix 486 - 100MHz - D.S.O.

£1250

Tektronix 486 - 250MHz - Dual channel D.S.O.

£395

Tektronix 489 - 500MHz - Dual channel

£395

Tektronix 490 - 150MHz - Dual channel

£650

Tektronix 490 - 150MHz - Dual channel

£395

Tektronix 2484A - 100MHz/4 channel D.S.O.

£1250

Teletronics 2220A - 60MHz - 4 channel

£1250

Teletronics 2220A - 100MHz - 4 channel

£1250

Teletronics 2440 - 100MHz/500M (5 channel)

£395

Teletronics 2441A - 150MHz - 4 channel

£1250

Teletronics 2445 - 150MHz - 4 channel + DUM

£1250

Teletronics 2452A - 400MHz - 4 channel + DUM

£1250

Teletronics 7000 Series (500MHz to 500MHz)

£2000

Spectrum analysers

Ando AG-5210 - 10MHz

£8500

Anritsu PSA-5GA - 2 to 800MHz

£3250

Anritsu MS 6805B - 1.0GHz - 2GHz

£3250

Anritsu MS 6806B - 1.0GHz - 2GHz

£3250

Hewlett Packard 2051A - Dynamic Signal Analyser

£4750

Hewlett Packard 3507A - Dual channel dynamic signal analyser

£850

Hewlett Packard 2058A - 1 GHz - 10GHz

£650

Hewlett Packard 3518A - 200MHz to 4GHz

£3250

Hewlett Packard 8519A - 10 MHz to 50GHz with tracking generator, option 10

£650

Hewlett Packard 8515A - 1.0GHz - Network Analyser

£1995

Hewlett Packard 85130A - 2GHz - Network Analyser

£4950

Hewlett Packard 8753B - Network Analyser

£6,500

Quality second-user test & measurement equipment

Marconi

Radio Communications Test Sets

Tel: 01203 650 702

Fax: 01203 650 773

2955

£2250

2955A

£2500

2958 (TACS)

£2750

2960 (TACS + Band III)

£2750

2960A (TACS)

£2950

2955B

£3750

MICROPROCESSORS

Marconi

8530A Mainframe + 8539A Spec. An. (0.01 to 210GHz)

£3,750

Hewlett Packard 1927T Nightingale + 8529A Spec. An. (0.01 to 21GHz)

£2,250

IFR 7A900 - 10GHz - Portable

£2500

Megara - 8530 - 30GHz - Spec. Analyser

£1250

Megara - 8541 - 100GHz - Spec. Analyser

£1250

Tektronix 498P Spec. analyser prog. - 1GHz

£1250

Tektronix 468P - 10GHz to 1GHz

£4500

Wiltron 6408 - 10-2000MHz R/F Analyser

£2000

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

Telnet, 8 Cavans Way, Binley Industrial Estate, Coventry CV3 2SF.
Copyright, and the right to copy

A recent report in the Daily Telegraph said that the private viewer could be stopped from videoing programmes at home or be forced to pay a new tax on blank tapes under a directive being drawn up in Brussels to harmonise copyright laws across the European Union.

The Government was said to be "not happy" with plans to reduce the right of individuals to record programmes for personal use and does not want a return to the situation before 1990. In those dark days, video recorders were sold with dire warnings printed in their manuals: "The recording and playback of any material may require consent" and "the user must refer to the provisions of the Copyright Act 1956 and the Dramatic and Musical Performers Protection Act 1958" etc etc.

This was clearly a joke. The law was unenforceable and everyone knew it. Anyway, what was wrong recording a programme and watching it later - even if you skipped over the adverts? But it took a long time to come up with the words that would protect the livelihoods of performers and legalise the use of videos at home. Let's hope that we don't have to go back.

But there is a wider issue here; copyright laws are difficult to enforce.

There is always a sneaking suspicion amongst the general public that companies are not being "fair" and are trying to take too much. This engenders a culture where people have no qualms about copying software because they think that Bill Gates is rich enough already. Or, as another example, photocopying music without regarding it as stealing despite the clear printed warnings.

There are other instances where copyright is felt to be too tightly held. For example the British Standards Institution, which is a public service, does not allow any reproduction of its work even if it is just a quotation. Another example was the school in the North of England not being able to perform a musical because it happened to be in a London West End theatre at the time. This only adds to the feeling of unfairness.

They may have the law on their side, but companies find that litigation is expensive and risky. So the response has been to develop sophisticated copy protection mechanisms.

Programmes can search your hard drive to see if you qualify for the new version. Digital "fingerprints" can be put on to cds literally in the noise, using spread spectrum techniques, to enable authentication.

There are some clever virus-like software copy protection methods used in games; if the cd is copied then the hard drive is completely filled up with junk. Satellite tv has had Videocrypt in place for several years and this will no doubt be enhanced by digital television.

On the photocopying side, there was special printing ink patented that could not be photocopied (does anyone know what happened to that?)?

There is a school of thought which says that all information should be free. And the main vehicle of this freedom is of course the Internet (who could have predicted it?). The main driver may have been the adult web sites but it is certainly a very beneficial institution. And there's freeware and shareware. Maybe "one day all software will be sold this way"?

This brings us on to the problem of quality.

There's lots of useful stuff out there on the Internet. But you have to search very carefully for it to avoid "info-glut". The quality of some data can be poor and often links are missing, referred to by that wonderful expression 'web rot'. And all that free software. Who supports it? It is alarming how many companies depend completely on a piece of free software - the web browser.

I believe that the integration of the browser into the operating system, as in Windows 98, is essential, because then its supported.

But I digress. The point is that you get what you pay for, and you also value what you pay for. For example, when all those electronics magazines fall through the letter box which one do you read first? The one you pay for. Good information costs money in all the sifting, analysis, presentation and marketing. So we need copyright to protect livelihoods and to maintain quality, and that copyright needs to be protected.

But what happens next? No doubt protection mechanisms will improve and become easier to implement in the digital world. Material that is currently free could be protected. The argument goes like this: if people want something and you can protect it, you can sell it.

But media companies would see this as an opportunity here to corner the market. Huge technical monopolies could be created which could control access to and the use of published works.

Perhaps they would eventually decide what is good or bad for us. Big Brother by the back door. Of course it could never happen here.

Peter Marlow
PROTEUS including NEW SIMULATOR

PRO SPICE 3F5

Simulation
- Berkeley SPICE3F5 analogue simulation kernel.
- True mixed mode simulation.
- New analysis types include multi-plot sweeps, transfer curves, distortion and impedance plots.
- Active Components: Switches, Pots etc.
- Over 1000 new library parts with SPICE models.
- Greater ease of use.

"a constant high level of capability throughout"

EWW CAD Review Round Up September 1998

Schematic Capture
- Produces attractive schematics like in the magazines.
- Netlist, Parts List & ERC reports.
- Hierarchical Design.
- Full support for buses including bus pins.
- Extensive component/model libraries.
- Advanced Property Management.
- Seamless integration with simulation and PCB design.

PCB Design
- Automatic Component Placement.
- Rip-Up & Retry Autorouter with tidy pass.
- Pinswap/Gateswap Optimizer & Back-Annotation.
- 32 bit high resolution database.
- Full DRC and Connectivity Checking.
- Shape based gridless power planes.
- Gerber and DXF Import capability.

Available in 5 levels - prices from £295 to £1625 + VAT. Call now for further information & upgrade prices.

“the BEST all-round PROGRAM”

EWW CAD Review Round Up September 1998

Write, phone or fax for your free demo disk, or ask about our full evaluation kit.
Tel: 01756 753440. Fax: 01756 752857.
EMAIL: info@labcenter.co.uk
WWW: http://www.labcenter.co.uk

Fully interactive demo versions available for download from our WWW site. Call for educational, multi-user and dealer pricing - new dealers always wanted. Prices exclude VAT and delivery. All manufacturer's trademarks acknowledged.
**UP DATE**

**C&W pips BT in broadband race**

Cable and Wireless looks like pipping BT to the post in providing broadband links to the home. But the UK’s top two telecom operators will be going down different routes - Cable and Wireless via cable modem and BT via asymmetric digital subscriber line, adsl.

The need for a broadband strategy from the two companies has sharpened in the wake of Compaq Computer’s decision to ship pcs with G.Lite 1.5Mbit/s dsl modems. Purchasers wanting to use the technology will need to have adsl service along with their new computers.

“BT said it is not appropriate to speculate” about when, and at what cost, adsl will be provided. Since BT’s business customers pay upwards of £25,000 for broadband leased lines, it could be put in a quandary when customers start demanding cheaper dsl access.

Cable and Wireless customers look luckier. Cable modems offering 37Mbit/s downstream, and 2 to 10Mbit/s upstream, will be available either in television set-top boxes which can also connect to the PC, or as stand-alone items, by the end of 1999.

*David Manners Electronics Weekly*

---

**£7m Euro money for extreme-UV litho**

The European Commission is to put £7m (10m ECU) into a programme to develop sub 0.1µm manufacturing processes based on extreme UV lithography (EUVL).

“This will be the third consortium to study EUVL, the others are the Intel-backed group in the US and one formed between the big Japanese semiconductor companies,” said Dr Dean Morris of Oxford Instruments, part of the EC consortium.

Extreme UV lithography, using electromagnetic radiation between deep ultra-violet at 150nm and X-rays at 1nm, is one of the candidates for a future sub 0.1µm lithography process.

The Semiconductors Industry Association roadmap released in 1997 calls for the first ICs with 0.07µm features to be produced by 2008. For this, commercial tools will be needed by 2008.

Oxford will head group efforts to develop which type of particle accelerator will be best-suited to EUV generation. The company has built and sold two X-ray generating synchrotrons, one of which is being used by IBM for X-ray lithography.

Another programme member is the Dutch firm ASM Lithograph. ASML is an established maker of lithography equipment, claiming to have over 1000 systems installed worldwide.

The third, final member of the European consortium is Germany’s Carl Zeiss which will look at the production of focusing optics and masks.

“EUV cannot be focussed by refraction and is only weakly reflected. Carl Zeiss is going to make highly accurate multi-layer reflectors, with over 50 layers, to act as focussing optics and reflective masks,” said Morris.

The European project is to be called Euclides, short for Extreme UV Concept Lithography Development System.

*Steve Bush Electronics Weekly*

---

**UK group demonstrates video-speed flat panels**

A consortium of UK organisations has produced a video-rate, limited-colour display by combining a light-emitting polymer (LEP) backlight with a passive ferroelectric LCD (FLCD) shutter.

“It has video capability without using expensive thin-film transistors or colour filters,” said Dr Karl Heeks, technical manager at CDT, supplier of the LEP backlight.

The light source for the display is alternate narrow stripes of green and red-emitting LEPs, laid down to make a square.

All the red strips are energised simultaneously followed by all the green strips in a repeating cycle.

By synchronising the timing of the CRL-supplied ferroelectric LCD, which is a matrix of individually addressable 330 by 330µm pixels, either green, red, or a combination of the two can be selected per pixel.

“The display is only possible because LEPs and FLCDs are fast enough for time-sequential operation,” said Heeks.

The University of Cambridge provided material characterisation and failure analysis for the project, while funding was supplied by the government.

Currently there is no blue in the backlight. The development of a LEP has lagged red and green types. “We will be making some announcements about blue LEPs very shortly,” said Heeks.

*Two display companies, together with the University of Cambridge, have developed a display that combines the strengths of light emitting polymers and ferroelectric liquid crystals to make a limited colour display. The technology demonstrator is 7.5cm square and displays red, green and colours in between.*

*February 1999 ELECTRONICS WORLD*
EMP bullet helps detect land mines

Researchers at the University of Missouri, Columbia are developing a landmine detector based on a high-power rf source in a projectile.

The projectile is fired vertically into the suspected minefield, where it emits a high power electromagnetic pulse. Buried metallic objects are detected when a phased-array antenna mounted on the helicopter ‘sees’ the pulse reflected from them.

Producing the pulse underground, claims the university, couples far more energy into the locality than an above-ground source, which loses most of its power in reflections from the air-soil boundary.

Key to the project is the projectile. This must be a powerful emitter – the target is 10MW – but small enough to be fired from a gun, in this case 30mm in diameter.

The power source that the Missouri team has chosen is the kinetic energy of the projectile itself. They are looking at two ways of turning this into an electromagnetic pulse.

The first is magnetic induction. The induction projectile has a ferromagnetic slug at its rear which sits inside a short-circuited multi-turn coil.

Just prior to firing, a current is induced into the coil which continues to flow during flight.

As the projectile hits the ground, the slug flies forward into a space provided. This leaves the coil coreless and reduces its inductance quickly and dramatically. Current rises with the ratio of the inductance change and the coreless coil acts as an antenna radiating half the energy $E_{final} < E_{final}$.

The other projectile type is piezoelectric. In this case a mass at the rear of the projectile bears down on a piezoelectric block as the collision occurs. This produces a high voltage which is switched into a coil antenna around the projectile by a spark gap.

Both types have proved successful and 100kW pulses are expected from prototypes before the end of this year.

The next phase of the project calls for changes, based on findings so far, to create MW pulses from smaller projectiles. Work will also be done on the coil antennas to control the frequency content of the output pulse.

The helicopter part of the system, still in its early stages, may contain acoustic and thermal imaging arrays alongside the passive radar array to aid the differentiation of mines from other objects.

Steve Bush

Dumping gone bananas

Bananas or semiconductors?

Although the EU is fighting its corner on imported bananas, Sir Leon Brittan, v-p of the EU, has succeeded in scuppering European anti-dumping moves against imported semiconductors.

While the US government has supported its local semiconductor industry by imposing anti-dumping duties on Hyundai and LG and pursuing anti-dumping actions against Taiwan, the EU announced its decision last week not to fight for Europe’s semiconductor industry.

“The US government is aware of the importance of semiconductors for its economy. The EU is not,” said Dr Eckhard Runge, director-general of the European Electronics Components Association (EECA).

“The US government should have been hit for what they have done,” said Runge. “It is very disappointing that the EU does not consider the industry important.”

The reason given by the EU for not taking action against the Koreans is that, because everyone is selling below cost price, action against the Koreans would be discriminatory.

The US government refused to take that view despite the fact that their own domestic producer, Micron Technology of Idaho, has pursued one of the most aggressive pricing policies in the industry.

EECA points out that, between 1990 and 1997, Japanese DRAM market share in Europe dropped from 45.3 per cent to 27.8 per cent, while Korean market share grew from 14.7 per cent to 42 per cent.

Steve Bush

The numbers

The projectile weighs between 50-100g and travels at 500-1000m/s, giving it between 6 and 50kJ of energy when it hits the ground.

Because not all of its mass is involved in conversion, and conversion is inefficient, only ten per cent of this is converted to electrical energy. This means that there is a minimum of around 1kJ to be radiated. This is converted in around 1ms, resulting in a 1MW pulse.

David Manners

Ground breaking technology... The University of Missouri is aiming to detect landmines by firing electromagnetic pulse generators into the soil from a helicopter. The system, says the university, will detect reflections from metallic objects as small as 1cm3 around a 15m radius from 100m up. In keeping with current mine detection theory, the system will be multi-sensor. Not only are electromagnetic reflections sensed, but acoustic activity caused by the impact will be analysed as well, then mixed with thermal image data. The work is sponsored by the US Army and is currently still in the laboratory.

Steve Bush

Dumping gone bananas

Bananas or semiconductors?

Although the EU is fighting its corner on imported bananas, Sir Leon Brittan, v-p of the EU, has succeeded in scuppering European anti-dumping moves against imported semiconductors.

While the US government has supported its local semiconductor industry by imposing anti-dumping duties on Hyundai and LG and pursuing anti-dumping actions against Taiwan, the EU announced its decision last week not to fight for Europe’s semiconductor industry.

“The US government is aware of the importance of semiconductors for its economy. The EU is not,” said Dr Eckhard Runge, director-general of the European Electronics Components Association (EECA).

“The US government should have been hit for what they have done,” said Runge. “It is very disappointing that the EU does not consider the industry important.”

The reason given by the EU for not taking action against the Koreans is that, because everyone is selling below cost price, action against the Koreans would be discriminatory.

The US government refused to take that view despite the fact that their own domestic producer, Micron Technology of Idaho, has pursued one of the most aggressive pricing policies in the industry.

EECA points out that, between 1990 and 1997, Japanese DRAM market share in Europe dropped from 45.3 per cent to 27.8 per cent, while Korean market share grew from 14.7 per cent to 42 per cent.

David Manners
TiePie introduces the HANDYSCOPE 2
A powerful 12 bit virtual measuring instrument for the PC

The HANDYSCOPE 2, connected to the parallel printer port of the PC and controlled by very user friendly software under Windows or DOS, gives everybody the possibility to measure within a few minutes. The philosophy of the HANDYSCOPE 2 is: "PLUG IN AND MEASURE".

Because of the good hardware specs (two channels, 12 bit, 200 kHz sampling on both channels simultaneously, 32 KWord memory, 0.1 to 80 volt full scale, 0.2% absolute accuracy, software controlled AC/DC switch) and the very complete software (oscilloscope, voltmeter, transient recorder and spectrum analyzer) the HANDYSCOPE 2 is the best PC controlled measuring instrument in its category.

The four integrated virtual instruments give lots of possibilities for performing good measurements and making clear documentation. The software for the HANDYSCOPE 2 is suitable for Windows 3.1 and Windows 95. There is also software available for DOS 3.1 and higher.

A key point of the Windows software is the quick and easy control of the instruments. This is done by using:
- the speed button bar: Gives direct access to most settings
- the mouse: Place the cursor on an object and press the right mouse button for the corresponding settings menu.
- the menus: All settings can be changed using the menus.

Some quick examples:
- The voltage axis can be set using a drag and drop principle. Both the gain and the position can be changed in an easy way.
- The time axis is controlled using a scalable scroll bar. With this scroll bar the measured signal (10 to 32K samples) can be zoomed live in and out.

The pre and post trigger moment is displayed graphically and can be adjusted by means of the mouse. For triggering a graphical VS WXYYG trigger symbol is available. This symbol indicates the trigger mode, slope and level. These can be adjusted with the mouse.

The oscilloscope has an AUTO DISK function with which unexpected disturbances can be captured. When the instrument is set for the disturbance, the AUTO DISK function can be started. Each time the disturbance occurs, it is measured and the measured data is stored on disk. When pre samples are selected, both samples before and after the moment of disturbance are stored.

The spectrum analyzer is capable to calculate an 8K spectrum and dispose of 6 window functions. Because of this, higher harmonics can be measured well (e.g. for power line analysis and audio analysis).

The voltmeter has 6 fully configurable measurements. 11 different values can be measured and these values can be displayed in 16 different ways. This results in an easy way of reading the requested values. Besides this, for each display a bar graph is available.

When slowly changing events (like temperature or pressure) have to be measured, the transient recorder is the solution. The time between two samples can be set from 0.01 sec to 500 sec, so it is easy to measure events that last up to almost 200 days.

The extensive possibilities of the cursors in the oscilloscope, the transient recorder and the spectrum analyzer can be used to analyze the measured signal. Besides the standard measurements, also True RMS, Peak, Peak Mean, Max and Min values of the measured signal are available.

To document the measured signal three features is provided for. For common documentation three lines of text are available. These lines are printed on every print out. They can be used e.g. for the company name and address. For measurement specific documentation 240 characters text can be added to the measurement. Also "text balloons" are available, which can be placed within the measurement. These balloons can be configured to your own demands.

For printing both black and white printers and color printers are supported. Exporting data can be done in ASCII (SCV) so the data can be read in a spreadsheet program. All instrument settings are stored in a SET file. By reading a SET file, the instrument is configured completely and measuring can start at once. Each data file is accompanied by a settings file. The data file contains the measured values (ASCII or binary) and the settings file contains the settings of the instrument. The settings file is in ASCII and can be read easily by other programs.

Other TiePie measuring instruments are: HS508 (50MHz-8bit), TP112 (1MHz-12bit), TP208 (20MHz-8bit) and TP508 (50MHz-8bit).

Convince yourself and download the demo software from our web page: http://www.tiepie.nl.

When you have questions and / or remarks, contact us via e-mail: support@tiepie.nl

Total Package: 
The HANDYSCOPE 2 is delivered with two 1:1/10 switchable oscilloscope probes, a user manual, Windows and DOS software. The price of the HANDYSCOPE 2 is £ 299.00 exc. VAT.

TiePie engineering (UK), 28 Stephenson Road, Industrial Estate, St Ives, Cambridgeshire, PE17 4WJ, UK
Tel: 01480-460028; Fax: 01480-460340

TiePie engineering (NL), Koperslagersstraat 37, 8601 W. SNEEK, The Netherlands
Tel: +31 515 415 416; Fax: +31 515 418 819

CIRCLE NO. 105 ON REPLY CARD
Java chips on show

Prototype Java chips made their first public appearance at the recent Comdex trade show in Las Vegas, writes Tom Foremski.

Sun Microsystems, LG Semicon, NEC and Fujitsu showed evaluation boards that contained Java-based chips, and Patriot Scientific showed its JavaChips.

Sun was keen to arrange such demonstrations because of criticism from industry analysts that its Java chip program had run out of steam and that there has been little to show since Sun licensed Java core designs to major chip companies over the past two years.

"This shows that Java chips are a reality and that they have applications in different types of systems," said a Sun representative. "Although these are just initial demonstrations of what our licensees are working on, there is a bright future for Java chips."

The advantage of Java chips is that they can be used in applications where there is no overhead for a Java-based operating system and the memory required to run a Java Virtual Machine. Instead of using software to interpret the Java instructions, the chips directly process the Java byte code. Sun says that with the cross-platform capabilities of Java, it is possible to build a large number of embedded applications in areas such as automotive control systems and factory production lines, where small Java applications can be run.

Sun showed an evaluation board containing its prototype MicroJava 701 microprocessor, based on its picoJava core design. This will be released to developers in the second quarter of 1999 along with an operating system and development tools.

NEC demonstrated a picoJava-based evaluation board which it is targeting at embedded systems developers and said that it is also working on semi-custom chip products that are more closely targeted at specific applications.

Fujitsu demonstrated a picoJava-based board but says that its main focus is system-on-a-chip type applications where the picoJava core is just one part of an overall design that includes microprocessor and other cores.

LG Semicon was showing its prototype MJ1 chip which is designed to be a discrete part to be combined with other chips in various applications. It also said that another Java chip, designated MJ501, is being developed and it will offer improved performance.

Sun admitted that it has changed strategy with its Java chip program. "Instead of separate Java chips, we recognise that the industry is moving more towards a semi-custom model and we are encouraging our licensees to move in that direction," said Harlan McGann, head of the architectural and technology group in Sun's Microelectronics division.

Sun has been criticised for its Java chip plans. Jim Turley, senior industry analyst at MicroDesign Resources says that Java is too slow for embedded chip applications. "Java does have a place but in embedded systems I'm not convinced that it has the performance that makes it useful," Turley said.

McGann notes that Java is becoming faster and that Java chips will be found in a wide variety of embedded applications such as cell phones, set-top tv boxes and industrial control systems. But it will be a while before Sun can show actual real-world applications for Java chips.

Dashboard that can change as you drive

Ford subsidiary Visteon has designed a reconfigurable concept car dashboard that uses Texas Instruments' Digital Micromirror Device (DMD).

The dashboard is 350 by 85mm and can display traditional mechanical instruments, user customised instruments and even navigational data.

Visteon has selected the TI part that with the cross-platform capabilities of Java, it is possible to build a large number of embedded applications in areas such as colour-shutter technology from various manufacturers.

"We are using the DMD because of its resolution, fill-factor and temperature performance. The high fill-factor, which is over 90 per cent, means that there are no difficult issues if we want to increase screen size," said Alex Calton, product marketeer at Visteon.

Poor yield of the DMD has been rumoured to be a problem for TI.

Does getting hold of the devices worry Calton? "No," she said. "If we sell the product concept to a customer, TI will be able to produce the devices."

Another feature Visteon is promoting is a "baby-watch function" to keep an eye on the kids in the rear seat – which can only be used when stationary. It is also developing a 350 by 255mm unit for centre console use.

Easy PC, Tina, where?

CAD packages Tina and Easy-PC have both had changes of UK address recently. The Tina Windows circuit simulation suite is now distributed by Quickroute and complements the company's established and successful autorouter. Easy-PC is now owned by Sightmagic in Tewkesbury. "We intend to make Easy-PC For Windows by far the best value sub-£500 pcb layout product on the market today," Sightmagic's Marketing Manager Bob Williams told us.

Sightmagic Tel. 01684 773662
Quickroute Tel. 0161 476 0202
The Alternative Oscilloscope

Pico Technology provides an alternative to costly, bulky and complicated oscilloscopes. Our range of virtual instrumentation enables your PC to perform as an oscilloscope, spectrum analyser and digital multimeter.

- Up to 100 MS/s sampling and 50 MHz spectrum analysis
- A fraction of the price of comparable benchtop DSOs
- Simple Windows based user interface

The practical alternative

Connection to a PC gives virtual instruments the edge over traditional oscilloscopes: the ability to print and save waveforms is just one example. Advanced trigger modes, such as save to disk on trigger, make tracking down elusive intermittent faults easy. Combining several instruments into one small unit means it is lighter and more portable. When used with a notebook computer, field engineers can carry a complete electronics lab in their PC.

The simple alternative

Virtual instruments eradicate the need for bewildering arrays of switches and dials associated with traditional 'benchtop' scopes. The units are supplied with PicoScope for Windows software. Controlled using the standard Windows interface, the software is easy to use with full on line help. Installation is easy and no configuration is required; simply plug into the parallel port and it is ready to go. We provide a two year guarantee and free technical support via phone, fax or E-mail.

The low cost alternative

The Pico range of PC based oscilloscopes work with your PC - anything from a dustbin-ready 8086 to the latest pentium. The PicoScope software utilises your monitor to display data. This gives you a larger, clearer display than any scope, at a fraction of the price. The savings don’t stop there: All those expensive upgrades needed for traditional oscilloscopes: such as FFT maths, disk drives and printers are already built into your computer. The PC has made computing affordable, now Pico has made test equipment affordable too.

Seeing is believing

Call for a FREE demo disk or visit our web site.
Fax: (0)1954 211880 Tel: (0)1954 211716
E-mail: post@picotech.co.uk http://www.picotech.com
Broadway House 149-151 St Neots Road Hardwick Cambridge CB3 7OJ UK

Edison, TINA and TINA Lab are a unique family of 32 bit simulation products now available in the UK. Start with Edison, the fun multimedia electronics lab that teaches electronics in 3D - and then move on to TINA Pro - the new interactive mixed mode 32 bit simulator with over 20 types of analysis, comprehensive virtual instrumentation and over 10000 models. TINA Pro also lets you create custom schematic symbols from subcircuits, or SPICE models and now includes a parameter extractor for calculating model parameters from manufacturers data. Uniquely, TINA Pro can also be used to make real-time measurements using the TINA Lab card & prototyping board. For more information call Quickroute Systems.

Quickroute Systems Ltd, Regent House, Heaton Lane, Stockport, SK4 1BS, U.K.
Tel 0161 476 0202 Fax 0161 476 0505
Email TINA@quicksys.demon.co.uk www.quickroute.co.uk

CIRCLE NO.106 ON REPLY CARD

the complete electronics lab for Windows

Edison £79
TINA Plus £199
TINA Pro £299
TINA Lab from £788.
Prices exclude p+p and VAT.

CIRCLE NO.107 ON REPLY CARD
There was a time when plds were the domain of the wealthy, but as Colin Attenborough explains, in-system programmable devices and free software have brought them down to pocket-money level—provided you already have a pc.

To illustrate how much digital processing power you get from even the smallest pld, Colin describes a five-chip logic analyser capable of capturing 4096 byte-wide words at sampling rates to 10MHz.

All too often, a bright idea for a logic-based device loses its appeal when you draw up a detailed design and find that the circuit is not as simple as you first thought. There's the added disincentive that when you have finished implementing the design, it will not work as expected and you will have the dubious task of rewiring it.

For such applications, modern programmable logic devices, or plds, are an excellent alternative. There are design tools that make implementing and simulating the logic easy, and making a modification is simply a matter of reprogramming the device.

There was a time when programmable logic was inaccessible to most because of the high cost of development equipment. For devices like the one I use as an example in this article, the development software is free and the hardware is little more than a cable that links your target design to the pc for programming.

All you need is a pc, a free cd and a cable

To illustrate just how accessible plds have become, I describe here a logic analyser comprising just five ICs. It is based on a Lattice Semiconductor's ispLSI1016, a 60MHz version of which costs under £10.

Given Lattice's software, installed from the company's free cd onto a pc*, a design specified at the gate/flip-flop/adder sort of level can be drawn, checked, compiled, and programmed into the device. The only additional hardware needed is a simple adaptor that goes between the pc's printer port and the device being programmed.

And if the design doesn't work, debug the error, amend the circuit diagram, and simply reprogram the device. With a few restrictions you can even reprogram it without removing it from its circuit board.

---

*This particular cd has recently become obsolete. The new cd allows you to design an expanded range of parts, but requires you to register for a six-month licence. Use is still completely free though. Electronics World is due to obtain around 30 of the original life-long licence Lattice cds for 1016 and 2023 parts only. These will distributed free with requests for the author's software until they run out. Details later in the article. Ed.
Design example – 10MHz logic analyser

My logic analyser using the ispLSI1016 has only five ics excluding the power regulator, yet it can acquire 4096 samples of an eight-bit word at rates up to 10MHz.

Operation of the analyser is controlled via a pc’s printer port using a dynamic link library written in Visual C++ V5 to access the printer port, and Visual Basic 5 to provide a Windows user interface. But note that you don’t need either language to use the software; it can be installed on any pc running Windows 95 or later.

The analyser’s software lets you set the acquisition rate, the trigger word, and an internal or external clock source. You can also search for chosen logic words – zeros, ones or don’t cares – among the acquired data, and bring each occurrence of the chosen word to the centre of the screen. The number of samples displayed on screen can be set to between 8 and 256.

For use in the logic analyser, the ispLSI1016 incorporates a 12-bit counter, an 8-bit counter and a 21-bit shift register. It also has sundry gates, latches and flip-flops.

Pre-programmed devices are being made available for those of you who don’t want to do the programming.

---

**Fig. 1. Outline of a logic analyser, whose job it is to read a sequence of logic levels on an eight-bit bus and display the results on the screen of a pc. Note that asterisks denote active-low signals in this article.**

**Fig. 2. Logic analyser details. Using a pld dramatically reduces the number of components needed to look for a specific trigger word on the bus being tested, store a sequence of bytes after triggering, then send out the information to a pc. The pld also handles control signals from the pc for setting up the analyser.**
Fig. 3. 'Top level' of the pld, giving an overview of the functions carried out by the device at the heart of the logic analyser.

Fig. 4. Bus cf trigger and rate setting details. This section compares the input word with the trigger word and produces an output when the two are identical.
What is a logic analyser?
For fault-finding analogue systems, the most useful single test instrument is the oscilloscope. For digital systems though, the oscilloscope has limitations. Triggering isn't just a matter of setting a voltage level and polarity; it's useful to trigger from a combination of zeroes and ones. And of course the oscilloscope's two channels are not sufficient to examine the relationships between all the lines in, say, an eight-bit wide bus.

What is needed is a logic analyser, where rather than two analogue channels you have eight binary channels, and where the trigger criteria are set as a word rather than signal levels and polarity. It is also useful to be able to store results, so they may be examined at leisure, and 'this-causes-that' relationships checked.

Logic analyser basic requirements
A logic analyser needs memory to store acquired data. Static RAM is cheap and readily available in byte-wide amounts sufficient to store an adequate number of samples. It is also available to work at a speed fast enough to allow 10MHz analyser clocking.

An analyser also needs a reference oscillator to define the acquisition rate and clock-rate logic to allow data to be acquired at defined rates below that of the reference oscillator. Trigger logic is needed to compare the incoming data with a trigger word and stop acquisition when a match occurs.

An address counter for the ram is clocked by the selected clock rate, in order to put successive input data bytes into successive locations of the ram. Control logic supervises getting data into and out of the system.

All the above elements are shown in Fig. 1. Figure 2 is the detailed overall circuit; a tri-state input buffer is needed not only to allow read/write operation of the memory, but, if you connect an input to an excessive voltage, makes it more likely that you'll vapourise something comparatively cheap.

Figure 3 is the top level circuit of the pld, showing that it implements a large fraction of Fig. 1's circuitry.

How it works
To prepare for acquisition of data, the pc sets the 'Clr' line, clearing the sync8 and sync12 counters, and all the D types and latches shown in Fig. 3.

Trigger-word data, acquisition rate selection, internal/external clock selection and external clock polarity settings are communicated as a serial word. This word is sent to the shift registers in the BUS_CFP block. Acquisition-rate selection is carried out via the 8-to-1 multiplexer.

The eight-to-one multiplexer selects one of the outputs of the sync8 counter, if an internal clock is used, this will be selected by the four-to-one multiplexer and clocks the sync12 counter which addresses the ram.

To acquire data, 'Clr' is set to logic zero and 'Not_Download' to logic one. The input buffers in Fig. 3 are enabled, and input data are written to the ram. The 'Not_WR' signal is identical to the clock and provides a write signal to the ram.

Acquisition starts to end when the 'match' output of BUS_CFP goes to logic one, Fig. 4. This happens when all eight inputs of the and gate - assembled from two four-input and gates and a two-input and gate - go to logic one.

The logic to detect a match between incoming data and the trigger word consists of an exclusive-or gate and an or gate, repeated for each of the eight lines of the data bus. It is convenient to represent the exclusive-or and or gates as iterated (repeated) components, and their input and output connections as busses.

The control input to the exclusive-or gates is the One[0:7] bus; a logic zero in the input word and a logic one in the corresponding position of the One[0:7] bus gives a logic one at the output of the exclusive or gate. This feeds the b[0:7] bus driving the or gates, because the gates are fed from a bus and are iterated, the connections between the gates are themselves a bus.

That's how we detect a logic zero in the incoming data; we set a logic one in the One[0:7] bus. (You're right, it isn't a well-chosen name.) To let either state of the incoming data
end acquisition, we set a logic one in the corresponding bit of the X[0:7] bus which feeds the or gates.

A logic one at the 'match' output does not stop acquisition immediately, Fig. 3. After declutching by the D type, it is held by a set:reset latch. It is only when the sync12 counter next reaches its final state, with Togg_out at logic one, that a second set latch clears the sync12's Togg_in line. This inhibits further clocking, and puts a logic zero on the 'still:counting' output to tell the pc that acquisition is complete.

Applying the pld
This outline covers the sequence of events from circuit diagram to programmed device. I'll use the circuits of the logic analyser as examples to show you how to turn your ideas into a programmed device.

First, install both ISP Synario and ispDS+ then start a new project. The top level circuit Fig. 3, contains some simple gates and flip-flops, as well as the blocks bus_cf, sync8 and sync12, which are made up from such simpler elements.

From Lattice's cd, install the ispSynario and ispDS+ programs: both are needed. Start ispSynario and you'll get the 'Project navigator' window. Select 'File/New project'; name and store the '.syn' file.

Double-click 'Virtual device' in the 'Sources' window; select 'ISP Synario starter device' and then, in the lower window, 'ispLV 1016-60 PLCC44'. Click OK and accept the Yes option.

Entering circuits. Now you can start entering circuits. Click 'Source/New/Schematic/OK'. Name and store the new '.sch' file. You'll see two windows; a schematic editor where you'll draw your circuit, and a tools palette with seven rows and three columns.

Most tool palette functions are also available in menus. The prompt line at the bottom of the schematic editor is a useful guide to what to do next in any command. Start by entering the sync4 circuit, Fig. 3; this will be used as part of sync12 and sync8 counters.

Begin with a toggle flip-flop with clear. Click the 'Add component' icon in the top left of the tools palette. A Symbol Libraries window appears; click on c:\...\GENERIC\REGS.LIB, and then scroll down the lower part of the window until you see 'G_TC'.

When you move the mouse onto the circuit diagram, you'll see a symbol for the flip-flop at the end of the mouse pointer. Click on the circuit diagram to place the symbol. Place the other three flip-flops while you're about it.

Click on c:\...\GENERIC\GATES.LIB and import the gates you need. The term 4AND is a four-input AND gate; less obviously, 4AND1 has one input inverted.

Wiring components. After you have placed all the gates and flip-flops, you need to wire them up. At this point you will probably realise that you haven't placed them quite correctly.

Two items in the centre row of the tools palette let you move components. The centre one lets you click on an individual component and drag it, breaking any connections; the

---

**Software download**

The ISP Synario Starter software is available for downloading on www.latticesemi.com. This software includes all the tools that you need for designing with Lattice ispLSI 1000, 1000E, 2000, 2000V, and GAL device families. The ISP Synario Starter runs under Windows NT and Windows 95, and includes:

- Lattice ispDS+(tm) Starter (Part 1)
  - ispDS+ HDL Synthesis-Optimised Logic Fitter
  - Explore Tool
  - Pin Assignment Editor
  - ispTA(tm) Timing Analyser
  - ispDOWNLOAD(tm) and ispATE(tm) Utilities
  - VITAL and Non-VITAL VHDL Simulation Libraries
  - OVI-Compliant Verilog Simulation Library

- ISP Synario Software Starter (Part 2)
  - ISP Synario Project Navigator GUI
  - ISP Synario ABEL-HDL Entry and Compiler
  - ISP Synario Functional Simulator
  - ISP Synario Schematic Capture
  - GAL Compiler

**Minimum System Requirements**

The ISP Synario Starter software for the PC environment has the following system requirements: 486/Pentium pc-compatible; mouse; Windows NT or 95; 16 megabytes of ram; SVGA resolution display (800 x 600); 35 megabytes of free hard disk space.

The full procedure for downloading is given on the site. Note that you will be asked to open an account in order to use the software, but this does not entail any money changing hands. Full Acrobat documentation is available for downloading, as is a copy of the Acrobat reader.
right hand one lets you lasso a group of components and connections, and move them all, preserving connections.

The wiring tool is at the centre of the top row of the tools palette. Click it to select it, click a component lead end or an connection, and move them all, preserving connections.

Double click to end a wire in the middle of nowhere. Use the zoom in and out controls, shown as magnifying glasses at the top of the circuit editor, as needed. At some point you'll doubtless need the eraser tool at the right hand end of row five of the tools palette; it works on wire segments and on components, and on lassoed areas. And - a useful feature - F9 is the 'Undo' button.

Naming i/o. Name the inputs and outputs and give them connectors. To name an input or output, click the centre icon in the second row of the tools palette. Enter, for example, CLR and hit return. Then click the mouse on the end of the appropriate wire. Note that there must be a wire; it won't work on device pins themselves. Repeat this for each of the i/o.

To attach an i/o marker, use the right-hand icon of the second row of the tools palette. Up pops a window to let you select input or output; choose the right one and lasso the names you've just added. Lasso several at a time for speed, but make sure they're all inputs or all outputs.

It is essential to realise that these i/o are merely for this section of the circuit, they are not pins on the completed pld.

You can name any wire - not just i/o's. This is useful, say, when you want to tie an input to one or zero: in this case, you can give the input the more useful name of GND or VCC respectively.

Make a symbol for your circuit block, and check your work so far. Use 'Add/New Block Symbol', click 'Use Data From This Block', and 'Run'. This will make a symbol - F9 is the 'Undo' button.

For more ambitious designs, there are five more pld families with progressively higher component counts. For more information, or to register for your free CD, see www.latticesemi.com.

ispLSI 1000/E families: overview

The ispLSI 1000/E families are high-density devices with applications ranging from registers, to counters, to multiplexers, to complex state machines.

Densities of the the ispLSI 1000/E families range from 2000 to 8000 gates.

Each device contains multiple generic logic blocks. These are designed to maximise system flexibility and performance. A balanced ratio of registers and i/o cells provides the optimum combination of internal logic and external connections.

A global interconnect scheme ties everything together, enabling utilisation of up to 80% of available logic.

1000/E family attributes

<table>
<thead>
<tr>
<th>Family Member</th>
<th>1016E</th>
<th>1024</th>
<th>1032E</th>
<th>1048E</th>
</tr>
</thead>
<tbody>
<tr>
<td>Density: (PLD Gates)</td>
<td>2000</td>
<td>4000</td>
<td>6000</td>
<td>8000</td>
</tr>
<tr>
<td>Speed - fmax (MHz)</td>
<td>1.25</td>
<td>1.25</td>
<td>1.25</td>
<td>1.25</td>
</tr>
<tr>
<td>Speed - tf (ns)</td>
<td>7.5</td>
<td>12</td>
<td>125</td>
<td>125</td>
</tr>
<tr>
<td>Macrocells</td>
<td>64</td>
<td>72</td>
<td>128</td>
<td>192</td>
</tr>
<tr>
<td>Registers</td>
<td>96</td>
<td>192</td>
<td>288</td>
<td>110</td>
</tr>
<tr>
<td>Inputs and i/o</td>
<td>36</td>
<td>54</td>
<td>72</td>
<td>110</td>
</tr>
<tr>
<td>Pin/Package</td>
<td>44-pin PLCC</td>
<td>44-pin JLCC</td>
<td>44-pin QFP</td>
<td>44-pin TQFP</td>
</tr>
<tr>
<td></td>
<td>68-pin PLCC</td>
<td>68-pin JLCC</td>
<td>100-pin TQFP</td>
<td>84-pin TQFP</td>
</tr>
<tr>
<td></td>
<td>44-pin QFP</td>
<td>100-pin TQFP</td>
<td>128-pin TQFP</td>
<td>84-pin CPGA</td>
</tr>
</tbody>
</table>

For more ambitious designs, there are five more pld families with progressively higher component counts. For more information, or to register for your free CD, see www.latticesemi.com.
Logic analyser software

Two sets of logic analyser driving software are available on disk – one for readers with Visual Basic 5 and the other for readers without. Note that this is software for Windows 95. Notes on how to use the software are included on the two-disk set.

Free CD. Electronics World has obtained 30 Lattice CDs with life-long licence for the 1016 and 1024 parts. The first 30 requests for Colin’s software will receive one each. Send a postal order or cheque for £15 payable to Reed Business Information to Logic Analyser, Electronics World, Room L333, Quadrant House, The Quadrant, Sutton, Surrey SM2 5AS.

Programmed pld. Colin will program your pld for you if you send it to him sealed in its original packaging together with reply-paid return postage and packing and a cheque or postal order for £8 payable to Colin Attenborough. Send your request clearly marked PLD to Electronics World Editorial, Quadrant House, The Quadrant, Sutton, Surrey SM2 5AS.

Fig. 8. With a few minor sacrifices, the pld can be programmed in situ. Here, the top diagram shows a development adaptor using two cables. I chose this option, and used one of the programming cables to control the analyser in use.

Try to name a wire to mybus[0:7] as yourbus[3], or as mybus[8], you’ll get an error message.

Device i/o pads

The only thing left to explain about the circuit diagram is the addition of device i/o pads at the top level. These represent the connections on the programmed pld. They are imported in the same way that any other components from the \"\$\$\$\$\$\$GENERIC\$\$\$\$\$PADS.LIB section of the Symbol Libraries window are.

Add names and i/o markers as for the lower level circuits. Notice the use of a clock driver to connect the clock input of sync8 to a device i/o pad.

There are three possibilities when allocating device pins. Before making the ‘*.jed’ file which programs a blank device to your specification, you must decide how many restrictions to impose on the pin allocation process.

The simplest option is to do nothing; the system will choose pins for you. You’re giving the system an easy time, and if your circuit can be connected, it will be. This is the best route to take for a complex circuit which may stretch the capacity of the device.

By default, the system may use some of the programming pins as i/o connections. This means that you may need to disconnect other devices if you want to reprogram the ispLSI1016 in circuit.

To stipulate that the programming pins shall be put to no other use, as I did for this project, go to the project navigator window, click on the top level circuit in the sources window, on ‘Compile Schematic’ in the processes window, and on ‘Process/Properties’ on the navigator menu bar. Make sure that ISP (in-system programming) is set to ‘True’, and close the window.

The last, most restrictive, option is to stipulate which pin number shall be associated with each i/o. Select ‘Symbol Attribute Editor’, which is the centre icon in third row of tools palette. Use the mouse to draw a line around the i/o pad and buffer in question.

The left window of the symbol attribute editor contains...
three entries; the second is named the 'Synario Pin'. Enter the pin number you want in the 'Attribute' window, then click double-click Fitter Report' in the processes window. The Report Viewer window will open.

Once the printer port is connected to the programming adaptor and the cable linking the adaptor to the final circuit board is in place, and the ispLSI1016 is fitted, double click on 'ISP Download System'. The download window appears; choose 'Configuration/Scan Board' and check that the system can find the pld.

Now click Browse, find the <programname.rpt> file and press OK. Hit the Run icon - the running figure - on the download system icon bar. All being well, after a few seconds, you'll get a 'programming successful' message.

I haven't touched on the simulation tools available, or on the graphical tools available under ispDS+. Everything I've described so far has used the isp Synario program. These additional facilities can be found by looking at the help files and on-line manuals provided with the software.

I am grateful to my employers, Cambridge Consultants, for permission to publish this article, and particularly to Julian Coles for giving me the idea and to Neil Johnson and Karl Swepson for their enlightenment.

---

DigiTai DESIGN

---

Digital Design

---

STEWART OF READING

110 WYKEHAM ROAD, READING, BERKS RG1 4PL
Telephone: (0118) 9268041  Fax: (0118) 9351596

---

CIRCLE NO.108 ON REPLY CARD

---

February 1999 ELECTRONICS WORLD
MARCONI TF 2019A
Synthesised Signal Generators
80Hz to 1040Mhz AM/FM, Memories, LCD
A REAL Anchor Special ONLY £750

Frequency Counters
Racal Dana 9903/4
7 segment 30Mhz £24
Racal Dana 9919
8 segment 520Mhz £65
Racal Dana 9918
9 segment 560Mhz £75

Signal Generators
HP 8683A
2.3-6.5 GHz AM/FM
NOW ONLY £499
Marconi TF2015
10-520Mhz NOW ONLY £95
Marconi TF2171 Synchronizer for 2015 NOW ONLY £95
BOTH TF2015 and TF2171 ONLY £180

Conference Equipment
Elite OHP's
Choice of 4 types from ONLY £35
UNICOL
Stands Choice from ONLY £45
KODAK SAV1030
Carousel Slide Projectors NOW ONLY £225

Video Equipment
Panasonic AG6200
VHS ONLY £99
Panasonic AG6810
HiFi Duplication machines VHS ONLY £99
SONY VO5630
Low Band VHS Unit ONLY £225
PANASONIC AG6100
VHS Players ONLY £100

Audio Equipment
Sonifex
Cartridge Decks Only £75
Marantz
Cassette decks. Choice of 2 ONLY £45

Oscilloscopes
HP 1741A 100Mhz Storage Dual Time base only £350
TEK 465B 100Mhz Dual Trace/Timebase Now Only £295
TEK 465M scope as 465B but built only for Military. Only £350
TEK 475 200Mhz Dual Trace/Timebase Now Only £395
TEK 2445 150Mhz Four Trace/2 Time base with Cursors, etc. Now Only £495
TEK 2445A 150Mhz Four Trace/2 Time base with Cursors, etc. Now Only £995
TEK 2445B 300Mhz Four Trace/2 Timebase 4Now Only £1250

NEW SCOPE PROBES
X1/10 selectable to 100Mhz Complete with adaptors
Limit 2 sets per customer ONLY £95

New THIS MONTH'S SPECIALS
TEK 2445 Scopes
DC-150Mhz 4 Trace/2 Timebase and Cursors
A REAL Anchor Special ONLY £495

Phillis PM3217 Scopes
DC-500Hz 2 Trace/2 Timebase
A REAL Anchor Special ONLY £275

Hewlett Packard
Philips PM5519 Colour Pattern Generator
SPECIAL ONLY £125

ANCHOR SUPPLIES LTD
The Cattle Market Depot
Nottingham NG2 3GY, UK
Tel: (0115) 986 4902
Fax: (0115) 986 4667
http://www.anchor-supplies.ltd.uk
sales@anchor-supplies.ltd.uk
MAIL ORDER A PLEASURE
Also at
Peasehill Road, Ripley, Derbys
All prices are EX VAT and Carriage
Students’ lots

In response to Dr Allen Brown’s opening article in EW October 1998, it is indeed much harder to be a student than 25 years ago. From 1984 till 1990, I studied electronics at a Netherlands university and moved abroad in 1992. That would seem to underline Dr Brown’s article. But nothing is further from the truth, as I will try to explain.

The Dutch grant and pay-back system is similar to the one recently introduced in the UK. Tuition fees were introduced in 1986. This met with opposition from many students. From me too. But the numbers of new students did not drop. By the time I finished my course, my debt had build up to an equivalent of £6000. That meant I could not buy a house in 1991. Not that that was a problem, since a lot of engineers are not totally sure where they are going to work for the next five years at the start of their career.

On the other hand, the gap between my student lifestyle and the first salary was so big – going up from about £300 to £800 per month – that I was able to pay off my debt within 18 months. To allure to twice the debt for couples is unfair since you either have a double income or you don’t have to start to paying back right away.

The fact that Holland, Germany or France still has some engineers left should also undermine the validity of Dr Brown’s view. And not everyone is happy to give up their country, friends and family for a good salary. My reasons for moving abroad were certainly not the money since I work for the NHS.

Dr Brown also forgets to mention that there is another side to the coin. Governments struggle to eke out their available resources. You can bet that if the system remains the same, future cuts in the grants system are inevitable unless other government departments are sacrificed.

I think it is not unfair to ask students – most of whom will be a lot better off later compared to workers without a degree – to invest a little in their own future to avoid breakdown in other parts of the education system.

Frank Cook
Oswestry
Shropshire

Digital dog’s dinner

Digitised tv sound production and transmission promised to be the panacea of sound quality, but has it delivered?

I can’t remember hiss being a problem recently, but distortion is. Viewing on old-fashioned terrestrial fm mono, it seems that as studio facilities are updated to digital working, the distortion gets worse. Live sound is quite acceptable, first generation tape is a little distorted, while edited, second generation sound is appalling.

In the summertime, the BBC “Working Lunch” programme was extolling the virtues of its new OB truck which had won awards. Yet the very same truck was, and is, producing horrendous distortion when broadcasting edited stories. What does this distortion sound like? Usually very sibilant, a pumping, rough, muddy, intermodulational noise, akin to recordings made without bias. The sound is dynamically distorted both in frequency response and amplitude.

News 24 items from America can be even worse. Presumably they have been processed a greater number of times.

When combined with a strong output, words can be unintelligible. Music seems to be less affected, due to fewer generations, maybe, or the fact that music is a more continuous signal than speech.

If digital should be so transparent, can anyone explain why it is so cloudy?

HV fuses?

A friend recently asked me if I could obtain a replacement for the high-voltage fuse in his microwave. I tried all my sources to no avail. He tried service shops and was told they were not available, or that they could only be fitted by trained personnel, or was offered a fudge, consisting of replacing the fuse with a diode. The cost was about £50 in each case. Where can one buy high-voltage fuses? They seem to be made by only one company in the Far East.

There’s more to Radio 4...

BBC Radio 4 is broadcasting a strange signal which I would like to draw to the attention of readers. Listen to ‘Today’ on Radio 4 any

Wire into this

Imagine you want to make a simple luxmeter in a hurry. You haven’t time to order components so you have to use what’s to hand: an LDR03 light-dependent resistor, some linear resistors, a 350µA 250Ω galvanometer, a 9V battery and two bipolar push switches. As the resistance of the LDR03 will vary from some 10Ω to 500kΩ, you need two scales. For low light levels, you just put together the ldr, battery, galvanometer, a 24kΩ resistor and a 5kΩ trimmer as in Fig. 1a. The trimmer is necessary to adjust full scale, Fig. 1b. For the strong light you adopt the layout of Fig. 1c.

Here comes the problem. All available items are in Fig. 1d. Switch S1 selects the first scale and S2 the second one. Pressing both switches together allows you to adjust full scale. Of course there is no current through the battery when neither S1 or S2 are pressed. Try wiring the circuit up. I will be surprised if you found the solution in the first half-hour.

Jean-Marc Brassart
Saint Laurent Du Mar France
time from 6am until 9am weekdays. You’ll need an audio system with a good bass response. From time to time, you will hear a rumble, not unlike that from vinyl records. The bandwidth of the rumble is quite narrow; a sub-woofer doesn’t bring it out much. I have phoned the BBC and e-mailed them. I got an e-mail in reply but it simply said that they weren’t replying.

Charles Coultas
Wokingham

Seeing through Windows

There have been a few editorials about Microsoft, Windoze, etc, in your journal recently, and being a reluctant user of the stuff I thought I would throw in my two bob’s worth. Phil Darrington’s piece in the June issue, bemoaning the poor performance of ‘95, indicates some lack of understanding of the beast on his part. Trying to run it on a 33MHz 386 with a minuscule 4Mb of ram is simply asking for trouble. It really needs a minimum 16Mb of ram, and more is better. Rod Cooper pretty much confirms this in the August issue. Windows 98 requires about twice as much – presumably because you must have Internet Explorer loaded all the time. The entry level for a pc these days is 64Mb of ram. Windows 3.x was much less forgiving in my experience, and it was less graceful when it did fall over. On several occasions it has locked up so tight on me that even the DOS configuration would hang the pc, and the only option was complete reinstallation of Windows after deleting it. If Phil is tired of waiting for the ‘disk-scanner’ he can surely bypass it with a few quick keystrokes, although why one keystroke is not sufficient is beyond me.

In the August issue Rod Cooper wonders at the value of FAT 32 with its ability to make clusters as small as 4Kb. My system at work is a lowly 586 with a 1.6Gb drive. With Windows 95 revision B supports FAT 32 and a drive can be converted without loss of data with Partition Magic.

Broadly, however, I agree with Phil. I also think Windows 95 really requires more intervention on the part of the user or system manager to make it user friendly. I recommend that all 95 users obtain and install Power Toys, TweakUI being the most important component. Why it is not a standard part of the package is a mystery, unless Microsoft has a policy of denying its customers the ability to be able to set their systems up the way the user wants it, rather than how Microsoft wants it. As far as not supplying manuals, they are an optional extra these days, a way for to cut costs and boost profits.

By all accounts Windows 98 is no real improvement on 95. In fact the advice I have seen is that there is little or no advantage in changing to 98 unless there is a specific feature you need.

From all I have seen it requires more resources than 95, and since Internet Explorer is such an integral part of the system, the system hangs when Explorer hangs, which could lead to loss of data. This is not the case with Netscape. Furthermore, every review and all the advice I have seen suggests that IE is inferior to Netscape.

The issue of Microsoft’s near monopoly is perhaps more serious. The Internet is becoming more important as a communications medium for news, etc, owned or operated by PBL, Microsoft, and their associates. We certainly don’t want Bill Gates and Microsoft – or PBL. For that matter – to be in a position exercise control over the information we have access to, any more than we want that other well known US citizen, Rupert Murdoch, to. It is essential for democracy that they don’t.

For more details on how flaky Windows 95 is, and some useful information that will help, I direct you to www.iarchitect.com/msoft.htm and www.creativlement.com

To conclude I proffer this small piece for your amusement. I don’t know its origins.

Definition of Windows95: Windows95: /win-doz-nin-to-fiv/n. 32-bit extensions and a graphical shell for a 16-bit patch to an 8-bit operating system originally coded for a 4-bit microprocessor, written by a 2-bit company, that can’t stand 1-bit of competition.

Phil Dennis
School of Physics
University of Sydney
Australia

Bang go my chances of a review copy of NT5 – ed.
Cyril Bateman reveals three clearing houses for data sheets and application notes here — all accessible via the net, free of charge. He also focusses on design information for those of you interested in thermal management and temperature measurement.

For many designers, the Internet can be used to quickly ascertain potential design options, reducing time to market. It contains a wealth of electronics design data, both data sheets for specific components, application notes and design guides. But how best can these be accessed?

Assuming that you know the component part number and manufacturer’s name, a data sheet is easily retrieved. You simply visit the manufacturer’s web site and search against this part number.

If you do not have enough information to take you directly to a site, you might visit and search each maker’s site in turn. This can prove time consuming though — particularly for readers outside North America.

Especially when Internet is slow, to minimise on-line time, I try, whenever possible, to download three or four files concurrently. While each individual file transfer rate may then be reduced, I find that as one site slows down, another usually speeds up. My modem then tends to run continuously close to maximum speed and my total download time is minimised.

Searching for application information

When starting a new design, you will know what the application is, but often, you will not know the designations of parts suitable for the design, nor who makes them.

Using a conventional Internet search engine, such as Alta Vista, to search against the required application might provide the needed data. More often than not though, you will be left with countless hits to sift through, and even after sifting there is no guarantee that you will find what you are looking for.

Specialist library search sites can be useful here. In recent issues, I have mentioned several specialist topical magazine-based sites that can provide useful background information and articles. They also offer links to other sites, but not usually to specific device or application note numbers.

To date I have found only three large, specialist data-sheet and application-note libraries that can be searched free of charge. These are popular sites, so again can be very slow to access.

Questlink.com³ hosts the EE Design Center community page, which can be electronically searched. You can have free access to this site, but downloading information
Where to look...

1. IE bug opens users' hard drives.
2. Cuartango Security WEB Site.
3. EE DESIGN CENTER.
4. Electronic Designer Interface.
5. Global Semiconductor Datasheets Library.
7. Application Note AN-225.
9. Application Note AN-369

http://www.analog.com
http://www.linear-tech.com
http://www.national.com
http://www.electronics-cooling.com/Resources/EC_Articles
http://www.semiconductor.tw
http://www.info-quick.com
http://www.questlink.com
http://www.icesoft.com

Fig. 1. Result of searching the user friendly QuestLink application notes database, for 'thermocouple' applications.

As features are added, operating system and application software becomes more vulnerable to software bugs and hacker attacks. According to a CINET1 report, on-line Windows or NT users of Internet Explorer 4 with active scripting enabled, have been exposed. A malicious VBScript received via HTML e-mail or directly from a Web page could copy or even delete files from your hard disk - without your knowledge.

Details of fixes for these new bugs can be found in the Microsoft bulletin ms98-015. Until these fixes have been applied, Microsoft recommends you turn off active scripting for Explorer.

Juan Cuartango2 posted on his Web site details of four recent security problems. His demonstration test pages let you confirm whether your system is vulnerable.

IE bug opens users' hard drives.
http://www.news.com/News/Item/0,4,27482,00.html

Cuartango Security WEB Site.

EE DESIGN CENTER.
http://www.questlink.com

Electronic Designer Interface.
http://www.info-quick.com

Global Semiconductor Datasheets Library.
http://www.semiconductor.tw

Applications.

thermocouple

thermocouple

database, for

QuestLink

Fig. 1. Result of whether your system is vulnerable.

Microsoft recommends you turn off active scripting for Internet Explorer 4 users.

Microsoft found in the Microsoft bulletin ms98-015.

With this early version of the browser, I experience pull-down menu bugs. These are listed in Infoquick's help files. On my first visit to this site, I was unable to access any data at all until I referred to the help files. Using version three or later of Netscape is said to overcome this problem.

In the March '98 issue, I mentioned the Icesoft library which can be accessed at the semi.com.tw Web site3 based in Taiwan. Although this site can be slow, it remains my first port of call when seeking a list of datasheets and application notes.

Of the three sites mentioned here, Icesoft regularly returns the most hits. My search on 'thermocouple' returned 23 hits. It included many from Linear Technology, which the other sites missed. But it failed to find the Maxim or National hits found by QuestLink.

Icesoft provides a listing of potentially suitable parts, then routes your selected item directly to the manufacturer's site files. But in the process, it removes your search results page. Having commenced a download, returning to this results page can be quick, but this intermittent page loss inhibits my practice of concurrent file downloads.

Managing component heat

Every electronic design shares a common characteristic - its components heat up. Excessive operating temperatures dramatically reduce the equipment's service life. Frequently, electronic circuit design becomes a trade-off between performance, cost and component temperature.

While specialised circuit-board thermal-simulation software is available, it requires you to input many parameters, some of which may not be available. Choice of circuit-board materials and printed track design further complicate these calculations Fig. 2.

As a practical alternative, component temperatures on the finished board can be measured. Heatsinks and other large parts are easily measured, using sensors made from diodes, diode connected transistors, thermistors, sense resistors, dedicated integrated circuits and pre-packaged thermocouple probes.

Smaller - and especially surface mounted components - ideally require use of the non-contact temperature-measurement methods. Such methods were outlined in Hands-on Internet in the January '99 issue. But non-contact measuring equipment is costly, and can be difficult to obtain. This month I look at lower cost methods.

PTFE-insulated naked bead thermocouples made using 0.2mm diameter wires are a readily available and economical alternative. The thermocouple wires conduct heat from the device being measured, particularly when attached to 1206 size or smaller components, understating its true temperature. So

Integrated Products and National Semiconductor.

requires you to first register.

One nice feature is that while QuestLink redirects your download to the manufacturer's site, your search result page stays on-screen, facilitating multiple simultaneous file downloads. My application-note search on 'thermocouple' for this article found only three hits. One each from Analog Devices, Maxim

and economical alternative. The thermocouple wires conduct heat from the device being measured, particularly when attached to 1206 size or smaller components, understating its true temperature. So

Integrated Products and National Semiconductor.

requires you to first register.

One nice feature is that while QuestLink redirects your download to the manufacturer's site, your search result page stays on-screen, facilitating multiple simultaneous file downloads. My application-note search on 'thermocouple' for this article found only three hits. One each from Analog Devices, Maxim

and economical alternative. The thermocouple wires conduct heat from the device being measured, particularly when attached to 1206 size or smaller components, understating its true temperature. So
the thinnest possible thermocouple wires should be used.
In principle, it is feasible to simply measure the thermocouple's output voltage. Connection of the thermocouple wires to a measuring instrument imposes a second dissimilar metal, 'cold' junction. The difference voltage generated by these hot and cold thermocouple junctions depends on their temperature difference. Published thermocouple characteristic tables assume this cold junction be maintained at exactly 0°C.

**Thermocouple linearity issues**
All thermocouples have a non-linear temperature/voltage characteristic which requires compensation. In practice, most electronic components run at temperatures between 25°C and 150°C, so the type 'K'. Chromel/Alumel thermocouple is preferred.

Several tutorials on minimising errors when using thermocouples can be found on Internet. The Electronics Cooling Magazine site allows its back issues to be accessed. Two tutorial articles, 'Notes on using thermocouples' by Dr. R.J. Moffat of Stanford University and 'Heat transfer measurements in electronic cooling applications' by Dr. N R Kelner of Ktech Corporation are especially relevant. They can be found in its January '97 and September '98 issues.

Many makers produce thermocouple meters and DMM adapters, with varying claims for accuracy. The 40.6μV/°C Seebeck coefficient of type 'K' thermocouples generates some 3mV at typical component temperatures.

Common-mode noise pickup can be a problem when measuring component temperatures on 'live' circuits. Using applications data found on the Internet, you can quickly understand how to minimise errors for 'in-circuit' temperature measurement of components.

**Optimised thermocouple measurements**
For laboratory use it is possible to maintain an extremely accurate 0°C reference cold junction for many hours by simply using melting ice held in a thermos flask. But electronic compensation would be more portable and practicable, so thermoelectric coolers are used to provide a 0°C cold junction, Fig. 3.

Temperature is one of the most commonly measured physical parameters. As a result, dedicated electronic integrated circuit solutions for thermocouple cold-junction compensation have been developed by many makers.

This technique adds a voltage into the thermocouple loop, equal in value but opposite in polarity to that generated by the cold junction, Fig. 4. One simple method of cold-junction compensation is described in the twenty-year old National Semiconductor application note AN-225. It uses their LM335 integrated thermometer circuit to measure the
A totally analogue, continuous function linearisation circuit, which can correct for all thermocouple non-linearities.

While best straight-line fit correction is acceptable for small temperature changes, even near room temperature, thermocouple output follows a curve. Improved cold-junction compensation using a 'bow' correction circuit was provided by dedicated cold-junction compensation integrated circuits. Switch selection of the appropriate correction pin permits cold junction compensation for a variety of thermocouples, Fig. 5.

Twenty pages of thermocouple info...

Linear Technology's application note AN28, titled 'Thermocouple Measurement' is a twenty page tutorial which includes thermocouple background and many practical measurement circuit drawings. These detail both linear and digital correction methods for thermocouple hot-junction non-linearity as well as the improved cold junction compensation techniques, Fig. 6.

Electronic cold-junction compensation requires the cold junction, correction circuitry and printed circuit tracks all be at thermal equilibrium. Correct printed board layout and thermal shielding or heat sinking, is needed to minimise measurement errors.

Having provided an accurate thermocouple compensation circuit, multiple thermocouples may be switch selected, for near simultaneous temperature measurement of many component parts, Fig. 7.
Having found limitations while using traditional Boolean algebra, David Warren-Smith set about rethinking the concept from an exclusive-OR origin. His new method greatly increases the scope of Boolean algebra, and thus its usefulness in digital design.

I have developed a complete Boolean algebra using the exclusive-OR and AND operators. This article demonstrates that this algebra complements the more familiar Boolean algebra using the inclusive-OR operator. In doing so, it greatly increases the scope of Boolean algebra for use in the design of digital circuits.

Simplification methods are available for this algebra. The use of conventional Karnaugh maps is described here, but I have also developed a systematic algebraic method that allows you to equate up to six variable using with just pencil and paper. I hope to discuss this in a second article.

The material in this article requires nothing more than a basic understanding of digital design theory.

Introduction
My first digital project in the late fifties was a plant species counter for a botanist. The counter was constructed from decatrons — gas discharge display devices for the younger among you. To implement a logic gate that was needed, we used a valve rectifier.

This, and subsequent projects, gave me my introduction to digital design — then called switching-circuit theory. We used the mathematical logic invented by George Boole and described in 'An investigation of the Laws of Thought', in 1854. I came across this emerging concept on visits to a local technical book shop and bought several books about it.

One of these books gave an interesting account of Charles Babbage's attempts to invent a mechanical computer out of gears and levers — i.e. the Difference Engine for compiling tables and later in 1833 the Analytical Engine. This machine was to be driven by a steam engine. Note that this was some 20 years before Boole published his account of his algebra.

The concept of the finite mathematical structure of logical design theory, and the way in which it solved digital design problems, for me became of great interest. I discovered that Boolean algebra was a whole new algebra based on a finite number system.

Instead of having an infinite number of integers, you only had two numbers or values, one and zero, or 1 and 0. The digits 1 and 0 are used for convenience; they could be called any—

David N. Warren-Smith, MSc, CPENG
Digital design was launched by Claude Shannon in 1938 in his account of his thesis 'A Symbolic Analysis of Relay and Switching Circuits', Trans AIEE, Vol. 57, pp. 713-723. Shannon made a good account of relating Boole's mathematical logic to switching circuits.

Digital design was launched by Claude Shannon in 1938 in his account of his thesis 'A Symbolic Analysis of Relay and Switching Circuits', Trans AIEE, Vol. 57, pp. 713-723. Shannon made a good account of relating Boole’s mathematical logic to switching circuits.

By the way, Shannon is better known for his major contributions to communications theory. Logical design is therefore quite a young subject and has grown with the development of computers and other digital systems. Further development of logical design theory is possible and ongoing.

The incredible and rapid development of personal computers has been made possible by the invention first of point contact transistors by Brattain, Bardeen and Shockley in 1948. Soon after, integrated circuits appeared with the development of planar transistors in about 1959.

First encounters
In the sixties, my first encounter with integrated circuits was with Fairchild resistor-transistor logic, known as rtl. This was quickly superseded by diode-transistor logic and then transistor-transistor logic, or ttl, that is still sometimes seen.

These developments were based on a sound understanding of the physics of solid state devices. The design of computers and other digital applications similarly requires a sound understanding of logical design theory and the Boolean algebra on which it is based.

In this article, I take a look at Boolean algebra as it is presented in popular books on digital design theory. In doing so, I hope to change some of the ways of thinking depicted in these books.

My aim is that you should discover that the Boolean algebra that is usually taught in technical schools or undergraduate universities is incomplete and inadequate. I redress this situation by filling in the missing bits.

My starting point is a detailed look at the exclusive-OR gate - ex-OR for short. This device is an essential part of Boolean algebra and should be treated as such. In order to reach the objective of being able to deal with these gates easily, I will develop basic theorems relating to these gates. I have also developed a method of using conventional Karnaugh maps to deal with them.

You will find that my approach is more decisive than the pattern matching idea given in some digital text books. I also explain why my approach has not been generally recognised, as far as I can tell, from reading books on digital design.

To get the most out of this article you will need to keep in mind my ground rules. I don’t feel that I understand something unless I can see how each part of it is arrived at. Consequently you will find that each step in my explanation depends on earlier steps described, down to the initial concepts that I describe first. If you start in the middle, the topic will look more complicated than it is.

Also, this article would have become too long if I had gone over ground well covered in existing books. Consequently I assume that you are familiar with basic Boolean algebra, as it is presented in popular books on digital design. This includes concepts such as a canonical expansion, the duality principle, and Karnaugh maps, abbreviated to K-maps. The way I display K-maps is the way I feel most comfortable.
with them. I find that this method makes them easier to draw too.

Exclusive-OR algebra is sometimes referred to as a Reed-Muller algebra. If you are familiar with R-M, then you might like to compare it with my approach. My approach has not originated from R-M, and you don’t need to understand this form of algebra in order to benefit from this article.

You might also have come across the concept of a Galois Field - GF(2) in particular. Exclusive-OR functions have a very wide spectrum of applications - particularly in communications and data storage applications, where GF(2) is used. I don’t go into this in this article.

If you have done any work with digital circuits, you will have noticed the rapid emergence of application-specific integrated circuits or ASICs. Many digital designers are now using programmable-logic devices, or pld.s. These are ASICs that offer instant digital designs.

A popular class of these devices are cplds, or complex plds, to distinguish them from the earlier programmable-array logic, and similar devices. Some of these plds are programmable. You can program them directly from your pc through a simple cable attached to your computer’s parallel port.

The whole process takes seconds. You don’t even have to remove the device from the printed circuit board for your application. This significantly speeds up the development process. The once popular ttl devices have gone into the junk box and discrete cmos logic is not far behind.

Many complex plds contain an exclusive-OR gate in their logic structure. Consequently, an easy way of dealing with these gates is useful.

This article offers such a way. If you are using a cpld development system such as Altera’s MaxPlus II, or one of the many other similar systems on the market, then you are being spoiled. These systems will do all your logical design drudgery work for you.

There are Altera systems in use at literally thousands of universities, technical colleges and design laboratories throughout the world. With this system you just have to type in what you want or draw it on the screen, make a few choices and press a button.

As an instructor in digital design I believe that you still benefit from understanding the theory. You will know what the system is doing, why it is doing it, and what the shortcomings and limitations in the system are.

Due to the convenience and capacity that these devices offer for development and small production run applications, new families of devices and new manufacturers of cplds, eplds, fpgas, etc., are still appearing. Devices keep getting better, faster, more efficient and more of them.

The proper use of these devices demands an understanding of the underlying theory that they all depend on. Think equations rather than circuits. In the context of cplds, circuits are both unnecessary and clumsy.

I believe that my use of K-maps for exclusive-OR algebra and my simplification method were original when I first investigated the material for this article in 1965. They may still be.

The derivation of Boolean algebras
To make the matter a bit more intelligible you need to go back briefly to the AND, OR, invert algebra.

Figure 1 shows truth tables for the AND, OR and invert operators, together with the symbols commonly used for these operators. If you look at the right-hand columns of these truth tables you can see the characteristic patterns of four possible values of two variables for the AND and OR operators and the characteristic pattern of two possible values for the inverse operator. For example the pattern for the AND operator is 0001 looked at from top to bottom.

I like to call the AND and OR operators binary operators and the invert a unary operator due to the number of variables involved in each case. To be more general you could construct 16 possible binary operators by making use of all possible patterns for the binary operators and you could construct four possible unary operators. Figure 2 illustrates the possibilities.

In this diagram, six of the binary operators are identified as non trivial by a tick along side them. Note that only one unary operator is non-trivial. The names for the operators are shown.

Trivial operators include such cases as the output stuck high or low, the familiar operators with one input inverted and cases where the output reduces to the case of a single input or the input inverted.

Looked at in this light, the AND, OR operators can be seen to be an arbitrary selection of two of the six possible non-trivial binary operators from which the well known Boolean algebra has been constructed. The fact that this is a complete algebra, in the sense that any arbitrary function of Boolean variables can be constructed from it, can be seen from the canonical expansion for this algebra.

Of course the AND and OR operators appear naturally when physical switches are connected together or where the construction of logic gates is considered, which has contributed to their popularity. This is a bit like the natural development of the decimal number system because we have ten fingers. We know we can develop other number systems. By the same token, we can also develop other Boolean algebras.

The theorems of AND, OR, inverse Boolean algebra can be derived by use of the truth tables in Fig. 1. Take the truth tables in Fig. 1 as the postulates - i.e starting point - for the algebra. From here, you simply plug the results from these truth tables into the truth tables constructed for the various theorems to prove the theorems.

This is the truth table method of proof - or proof by exhaustion. It is possible because there are only a finite number of possible combinations of values of Boolean variables so we can consider all possibilities. This method of proof allows you to derive all the results that we need directly.

Keep in mind that all mathematical structures are abstractions. I won’t do the derivation here since the results are well known. To refresh your memory the theorems are shown in Fig. 3. Note the way that they are arranged.

Considered first is the case of each binary operator with one variable and 0 or 1 as the second variable, then the case of each binary operator with one variable and the same variable uninverted or inverted as the second variable.
Exclusive-OR algebra basics

Now you can make another arbitrary choice of binary operators and develop another Boolean algebra. Take the exclusive-OR and AND operators. You don’t specifically need the inversion operator for this algebra since the exclusive-OR function has an inversion property built in. But you will need the inverse of variables.

Also, there is nothing to stop you using results already obtained for the AND, OR, Invert algebra, so all the results from this algebra carry over. You are actually extending this algebra.

Other choices of operators are possible. For example I could have chosen the exclusive-NOR operator with one of the AND or OR operators. Out of the six non-trivial binary operators, three of them are the same as the other three, but with outputs inverted. This gives them a degree of relatedness. A complete development of Boolean algebra should include at least the AND, OR, exclusive-OR and invert operators.

To start the process I will first extend Fig. 1 to show the exclusive-OR function as in Fig. 4. This diagram also shows the symbol that we will use for the exclusive-OR operator.

The basic theorems can be derived algebraically using the results from AND, OR, Invert logic. This is simpler than drawing up the truth tables.

In terms of the inclusive-OR, the exclusive-OR is given by

\[ x \oplus y = xy' + x'y \]

where \( \oplus \) represents the exclusive-OR operator.

The theorems have been labelled for convenience in referencing, as will be the following ones.

Equation T1 shows that applying the same signal to both inputs gives an output stuck low, while T2 shows that applying a signal and its inverse to an exclusive-OR gives an output stuck high.

In T3, applying a logic low signal to one input gives an output that is the same as the other input. Equation T4 shows that applying a logic high to one input gives an output that is the inverse of the other input.

Both T3 and T4 show the well known result that the exclusive-OR gate can be used as a means of controlling the polarity of a logic signal under the control of one of its inputs. This result is frequently used for toggling a bit in a microcontroller output between high and low by exclusive-ORing the bit with a logic-1 bit.

Inversion theorems

Equations T5 and T6 derived in Fig. 5 are theorems relating to inversion. In addition, T6 follows from T5 by double inversion. These are in addition to T4.

\[ (x \oplus y)' = x'y' \]

Many of these results can be seen by considering physical arguments. However, by representing all results in the form of equations you can avoid having to depend on physical arguments - which can quickly get you in a tangle.

Conmutative, associative and distributive laws

The commutative, associative and distributive laws are similar to the case of the inclusive OR. Proofs can be made by the truth table method or by expanding both sides and using the results for the inclusive-OR case. The proofs are omitted here.

These theorems show how to deal with parenthesis and rearrangements.

\[ x \oplus y = y \oplus x \] Commutative law
\[ x \oplus (y \oplus z) = x \oplus (y \oplus z) \] Associative law
\[ x \oplus (y \oplus z) = x \oplus (y \oplus z) \] Distributive law

Converting AND, OR Invert logic

The next theorem provides a way to convert AND, OR logic to AND, exclusive-OR logic. This will be the starting point in the development of a systematic approach to finding forms of functions that include an exclusive-OR operator.

Theorem T10 states that if \( g, h \) are functions of the same switching circuit variables, then if \( f = g \oplus h \) and \( gh = 0 \), then \( f = g + h \). Disjunction theorem T10 can be proved as follows:

\[ f = g \oplus h = gh' + g'h \]

since \( gh = 0 \),

\[ g + h = g(1 + h) = (g' + g)h = g'h + gh \]

which is the required result.

Canonical forms for the exclusive-OR logic

Theorem T10 can be used for expressing a function given in terms of the + operator in terms of the \( \oplus \) operator. The function in terms of the + operator is expanded to minterm form, so that all terms are disjoint - i.e. the product of any two terms is 0. The + operators can then be replaced with \( \oplus \) operators.

This means that any function can be expressed in exclusive-OR form directly from its truth table or Karnaugh map. A canonical form for the exclusive-OR operator is therefore with three variables:

\[ f(abc) = a'b'c'b c'b'c'c'b'c'c'b c'c'b'c'c'b c'c'b'c'b c'c'b'c'b c'c'b'c'b c'c'b'c'b c'c'b'c'b c'c'b'c'b c'c'b'c'b c'c'b'c'b c'c'b'c'b c'c'b'c'b c'c'b'c'b c'c'b'c'b c'c'b'c'b c'c'b'c'b c'c'b'c'b c'c'b'c'b c'c'b'c'b c'c'b'c'b c'c'b'c'b c'c'b'c'b c'c'b'c'b c'c'b'c'b c'c'b'c'b c'c'b'c'b c'c'b'c'b c'c'b'c'b c'c'b'c'b c'c'b'c'b c'c'b'c'b c'c'b'c'b c'c'b'c'b c'c'b'c'b c'c'b'c'b c'c'b'c'b c'c'b'c'b c'c'b'c'b c'c'b'c'b c'c'b'c'b c'c'b'c'b c'c'b'c'b c'c'b'c'b c'c'b'c'b c'c'b'c'b c'c'b'c'b c'c'b'c'b c'c'b'c'b c'c'b'c'b c'c'b'c'b c'c'b'c'b c'c'b'c'b c'c'b'c'b c'c'b'c'b c'c'b'c'b c'c'b'c'b c'c'b'c'b c'c'b'c'b c'c'b'c'b c'c'b'c'b c'c'b'c'b c'c'b'c'b c'c'b'c'b c'c'b'c'b c'c'b'c'b c'c'b'c'b c'c'b'c'b c'c'b'c'b c'c'b'c'b c'c'b'c'b c'c'b'c'b c'c'b'c'b c'c'b'c'b c'c'b'c'b c'c'b'c'b c'c'b'c'b c'c'b'c'b c'c'b'c'b c'c'b'c'b c'c'b'c'b c'c'b'c'b c'c'b'c'b c'c'b'c'b c'c'b'c'b c'c'b'c'b c'c'b'c'b c'c'b'c'b c'c'b'c'b c'c'b'c'b c'c'b'c'b c'c'b'c'b c'c'b'c'b c'c'b'c'b c'c'b'c'b c'c'b'c'b c'c'b'c'b c'c'b'c'b c'c'b'c'b c'c'b'c'b c'c'b'c'b c'c'b'c'b c'c'b'c'b c'c'b'c'b c'c'b'c'b c'c'b'c'b c'c'b'c'b c'c'b'c'b c'c'b'c'b c'c'b'c'b c'c'b'c'b c'c'b'c'b c'c'b'c'b c'c'b'c'b c'c'b'c'b c'c'b'c'b c'c'b'c'b c'c'b'c'b c'c'b'c'b c'c'b'c'b c'c'b'c'b c'c'b'c'b c'c'b'c'b c'c'b'c'b c'c'b'c'b c'c'b'c'b c'c'b'c'b c'c'b'c'b c'c'b'c'b c'c'b'c'b c'c'b'c'b c'c'b'c'b c'c'b'c'b c'c'b'c'b c'c'b'c'b c'c'b'c'b c'c'b'c'b c'c'b'c'b c'c'b'c'b c'c'b'c'
The majority function

Certain functions are true in both inclusive and exclusive-OR form. Take, for example, the majority -- or arithmetic carry -- function:

\[ a \cdot b \cdot c + a \cdot b \cdot c + a \cdot b \cdot c \]

Alternative representation of basic theorems

Equations T1-4 are dual theorems and are frequently labelled as theorems. A useful theorem

The duality principle states that "Given any of the basic theorems of Boolean algebra, changing OR operators to AND operators, AND operators to OR operators, and changing zeros to ones and ones to zeros where these occur leads to another of the basic theorems." This applies specifically to the AND and inclusive OR operators.

Duality in the exclusive-OR theorems

The duality principle states that "Given any of the basic theorems of Boolean algebra, changing OR operators to AND operators, AND operators to OR operators, and changing zeros to ones and ones to zeros where these occur leads to another of the basic theorems." This applies specifically to the AND and inclusive OR operators.

However, if you apply the inversion theorems to both sides of the basic theorems of the exclusive-OR operator you can see that T1 becomes T2 and vice versa. The same holds for T3 and T4. This gives a sort of duality to exclusive-OR operators.

A useful theorem

A theorem that gives exclusive-OR logic an unusual degree of freedom is T11: If f, g, h are functions of the same switching circuit variables and \( f = g \cdot h \), then \( g = f \cdot h \) and \( h = g \cdot f \).

Theorem T11 can be derived as follows. Given that \( f = g \cdot h \), then adding \( h \) to both sides of the equation gives:

\[ f \cdot h = g \cdot h \cdot h = g \]

since \( h \cdot h \) disappears due to T1 and T3. As a result,
Similarly by the extended form of T3, where the minterm is plotted once or an odd number of times it will be retained.

Generalising this observation for the exclusive-OR form gives the rules: 'any minterm included in the function must be plotted an odd number of times,' and 'any minterm that is to be excluded from the function must be plotted an even number of times, or zero.'

Two examples of this result are shown in Fig. 8. The first result is the example given at the start of this section. You can see that one term a'bc has been plotted twice and is therefore excluded from the equation.

The second example is the function that had the same form for the exclusive-OR operators as it had for the AND, OR, Invert operators. Here, one term has been plotted three times and is therefore included in the function.

\[ x \otimes y = x'y + xy' \]

Fig. 7. Exclusive-OR function plotted on a Karnaugh map.

Fig. 8. Examples of exclusive-OR forms of logic equations.

The function:
\[ A'B'C' + AC + B'C = C \oplus A'B \]

Fig. 9. Four variable examples of exclusive-OR functions.

The function:
\[ f_1 = a'b'c + a'cd + bc'd + ac'd' + ab'd' = a\oplus b' \oplus bd \oplus ac'd \]

Fig. 10. An example of using a Karnaugh map to find an expression for a Boolean function in terms of exclusive-OR operators.

The function:
\[ f_2 = (a \oplus b) \oplus (c \oplus d) = a' \oplus b \oplus c' \]

Fig. 11. Another example of using a Karnaugh map to find an expression for a function in terms of the exclusive-OR function.

With a little practice, the exclusive-OR forms can be readily found for three variable functions and sometimes for four variable functions. Figure 9 shows two examples of four variable exclusive-OR functions.

A procedure for using the K-map to find opportunities for simplification of a logic expression by using exclusive-OR gates, by inspection, is to look for a grouping of ones that could be simplified if an extra square or squares between them are filled in with ones to combine the terms. This is applicable if only one exclusive-OR is needed to represent the function. The following examples show a more general approach where more than one exclusive-OR is needed.

To plot a function given in exclusive-OR form, simply plot individual terms by placing ones in all squares for the term and cancel all squares that have an even number of ones.

Don't care conditions are treated in the K-map approach the same way as for the inclusive-OR case: the don't care term is used or not, as required. For the exclusive-OR function, don't care terms can be plotted an even or odd number of times.

In the case of \( f_1 \) in Fig. 9, the minimal exclusive-OR form of the equation may not be so easily found by inspection. Here it would be useful to have an algebraic simplification procedure. I hope that the description of my algebraic simplification procedure will appear in a subsequent article.

Using a K-map to find ex-OR representations

Two more examples are shown in Figs 10 and 11. Here, more than one exclusive-OR is required to represent the function. These figures show the step-by-step procedure to be followed.

Consider the function plotted on the K-map shown in Fig. 10a). You might start by plotting variable \( a \), as in 10b). This covers three of the ones in the map but places an additional 1 at position abc. The additional ones in Figs 10 and 11 are shown in lighter text.

Next, you might plot variable \( c \) as shown at 10c). This cancels the extra one at abc, covers the ones at position ab'c and a'bc but cancels the one at position ab'c. To regain a one at this position, place an additional one there and map that position as shown at 10d). This gives the final result as shown below the K-map at 10d).

From a practical point of view, you might implement the resulting expression as follows, since there is generally only one exclusive-OR function available in a complex pld macrocell:

\[ y = \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \oplus \
method is somewhat heuristic but at least in general the method gives the result in a direct way.

The last example show a slightly different way of using the Karnaugh map. Assume that you entered the following expression into your complex-pld hardware-description language software:

\[ y = a \oplus c \oplus d \oplus a b c + d + b c + d + a b c \oplus d \]

The compiler in your cpld software has came up with the following expression for this logic function and you would like to confirm that it is the same function,

\[ y = a \oplus (b c \oplus a b c \oplus a b c d) \]

The Karnaugh map shown in Fig. 12 confirms the identity. Note that you can plot all the terms in parenthesis as a function and use this as a whole with the exclusive-OR approach with the term \( a \).

A reduction of five product terms to three is achieved with this function. The use of the Karnaugh map is obviously a lot less work than expanding out the exclusive-OR function.

In summary

Figure 13 is a round up of the theorems for the exclusive-OR operator. This may be about as far as you need to go with this subject. But, it is possible to treat the simplification of exclusive-OR forms of equations by a systematic algebraic procedure. I hope to bring you my description of this procedure in a later article.

This article has demonstrated that a complete Boolean algebra can be developed in terms of the exclusive-OR operator in place of the inclusive-OR operator. Examples have been given that demonstrate the use of this approach to Boolean algebra. The exclusive-OR algebra adds to and does not replace inclusive-OR algebra. The algebra is complete with simplification methods including the use of conventional Karnaugh maps.

I hope that reading this paper will have given you a few new ideas about using Boolean algebra and that you will no longer be put off when you see exclusive-OR operators in logic expressions.

\[ y = a \oplus (b'c' + abc + ab'c + b'cd + a'b'c'd) \]

Fig. 13. Summary of the theorems for the exclusive-OR operator.

T1. \( x \oplus 0 = x \)
T2. \( x \oplus x = 0 \)
T3. \( x \oplus 0 \oplus x = 1 \)
T4. \( x \oplus 1 \oplus x = 1 \)
T5. \( (x \oplus y) \oplus (y \oplus x) = x \oplus y \)
T6. \( x \oplus y \oplus x = x \oplus y \)
T7. \( (x \oplus y) \oplus (y \oplus z) = x \oplus (y \oplus z) \)
T8. \( x \oplus y \oplus z \oplus (y \oplus z) = x \oplus y \)
T9. \( x \oplus (y \oplus z) = x \oplus y \oplus z \)
T10. \( f = g \oplus h \) and \( gh = 0 \), then \( f = g + h \)
CIRCUIT IDEAS

Over £600 for a circuit idea?

New awards scheme for circuit ideas

- Every circuit idea published in Electronics World receives £35.
- The pick of the month circuit idea receives a Pico Technology ADC42 — worth over £90 — in addition to £35.
- Once every six months, Pico Technology and Electronics World will select the best circuit idea published during the period and award the winner a Pico Technology ADC200-50 — worth

How to submit your ideas

The best ideas are the ones that save readers time or money, or that solve a problem in a better or more elegant way than existing circuits. We will also consider the odd solution looking for a problem — if it has a degree of ingenuity.

Your submission will be judged on its originality. This means that the idea should certainly not have been published before. Useful modifications to existing circuits will be considered though — provided that they are original.

Don’t forget to say why you think your idea is worthy. We can accept anything from clear hand writing and hand-drawn circuits on the back of an envelope. Type written text is better. But it helps us if the idea is on disk in a popular pc or Mac format. Include an ascii file and hard-copy drawing as a safety net and please label the disk with as much information as you can.

Turn your PC into a high-performance virtual instrument in return for a circuit idea.

The ADC200-50 is a dual-channel 50MHz digital storage oscilloscope, a 25MHz spectrum analyser and a multimeter. Interfacing to a pc via its parallel port, ADC200-50 also offers non-volatile storage and hard-copy facilities. Windows and DOS virtual instrument software is included.

ADC42 is a low-cost, high-resolution a-to-d converter sampling to 12 bits at 20ksample/s. This single-channel converter benefits from all the instrumentation features of the ADC200-50.
Medium-power inverting driver

Since the 555 can sink and source up to 200mA, it provides sufficient power to drive small lamps, relays, motors and low-power inverters.

As shown, it can be used as a static or alternating inverting 200mA driver capable of operating at moderately high frequencies. In H-bridge inverters, it replaces the normal gate and power transistor, with the bonus that it has in-built protection.

Make sure that the input cannot exceed the supply voltage. If there is no risk of negative input excursions, the diode can be left out.

K Samson
Thornton Cleveleys, Lancashire C8

Capacitance bridge

Comparing two time constants is the method used in this bridge. Two integrators producing triangular waves are connected to one comparator to produce a comparison between the unknown and a standard. Balance is indicated by LEDs.

At balance, \( R_x C_y = R_y C_x \) and

\[ C_z = R_y C_y / R_x \]

where \( C_z \) is constant, \( R_y \) is a calibrated variable resistor and \( R_x \) is the range-selecting resistor. In the balance condition, both integrators produce a triangular wave of the same frequency. Their outputs A and B are capacitively coupled to a rectifier and smoothing capacitor to drive comparator IC3a.

Output from IC3a drives the indicator amplifier IC3b, which illuminates 'high' and 'low' LEDs. In the out-of-balance state, one of the integrators will have too long a time constant and lower amplitude than the other, the LEDs indicating the fact.

Since only relative values are important, the only components whose absolute values need care are the range-selecting resistors and \( C_y \).

ADC42 Winner

Time constant measurement of two CR circuits, translated to a voltage output with led indication, is the basis of this capacitance bridge.

February 1999 ELECTRONICS WORLD
Chopper-stabilised bridge amplifier

This instrumentation amplifier with a bridge input is stabilised against input offset voltage drift by means of a chopper driven by a microcontroller and is of the type used in load cell measurement, pressure sensors and others. 'Chopping' is removed in software.

Between points A, B to point C, the circuit is that of a conventional instrumentation amplifier, before which comes the 4066 cmos switch ic, receiving its switching input from the microcontroller. During alternate switching intervals, points X, Y are connected to point A, B and vice versa. Input voltage plus drift is amplified in one state of the switch and amplified in the reverse condition in the other. It is then converted to digital form in the ICL7135 a-to-d converter and stored in the controller’s memory.

Since the resistance from A to B and from both to ground is of close balance, only drift and offset drift is cancelled, i.e:

\[ V_{\text{even}} = k(\text{Vin} + V_{\text{offset}}) \]
\[ V_{\text{odd}} = k(-\text{Vin} + V_{\text{offset}}) \]

Subtracting:
\[ V_{\text{out}} = kV_{\text{in}} \]

The whole thing goes in a thermally insulated case, care being taken with thermocouple and leakage current effects. The 100Ω and 1Ω resistors should be matched pairs of metal-film types.

In the original, all calibration data is held in an eeprom.

Popovici Dan lancu
Bucharest
Romania
C17

Switch-operated set/reset and bistable flip-flops

The main feature of these two flip-flop circuits is their very low off current - about 65µA - and they always start in the off state.

At (a) is the set/reset type, which has separate switches for each state and which may have a relay instead of S1 or S2. For lowest off state current, R1 may be 150kΩ and R6 270kΩ, off current being 65µA and current in the on state 4mA - a ratio of more than 60:1.

Circuit (b) is a bistable arrangement, in which the same switch triggers both states. Cycling rate is slow at about 100ms with C1 at 0.47µF; contact bounce may cause problems with lower values.

Current gain spreads cause no trouble, several examples of the transistors shown have been tried successfully. Increasing the value of R1,2 to 10kΩ reduces on-state current; at 1kΩ, the on voltage across these resistors is 4V.

For other supply voltages, resistors must be scaled accordingly.

Peter Kenyon
Almancil
Portugal, C19

Two flip-flops for manual operation by switches. At (a) is a set/reset type, which could be modified to take a split power supply and a centre-biased toggle switch. The bistable at (b) uses one switch. Both exhibit an off-state current of as low as 65µA.

122 ELECTRONICS WORLD February 1999
The TELEBOX is an attractively finished case which houses powered unit, containing all electronics needed for operation. Includes \Micrometric switches, \Atari, \Sony, \Commodore, Philips, Talsam, AMSTRAD etc. The composite video signal is passed through an analogue to digital converter, which digitises the video signal, allowing for easy storage and retrieval. The TELEBOX features a high-quality power supply, ensuring reliable operation. The TELEBOX is compact and portable, making it ideal for use in various environments.

The TELEBOX is available in a variety of colors, including black, white, and red. The color depends on the customer's preference and the specific model of the TELEBOX being purchased. The TELEBOX comes with a 1-year warranty against manufacturing defects.

The TELEBOX is designed for use in a wide range of applications, including TV broadcasting, video production, and entertainment. It is suitable for use in homes, offices, and small businesses. The TELEBOX is also ideal for use in educational settings, such as schools and training centers.

TEST EQUIPMENT & SPECIAL INTEREST ITEMS

The TELEBOX is also available as a test equipment and special interest item. It is suitable for use in a variety of applications, including electronics testing, home entertainment, and education. The TELEBOX comes with a 1-year warranty against manufacturing defects.

The TELEBOX is also available as a test equipment and special interest item. It is suitable for use in a variety of applications, including electronics testing, home entertainment, and education. The TELEBOX comes with a 1-year warranty against manufacturing defects.

The TELEBOX is also available as a test equipment and special interest item. It is suitable for use in a variety of applications, including electronics testing, home entertainment, and education. The TELEBOX comes with a 1-year warranty against manufacturing defects.

The TELEBOX is also available as a test equipment and special interest item. It is suitable for use in a variety of applications, including electronics testing, home entertainment, and education. The TELEBOX comes with a 1-year warranty against manufacturing defects.

The TELEBOX is also available as a test equipment and special interest item. It is suitable for use in a variety of applications, including electronics testing, home entertainment, and education. The TELEBOX comes with a 1-year warranty against manufacturing defects.
Linear sawtooth from a 555

A 555 free-running oscillator provides a ramp output, but not one sufficiently linear for measurement purposes. This one uses a constant-current source to charge the capacitor C1 in a linear manner. The resulting output was used to simulate a chart recorder output on a CRT display.

Output from pin 3 is a sync., the input to pin 2 sync. in for one-shot working and the sawtooth comes from pin 6 and is buffered for use.

M J Nicholas
Bournemouth
Dorset
C18

Lf signal rectifier

Many signal rectifiers have diodes in the signal path. This one doesn't; instead, there is a variable "ground" that is only present during half-cycles of the input, making it possible to obtain an output with little or no distortion.

Looking at the circuit diagram in Fig. 1, diode D1 does not conduct during negative half-cycles and R1, 3 form a potential divider, pin 2 of IC2a being held at ground by its feedback through D4. Loss of amplitude in the divider is compensated in IC1a by the addition of R7 to change it from a unity-gain follower to a amplifier.

During positive excursions, D1 conducts and maintains the non-inverting input of IC1a at ground. As the inverting input is at the same level, the op-amp is now an inverting amplifier, so that the output appears as a negative output with the same amplitude. Resistor R7 has no effect at this time since both connections are at the same level.

Waveforms are shown in Fig. 2. Diode D4 clamps IC2a output at 0.6V to prevent saturation, which would introduce distortion at crossover, since there would be a delay between change in polarity and the start of regulation of the ground level, as shown in Fig. 3.

A certain amount of distortion is caused by the level at the non-inverting input of IC2a being added to the input signal when it is working as an inverter, which does not happen when it is a non-inverter. The distortion is clearly worse with small signals. There is also a difference in input impedances in the two half-cycles.

Van den Abeele Bernard
Evergem
Belgium
C15
### BASIC Stamp Computers

BASIC Stamps are small computers which are programmed in PBASIC, a powerful BASIC dialect that includes many enhancements specifically designed for embedded control. PBASIC programs are downloadable directly from a PC to the BASIC Stamp where they are executed from on board EEPROM.

- **Development environment:**
  - Program directly from PC.
  - Reprogrammable up to 10,000 times.
  - I/O pins can source/sink up to 20mA.
  - Easily interfaced to ADCs, LEDs, motors, relays.
  - Built in functions for Serial, PWM, pulse in/out etc.

- **Basic Stamp 1 - 8 I/O:**
  - 240 baud serial, 16 pin SIP Module - IRED2

- **Basic Stamp 2 - 16 I/O:**
  - 2D 54 pin DIP - IRED2

- **Basic Stamp 3 - 24 I/O:**
  - 240 baud serial, 32 pin DIP module - IRED2

- **Basic Kits from IRED:**
  - (All prices exclude V.A.T. and delivery)

#### CONTROL & ROBOTICS

**Milford Instruments**

**Basic Stamps**

- **Re-Programmable**
- **Basic language**
- **RS232 Serial ports**
- **8 or 16 I/O lines**
- **PB/PDMA**
- **Fast development**

**Scenix**

- **Fastest 8-bit micro**
- **50MIPS**
- **Flash Empon**
- **18/28 pins**
- **PIC16C5X**
- **Pin replacement**

**R3x**

- **Humanoid**
- **5-Axis Arm**
- **Walking Insect**

**Servo Controller**

- **Control up to 8 servos**
- **RS232 Commands**

**IR Decoder**

- **Uses any remote**
- **7 digital outputs**
- **Pyro switch**
- **Re-Programmable**

---

**CIRCLE NO.113 ON REPLY CARD**

---

**CIRCLE NO.114 ON REPLY CARD**
**POWER AMPLIFIERS**

<table>
<thead>
<tr>
<th>Model</th>
<th>Type</th>
<th>Output Power</th>
<th>Weight</th>
<th>Size (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>STA900</td>
<td>2x490W (4ohm)</td>
<td></td>
<td>15kg</td>
<td>39x38x23</td>
</tr>
<tr>
<td>STA300</td>
<td>2x190W (4ohm)</td>
<td></td>
<td>1kg</td>
<td>39x38x23</td>
</tr>
<tr>
<td>STA150</td>
<td>2x160W (4ohm)</td>
<td></td>
<td>14kg</td>
<td>39x38x23</td>
</tr>
</tbody>
</table>

**DCA50 COMPONENT ANALYSER**

- **Functionality**: Analyzes resistors, capacitors, diodes, transistors, and ICs.
- **Features**: Displays component values and identifies them.
- **Components**: Measures diodes and LEDs.
- **Applications**: Ideal for hobbyists and professionals.

**SPY CAMERAS**

- **Model**: 4.0MP size 39x38x23mm spy camera.
- **Features**: With 6 infra red leds (gives the same illumination as a small torch)
- **Price**: £108.00

**WATCH SLIDES ON TV**

- **Device**: Liesgang diatu automatic slide viewer.
- **Features**: Plays slides on TV with composite video out.
- **Price**: £49.50 per 10,000

**AMIGA GUNLOCK PCB**

- **Features**: For titling videos, has a 23pin D connector.
- **Price**: £49.50

**CMOS TTL 74HC 74F LINEAR TRANSISTORS KITS**

- **Price**: £1.55 each (18-264 vac input 8 pin DIL package)

**TRANSDUCER**

- **Features**: Offers different sizes and readings.
- **Price**: £2.95 each

**MIL HEMT**

- **Features**: Uses different sizes and readings.
- **Price**: £2.60 each

**SHOCK MOUNT**

- **Features**: Has varying sizes and readings.
- **Price**: £2.40 each

**DIODES & LEDS**

- **Price**: £92.76 + vat = £109.00

**DISTRIBUTORS OF ELECTRONIC VALVES**

- **DISTRIBUTOR**: LANDREX SUPPLIES LTD.
- **Contact**: DORSET, LANS.

**DISCOUNTS**

- **Discount**: 10% for orders over £100

**RITEK 5V BATTERIES**

- **Model**: Carc-A-Volt PC21/02
- **Capacity**: 240mAh

**GAMEBOY BATTERIES**

- **Model**: Carc-A-Volt PC41/02
- **Capacity**: 550mAh

**PC BOARD CAMERAS**

- ** Features**: All board cameras all with 512x582 pixels.
- **Price**: £159.97

**COAXIAL CONNECTORS**

- **Features**: 1.5mm coaxial connector for connecting coaxial cable.
- **Price**: £139.95

**COMMUNICATIONS VALVES**

- **Features**: Different types and sizes.
- **Price**: £64.99

**TRANSMITTER PCB**

- **Features**: Various sizes and readings.
- **Price**: £9999

**MULTIPLIER PCB**

- **Features**: With different sizes and readings.
- **Price**: £69.95

**5 BUTTON CELL 6V 280mAh BATTERY WITH WIRES**

- **Model**: Carc-A-Volt PC7/02
- **Capacity**: 31500mAh, 6V 280mAh

**12V 5AH.. AA 950mAH.. AAA 290mAH.. D 4AH.. C 2.3AH..**

- **Features**: Different types and sizes.
- **Price**: £13.00 each

**EQUIPMENT PRICES**

- **Prices**: Correct when published.
- **Contact**: LANGREX SUPPLIES LTD.

**DEMO SOFTWARE**

- **Source**: Available from our Web Address

**24 HOUR EXPRESS MAIL ORDER SERVICE**

- **Service**: On stock items.
Paul Bennett's three-phase power inverter uses high-frequency switching to avoid the bulky and expensive inductive components associated with non-switching 400Hz inversion.

400Hz inverter

This design is for a three-phase 400Hz inverter for running 200V aircraft equipment from a normal 230V mains supply. High-frequency techniques are used, i.e. there are no 400Hz magnetics or other special components. Each phase is separately regulated and isolated from the mains, output neutral being connected to earth. Maximum output is around 1kVA, about 3A per phase.

Input converter
This design divides into two parts – the mains input converter and the three phase output bridge.

For the input side, a half-bridge forward converter is used, sometimes called an asymmetric half bridge. This provides two outputs, ±200V either side of ground. Only the positive side is sensed for regulation. Acceptable regulation is achieved for the negative output by cross coupling the smoothing inductors.

Mains supply is filtered, rectified and smoothed. A thermistor with a negative temperature coefficient provides inrush limiting. Two IGBTs are used for the switching transistors, type IRGP440U from International Rectifiers. These are 500V die-size 4 types but size 3 or above, 500 or 600V ultra-fast types should prove satisfactory. Size 5 mosfets could also be used.

When IGBTs are used, a reverse diode across the transistor is needed to clamp any reverse voltage transient. The devices are rated for some reverse voltage, but at unrealistically low current for most power-switching applications. A fast turn on diode should be used such as a slow or moderate reverse recovery speed type.

Generally with low voltage output switch mode power supplies, diode reverse recovery can be ignored. The resulting current spike at turn on of the power switches is very short and requires little energy.

As the output circuit impedance level increases with higher output voltages, the diode recovery transient becomes more significant – even with the latest ultra fast types. This can be tolerated, but it causes higher EMI, extra stress in the switch and diode, and fast current sensing problems.

The spike can be reduced by slowing the turn on of the power switch, but this increases losses. The technique I have used is a current snubber. This device slows down the current rise by placing an inductor in series with the switch.

At turn off, some energy is returned to the supply by the BYW96 diodes. The IGBTs now turn on at zero current and the current wave form is very clean.

Another bonus is that during output short circuits, such as with the output capacitors uncharged, the snubber lengthens the PWM duty cycle required. This reduces demands on the current limit speed and propagation delays.

Drive to the IGBTs is provided by an RM8 size transformer. The driver IC and IN4148 diode network is effectively the same topology as the power converter. This arrangement ensures proper reset of the RM8 core every cycle under all conditions, including under current limit when the duty cycle may vary rapidly.

The pulse-width modulation IC is the popular voltage mode SG3525A, running at around 30kHz and 50% maximum duty cycle. Digital current limiting is employed which terminates the PWM on a pulse by pulse basis.

The LM319 provides more accurate limiting than the SG3525A’s shut-down pin. An RM6 transformer senses current at the collector of the lower IGBT. The current limit sets the inverter's maximum overall power output to around 1kW, giving a peak switch current of about 7A.

Output bridge
Design of the three-phase output bridge is conventional. It uses closed-loop PWM at 25.6kHz.

Three reference sine waves are generated by the crystal oscillator, counter/divider, eprom and d-to-a converter circuit. All three phases are identical, apart from a 120° and 240°

Warning
In addition to live mains, this circuit involves equally lethal dc voltages. Don’t forget that high-voltage capacitors can hold lethal charges when the circuit is switched off too.
CONTROL ELECTRONICS

Packaged inverter

Artificial horizon and motors

Mains input converter. Its main task is to produce a ±200V supply from the mains. At the bottom is the 3525 pulse-width modulator.

Artificial horizon and motors

The most significant address line is used to swap between two look up tables which swap the codes around for the A and B phases. This reverses the phase rotation.

The algorithm used, in floating-point decimal, is:

\[
A = \text{INT} \left( 128 \times \left( 1 + \sin(2 \pi \times (x + 0.5) / 4096) \right) - 0.5 \right)
\]

\[
B = \text{INT} \left( 128 \times \left( 1 + \sin(2 \pi \times (x + 1365.83) / 4096) \right) - 0.5 \right)
\]

\[
C = \text{INT} \left( 128 \times \left( 1 + \sin(2 \pi \times (x + 2731.17) / 4096) \right) - 0.5 \right)
\]

To check the rounding errors, etc., the resulting sine wave should look perfect with no flat on the peak or trough. The resulting code should contain equal numbers of 0s and 255s and change from 127 to 128 as the address changes from 2047 to 2048 for phase A.

The reference signal is compared to a sample of the output by an LF347 op-amp. This modifies the reference to the pwm generator to remove any distortion in the output. I chose the compensation to give a good compromise between stability and transient response.

1RGP440U

BYW96C

RUR8100

68

68

2000µ

200V

250V

+200V

-200V

0V

1N4148

220R

100µ

47n

Adjust for 1kW

Adjust for 200V

SG3525A

ICL7667

22R

10k

47n

20k

100p

20k

22k

100p

1n

1k

1N4148

BYW96C

RUB8100

HFA8

TB60

200µ

200V

250V

470K

+12V
An LM319 compares the modified reference to a 25.6kHz triangle wave derived from the crystal. Basic PWM is then modified by the monostables to give two outputs including some dead time to avoid cross conduction in the bridge.

The modified reference is not bounded to the triangular wave so the PWM could saturate positive or negative. This is undesirable as the bridge current is sensed with transformers which cannot pass DC.

To prevent total saturation addition pulses are added to the PWM by the NAND gates. Current limiting is achieved by terminating each PWM pulse on detection of over current at each switch. The 74HC74 bistable device is set by an over-current turning off both PWM drives. It is then reset twice each cycle at 51.2kHz.

As with the input converter IGBTs are used, type IRGBC20U. Other ultra-fast IGBTs, size 2 or 3, 500 or 600V, should prove suitable or size 4 MOSFETS.

Recovery problems
Diode recovery is potentially a bigger problem in PWM inverters, where the duty cycle swings close to 0 or 100%.

The snubber used in the input converter cannot be used as there is insufficient time for it to properly reset. Instead, after much experimentation, I simply limited the turn on speed by inserting a 100Ω gate resistor. A 1N4148 diode across this resistor makes sure that turn off is still as fast as possible.

Electromagnetic interference is not a significant problem as the converter is referenced to true ground. Gate drives are provided by high-speed opto couplers and buffer ICs. This means that four floating gate drive supplies are needed, provided by a simple DC-to-DC converter.

The low side switches use a common supply. Current sensing is by six RM6 size transformers. Each transistor is individually sensed so that all combinations of phase-to-phase and phase-to-neutral faults are protected against.

A single potentiometer sets the current-limit comparator references. This determines the overall kVA rating of the inverter and is set to approximately 5A for 3A RMS output.

Output filtering
The output filter inductor and capacitor have to be chosen carefully and an exacting compromise is required. Too large a value for L will cause droop at the 400Hz output frequency necessitating a higher DC supply. Too low a value will cause over current in the bridge.

Diode recovery is potentially a bigger problem in PWM inverters, where the duty cycle swings close to 0 or 100%.
value will increase the peak transistor current and associated losses and output 25.6kHz ripple. Too high a value for C will increase circulating current inside the bridge legs, and again if the value is too low, 25.6kHz ripple will increase.

Further constraints are placed on L by available core sizes and materials. The values chosen just allow 115V output with 400V dc bus and give around 1.5V rms 25.6kHz ripple.

The complete inverter was spread out on an aluminium sheet ground plane then repackaged in a custom-made box. A 12V 100ft/min fan was used for cooling with the +12V and +5V supplies derived from 78/79 series regulators and a 12VA 50Hz transformer. Both converters have fuses between the converters and electrolytic capacitors.

It is surprising how many commercial power switching designs have inadequate fusing. Without it, all manner of expensive blow-outs can occur.

Five neon indicate, mains present, intermediate dc voltage present and output phases on. The output was tested using various 400Hz loads, small fans and blowers, an artificial horizon and array of 115V 100W lamps.

**Simplifications and enhancements**
Various simplifications and enhancements appear possible. Numerous possibilities exist for the sine wave references, with perhaps reduced precision. One technique is to have a six-pole filter extract the fundamental from the 400Hz square wave.

Three 120°-spaced square waves are easy to generate with logic. PWM signals can be directly encoded ineprom with a simple RC filter to decode the pwm back to a sinewave. A 1.6384MHz clock would allow 64
samples per 400Hz cycle with 65 levels. All six drive signals for the bridge could be encoded in eprom. This would reduce the component count significantly but would not allow closed loop waveform or voltage regulation. Only the overall output could be regulated by regulating the dc input.

Recently Micro Linear has brought out a sine-wave reference generator IC series, the ML2037/8/9, and a simple three-phase pwm driver IC including sine reference, the ML4423. The former works well and is very flexible with regard to clock and output frequencies. Synchronising three at 120° may be tricky or an analogue means will be needed for the other phases. The ML4423 proved less satisfactory with various stability and output purity problems. It is intended for low cost driving of three phase motors. Linfinity has brought out an audio pwm controller for class D amplifiers. This is designed to drive two full bridges for stereo, and features closed loop and current limiting. Fully independent operation of each phase may be a problem but these should match the precision of the eproms with far fewer components.

My prototype included a little extra circuitry to offer 50Hz, variable frequency, variable amplitude and linear voltage-to-frequency operation for motor driving. Slightly more logic or different clock frequency could give 60Hz.

The output control loop may benefit from refinement for difficult loads. The system may even benefit from open-loop operation in some circumstances. Various ICs are available for high side driving bridges. These would eliminate the need for the dc-to-dc converter and opto-couplers. These may not be able to cope with the split rails about ground though. The HCPL320 and HCPL350 igbt opto-coupled gate drivers from Hewlett Packard are simpler and cheaper than the HCPL2201 and ICL7667CPA employed here.

The input converter needs little regulation, so a power-factor correction scheme could be added. This would do away with the electrolytic and surge suppressor. But it would also result in much higher peak currents in the input converter. If the inverter only needs to run at one output frequency, say 400Hz, then a transformer could be used at the output. This could be wired delta/star fashion to produce a neutral and provide isolation. The three phase bridge could then work directly from rectified mains or the usual boost power-factor correction circuit.

Only one current sense per phase would be needed. The disadvantage would be getting hold of a suitable transformer.

Thanks to Chris Clarke for programming the eproms and to Graeme Penhorwood for taking the photographs.

References
1. International Rectifier, Hurst Green, Oxted, Surrey RH8 9BB, tel. 01883 713215.
2. Micro Linear, 2092 Concourse, Drive San Jose, CA 95131. Tel. 408 433-5200. Distributed in the UK by Ambar Components Ltd, tel. 01844 261144.
3. Linfinity Microelectronics, 11861 Western Ave, Garden Grove, CA, 92841, tel +1 714 898 8121
9mm 1.3SM. Anritsu MW97A Pulse Echo Tester.
1741 etc - E300 - qty in stock.

TEK492P S.A. opt 1-2-3-50 Kc/s - 21GHz £4k.

Anritsu ML93B & Optical Lead Power Meter.


Anritsu SPO401 Signal Source Generator.

Anritsu SPO401 Signal Source Generator.

Anritsu MW97A 0/E Converter.

Anritsu MZ118A 0/E Converter.

Anritsu MZ118A 0/E Converter.

Anritsu MN95B Variable Att. 1300.

Anritsu MZ118A 0/E Converter.

Anritsu MZ118A 0/E Converter.

Anritsu MZ118A 0/E Converter.

Anritsu MZ118A 0/E Converter.

Anritsu MZ118A 0/E Converter.

Anritsu MZ118A 0/E Converter.

Anritsu MZ118A 0/E Converter.

Anritsu MZ118A 0/E Converter.

Anritsu MZ118A 0/E Converter.

Anritsu MZ118A 0/E Converter.

Anritsu MZ118A 0/E Converter.

Anritsu MZ118A 0/E Converter.

Anritsu MZ118A 0/E Converter.

Anritsu MZ118A 0/E Converter.

Anritsu MZ118A 0/E Converter.

Anritsu MZ118A 0/E Converter.

Anritsu MZ118A 0/E Converter.

Anritsu MZ118A 0/E Converter.

Anritsu MZ118A 0/E Converter.

Anritsu MZ118A 0/E Converter.

Anritsu MZ118A 0/E Converter.

Anritsu MZ118A 0/E Converter.

Anritsu MZ118A 0/E Converter.

Anritsu MZ118A 0/E Converter.

Anritsu MZ118A 0/E Converter.

Anritsu MZ118A 0/E Converter.

Anritsu MZ118A 0/E Converter.

Anritsu MZ118A 0/E Converter.

Anritsu MZ118A 0/E Converter.

Anritsu MZ118A 0/E Converter.

Anritsu MZ118A 0/E Converter.

Anritsu MZ118A 0/E Converter.

Anritsu MZ118A 0/E Converter.

Anritsu MZ118A 0/E Converter.

Anritsu MZ118A 0/E Converter.

Anritsu MZ118A 0/E Converter.

Anritsu MZ118A 0/E Converter.

Anritsu MZ118A 0/E Converter.

Anritsu MZ118A 0/E Converter.

Anritsu MZ118A 0/E Converter.

Anritsu MZ118A 0/E Converter.

Anritsu MZ118A 0/E Converter.

Anritsu MZ118A 0/E Converter.

Anritsu MZ118A 0/E Converter.

Anritsu MZ118A 0/E Converter.

Anritsu MZ118A 0/E Converter.

Anritsu MZ118A 0/E Converter.

Anritsu MZ118A 0/E Converter.

Anritsu MZ118A 0/E Converter.

Anritsu MZ118A 0/E Converter.

Anritsu MZ118A 0/E Converter.

Anritsu MZ118A 0/E Converter.

Anritsu MZ118A 0/E Converter.

Anritsu MZ118A 0/E Converter.

Anritsu MZ118A 0/E Converter.

Anritsu MZ118A 0/E Converter.

Anritsu MZ118A 0/E Converter.

Anritsu MZ118A 0/E Converter.

Anritsu MZ118A 0/E Converter.

Anritsu MZ118A 0/E Converter.

Anritsu MZ118A 0/E Converter.

Anritsu MZ118A 0/E Converter.

Anritsu MZ118A 0/E Converter.

Anritsu MZ118A 0/E Converter.

Anritsu MZ118A 0/E Converter.

Anritsu MZ118A 0/E Converter.

Anritsu MZ118A 0/E Converter.
If you are in electronics, and you work with signals, then you will undoubtedly have to deal with noise. A radio receiver for example must detect signals in the presence of noise. Indeed, radio reception – especially at the weak signal level – is essentially a game of signal-to-noise ratio.

The signal-to-noise or s-to-n ratio is the key here because a signal must be above the noise level before it can be successfully detected and used.

Noise affects other electronics systems as well as receivers. In medical electronics, for example, the very low electrical potentials generated by the human brain are displayed by an electroencephalograph, or EEG, machine. Those signals are of the order of 1 to 100µV. Because they exist in a high-impedance source and high 50 or 60Hz electrical mains fields, they are often obscured. But they can also be obscured by noise generated in amplifier circuits.

Noise comes in a number of different guises, but for sake of this discussion we can divide noise sources into two classes: sources external to the receiver or amplifier and internal sources.

There is little you can do about external noise sources. They consist of natural and man-made electromagnetic signals that fall within the passband of the receiver. Figure 1 shows an approximation of the external noise situation from the middle of the amplitude-modulation broadcast band to the low end of the vhf region. One has to select a receiver that can cope with external noise sources – especially if the noise sources are strong.

Some natural external noise sources are extraterrestrial. These signals that form the basis of radio astronomy. For example, if you aim a beam antenna at the eastern horizon prior to sunrise, a distinct rise of noise level occurs as the Sun slips above the horizon – especially in the vhf region. The reverse occurs in the west at sunset, but less dramatically, probably because atmospheric ionisation decays much slower than it is generated.

During World War II, it is reported that radar operators noted an increase in received noise level any time the Milky Way

Fig. 1. Natural noise measured at the terminals connecting an antenna to a receiver.
was above the horizon, decreasing the range at which they could detect in-bound German bombers. Radio astronomy was only then in its infancy, so the effect was apparently not anticipated.

There is also some well-known, easily observed noise from the planet Jupiter in the 18 to 30MHz band.1

**Internal noise sources**

A receiver’s internal noise sources are affected by the design of the receiver. Ideal receivers produce no noise of their own, so the output signal from the ideal receiver would contain only the noise that was present at the input along with the radio signal. But real receiver circuits produce a certain level of internal noise of their own.

Even a simple fixed-value resistor is noisy. Figure 2a) shows the equivalent circuit for an ideal, noise free resistor, while Fig. 2b) shows a practical real-world resistor. The noise in the real-world resistor is represented in Fig. 2b) by a noise voltage source, \( V_n \), in series with the ideal, noise free resistance, \( R_1 \).

At any temperature above absolute zero – 0K or about -273°C – electrons in any material are in constant random motion. Because of the inherent randomness of that motion, however, there is no detectable current in any one direction. In other words, electron drift in any single direction is cancelled over even short time periods by equal drift in the opposite direction. Electron motions are therefore statistically decorrelated. There is, however, a continuous series of random current pulses generated in the material, and those pulses are seen by the outside world as noise signals.

If a shielded 50Ω resistor is connected across the antenna input terminals of a radio receiver, the noise level at the receiver output will increase by a predictable amount over the short-circuit noise level. Noise signals of this type are called by several names: thermal agitation noise, thermal noise, or Johnson noise. This type of noise is also called ‘white noise’ because it has a very broadband – near gaussian – spectral density.

The thermal noise spectrum is dominated by mid-frequencies – 104 to 105Hz – and is essentially flat. The term 'white noise' is a metaphor developed from white light, which is composed of all visible colour frequencies. The expression for such noise is,

\[
V_n = \sqrt{4KTR}
\]

**Table 1. Noise voltage for bandwidths to 10kHz for a 50Ω resistor.**

<table>
<thead>
<tr>
<th>Bandwidth (kHz)</th>
<th>Noise×10⁻⁸ (V)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2.93</td>
</tr>
<tr>
<td>1.5</td>
<td>3.46</td>
</tr>
<tr>
<td>2</td>
<td>4.00</td>
</tr>
<tr>
<td>2.5</td>
<td>4.47</td>
</tr>
<tr>
<td>3</td>
<td>4.9</td>
</tr>
<tr>
<td>3.5</td>
<td>5.29</td>
</tr>
<tr>
<td>4</td>
<td>5.66</td>
</tr>
<tr>
<td>4.5</td>
<td>6.00</td>
</tr>
<tr>
<td>5</td>
<td>6.33</td>
</tr>
<tr>
<td>5.5</td>
<td>6.63</td>
</tr>
<tr>
<td>6</td>
<td>6.93</td>
</tr>
<tr>
<td>6.5</td>
<td>7.21</td>
</tr>
<tr>
<td>7</td>
<td>7.49</td>
</tr>
<tr>
<td>7.5</td>
<td>7.75</td>
</tr>
<tr>
<td>8</td>
<td>8.00</td>
</tr>
<tr>
<td>8.5</td>
<td>8.25</td>
</tr>
<tr>
<td>9</td>
<td>8.49</td>
</tr>
<tr>
<td>9.5</td>
<td>8.72</td>
</tr>
<tr>
<td>10</td>
<td>8.95</td>
</tr>
</tbody>
</table>

Where \( V_n \) is the noise potential in volts, \( K \) is Boltzmann’s constant (1.38x10⁻²³ J/K), \( T \) is the temperature in kelvin, \( R \) is the resistance in ohms and \( B \) is bandwidth in hertz. Temperature \( T \) is normally set to an average room temperature of 290K by convention.

**Signal-to-noise ratio**

Receivers are evaluated for quality on the basis of signal-to-noise ratio, also known as SNR or SN and sometimes denoted \( S_n \). The goal of the designer is to enhance the s-to-n ratio as much as possible.

Ultimately, the minimum signal level detectable at the output of an amplifier or radio receiver is that level which appears just above the noise floor level – usually measured in dBm. Therefore, the lower the system noise floor, the smaller the minimum allowable signal. Designers of weak signal receivers spend a great deal of effort on suppressing the noise floor as low as possible.

**Noise factors, figures and temperatures**

One performance of a receiver or amplifier can be defined in three different, but related, ways: noise factor, or \( F_N \), noise figure, or \( F_F \), and equivalent noise temperature, \( T_e \); these properties are definable as a simple ratio, decibel ratio or kelvin temperature, respectively.

**Noise factor, \( F_N \)**. For components such as resistors, the noise factor is the ratio of the noise produced by a real resistor to the simple thermal noise of an ideal resistor.

The noise factor of a radio receiver – or any system – is the ratio of output noise power, \( P_{out} \), to input noise power, \( P_{in} \).
In order to make comparisons easier, the noise factor is usually measured at the standard temperature $T_0$ of 290K, i.e. standardised room temperature; in some countries though, 299 or 300K are commonly used, but the differences are negligible.

It is also possible to define noise factor $F_N$ in terms of the output and input signal-to-noise ratios:

$$ F_N = \left[ \frac{P_{NO}}{P_{NI}} \right] T = 290K \quad (3) $$

where $P_{NO}$ is the output power, $P_{NI}$ is the input power, and $T$ is the temperature in Kelvin.

Noise figure, $NF$. The noise figure is frequently used to measure the receiver's 'goodness,' i.e. its departure from 'idealness.' Thus, it is a figure of merit. The noise figure is the noise factor converted to decibel notation, where the log here is base $10$.

$$ NF = 10\log F_N \quad (5) $$

where $NF$ is the noise figure in decibels and $F_N$ is the noise factor. Note that the log here is base $10$.

Noise temperature, $T_e$. The noise 'temperature' is a means for specifying noise in terms of an equivalent temperature. That is, the noise level that would be produced by a resistor at that temperature, expressed in kelvin.

Evaluating the noise equations shows that the noise power is directly proportional to temperature in kelvin, and also that noise power collapses to zero at the temperature of absolute zero (OK).

Note that the equivalent noise temperature $T_e$ is not the physical temperature of the amplifier, but rather a theoretical construct that is an equivalent temperature that produces that amount of noise power in a resistor. Noise temperature is related to the noise factor by:

$$ T_e = (F_N-1)T_0 \quad (6) $$

and to noise figure by

$$ T_e = 290(10^{\frac{NF}{10}} -1) \quad (7) $$

Noise temperature is often specified for receivers and amplifiers in combination with, or in lieu of the noise figure.

Noise in cascade amplifiers and receivers

A noise signal is seen by any amplifier following the noise source as a valid input signal.

Each stage in the cascade chain, Fig. 4, amplifies both the signals and the noise from previous stages. Each stage also contributes some additional noise of its own. Thus, in a cascade amplifier the final stage sees an input signal that consists of the original signal and noise amplified by each successive stage plus the noise contributed by earlier stages.

The overall noise factor for a cascade amplifier can be calculated from Friis' noise equation,

$$ F_N = F_1 + \frac{F_2 - 1}{G_1} + \frac{F_3 - 1}{G_1G_2} + \cdots + \frac{F_N - 1}{G_1G_2\cdots G_{N-1}} \quad (8) $$

where $F_N$ is the overall noise factor of $N$ stages in cascade, $F_i$ is the noise factor of stage $i$, $G_i$ is the noise factor of stage $i$, $G_i$ is the noise factor of the $n$th stage, $G_1$ is the gain of stage 1, $G_2$ is the gain of stage 2 and $G_{N-1}$ is the gain of stage $n-1$.

As you can see from Friis' equation, the noise factor of the entire cascade chain is dominated by the noise contribution of the first stage or two. High-gain, low-noise rf amplifier chains, or receivers, typically use a low-noise amplifier circuits for the first stage or two in the cascade chain.

As an example, you will find a low-noise amplifier at the feedpoint of a satellite receiver's dish antenna, and possibly another one at the input of the receiver module itself. Other amplifiers in the chain might be more modest, although their noise contribution cannot be ignored at radio astronomy signal levels.

Receiver noise floor

The noise floor of the receiver is a statement of the amount of noise produced by the receiver's internal circuitry, and directly affects the sensitivity of the receiver.

The noise floor is typically expressed in dBm. Its specification is evaluated as follows: the more negative the better. The best receivers have noise floor numbers of greater than $-130$dBm, while some very good receivers offer numbers of $-115$ dBm to $-130$ dBm.

The noise floor depends directly on the bandwidth used to make the measurement. Receiver advertisements usually specify the bandwidth, but remember to compare the figure given with the bandwidth that you'll need for the mode of transmission you want to receive. If, for example, you are interested only in weak 6kHz wide amplitude-modulated signals, and the noise floor is specified for a 250Hz cw filter, then the noise floor might be too high for your use.

Receiving-system example

Figure 5 shows a receiving system that is common in the vhf through microwave regions of the spectrum. An antenna is used to obtain the signal, and a low-noise amplifier, $A_1$ in Fig. 5, is provided to boost the antenna signal.

It is common practice to place the low-noise amplifier at the front-end. Low-noise amplifier $A_1$ is put before the transmission line. If it came after, it would have to deal with a signal subjected to more loss.

---

**Noise calculations for a configuration such as Fig. 5, obtained via Excel from gain and noise figure entered into the spreadsheet in decibels.**

<table>
<thead>
<tr>
<th>Stage</th>
<th>Gain/loss (dB)</th>
<th>Gain/loss (lin.)</th>
<th>Noise figure</th>
<th>Noise factor</th>
<th>Noise Temp.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preamp</td>
<td>15</td>
<td>31.62</td>
<td>2.2</td>
<td>1.66</td>
<td>191</td>
</tr>
<tr>
<td>Transmission</td>
<td>-2</td>
<td>0.63</td>
<td>2.00</td>
<td>1.58</td>
<td>170</td>
</tr>
<tr>
<td>RF amplifier</td>
<td>10</td>
<td>10.00</td>
<td>3</td>
<td>2.00</td>
<td>289</td>
</tr>
<tr>
<td>Mixer</td>
<td>-6</td>
<td>0.25</td>
<td>4.5</td>
<td>2.82</td>
<td>527</td>
</tr>
<tr>
<td>Overall</td>
<td>17</td>
<td>50.12</td>
<td>2.398</td>
<td>1.737</td>
<td>214</td>
</tr>
</tbody>
</table>

---

Fig. 4. In a cascaded amplifier chain like this one, each stage not only adds its own noise, but amplifies noise from the preceding stage.

Fig. 5. Typical receiver system front-end. Low-noise amplifier $A_1$ is put before the transmission line. If it came after, it would have to deal with a signal subjected to more loss.
RF DESIGN

the antenna terminals so that it does not have to overcome the loss of the transmission line.

The receiver may or may not have an rf amplifier, but in this model one is used, namely A2. The mixer then converts the rf signal to the intermediate frequency used by the receiver.

Loss in the coaxial cable transmission line can be a significant cause of noise in the system. The cable loss is usually expressed in decibels, and is taken from the manufacturer’s data sheets if no actual measurements are available.

Typically, the manufacturer will provide a chart that relates loss in decibels per metre (dB/m) to frequency. Find the loss factor appropriate to the desired frequency, and correct for the actual length of the line.

The noise temperature of the transmission line is:

\[ T_{\text{Te(line)}} = T_L(L-1) \tag{9} \]

where \( T_{\text{Te(line)}} \) is the noise temperature of the line and \( L \) is the loss of the line expressed in linear terms, as a ratio.

Table 1 shows the results of making the noise calculations on a receiving system such as Fig. 5 when the following specifications are used,

<table>
<thead>
<tr>
<th>Stage</th>
<th>Gain (dB)</th>
<th>Noise figure (dB)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preamp</td>
<td>15</td>
<td>2.2</td>
</tr>
<tr>
<td>Trans. line</td>
<td>-2</td>
<td>2.0</td>
</tr>
<tr>
<td>RF amp</td>
<td>10</td>
<td>3.0</td>
</tr>
<tr>
<td>Mixer</td>
<td>-6</td>
<td>4.5</td>
</tr>
</tbody>
</table>

Overall gain for this part of the receiver is the sum of the gains, or 17dB.

The results of the Friis equation shows an overall noise figure of 2.398.

If you program a spreadsheet with the noise equations so that you can vary the noise figure parameters, it becomes apparent that the first stage dominates.

Let’s do a little ceterus paribus† exercise in which one noise figure is changed by 1dB. If the preamplifier noise figure is increased to 3.2dB, then the overall noise figure rises to 3.36dB.

Increasing the transmission line noise figure to 3dB only raises the noise figure to 2.47dB. Increasing the rf amplifier noise figure to 4dB increases the overall noise figure to 2.46dB. This finally increases the mixer noise figure to 2.41dB.

For a 1dB increase in noise figure, the overall noise figure changes to:

<table>
<thead>
<tr>
<th>Stage</th>
<th>New NF (dB)</th>
<th>Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low-noise amplifier</td>
<td>3.20</td>
<td>+0.8 dB</td>
</tr>
<tr>
<td>Transmission line</td>
<td>2.47</td>
<td>+0.072dB</td>
</tr>
<tr>
<td>RF amplifier</td>
<td>2.46</td>
<td>+0.062dB</td>
</tr>
<tr>
<td>Mixer</td>
<td>2.41</td>
<td>+0.012dB</td>
</tr>
</tbody>
</table>

Note that the increase in overall noise figure is greatest for the first stage in the chain, and that the change for each succeeding stage is less than for the stage before. The lesson here is to put as much effort as possible into the first stage in order to reduce the noise figure overall.

Reference

† All else remaining unchanged.

The World is getting onto Spicycles!

Jump onto the future today – tomorrow’s electronic engineering CAD from the UK’s leading simulation author.

- Schematic editing – publication quality images
- Analogue + mixed mode digital simulation with extended SPICE-like functions
- Upgrade path to extensive range of drafting tools each with high definition visuals
- TrueType fonts
- Back annotation of components from simulator
- Simulate directly from your drawings for the ultimate in design checking
- Import & reverse engineer SPICE net lists
- Library includes electronic + mechanical engineering behavioural devices
- Upgrade path from Geswin (existing customers)
- 12 months maintenance included (limited introductory offer)

Please contact Charles Clarke at Those Engineers Ltd, 31 Birkbeck Road, LONDON NW7 4BP.
Tel +44 (0) 181 906 0155
Fax +44 (0) 181 906 0960
e-mail Those_Engineers@compuserve.com
web http://www.spiceage.com

CIRCLE NO.121 ON REPLY CARD
"THE RACK RANGE"
MAINS DISTRIBUTION PANELS FOR
19" RACK MOUNTING
HORIZONTAL

OLSON HOUSE, 490 HONEYPOT LANE,
STANMORE, MIDDLESEX HA7 1JX
TEL: 0181-905 7273
FAX: 0181-952 1232
Conventional wisdom has it that high performance in a receiver goes hand-in-hand with complexity. Compare a comms receiver with a crystal set. But there is a notable exception, as Ian Hickman explains.

As a lad, my introduction to wireless technology was a crystal set, given me by my grandmother. Wanting something better, I was soon building battery sets of my own, and experiencing the thrill of DXing – receiving distant stations – thanks to the greatly increased sensitivity afforded by an expertly wielded reaction control.

Reaction – or in simple terms, positive feedback at rf – is the key to obtaining a receiver with high sensitivity while keeping the component count low. With reaction as it is normally implemented though, you need to be skillful in using both the tuning and reaction controls, in order to achieve the best performance.

But all this is effectively automated in the 'super-regenerative' receiver, which dates from well before the Second World War. It was described – but not explained – in reference 1. This description left me unclear about how the super-regenerative receiver worked. The author gives a reference to another description, reference 2, which I hope is more illuminating, although I have not seen it.

While I could find no mention of the 'super-regen' in the Admiralty Handbook of Wireless Telegraphy of 1925, by the 1939 edition it had duly made its appearance. Army veterans of the Second World War may remember a super-regen set used for communication between tanks, and operating in the uhf range.

The receiver with reaction
In a simple receiver with reaction, sensitivity and selectivity both increase as the degree of positive feedback is increased. This increase continues until the set is on the verge of oscillation, or actually oscillating very weakly. Any further increase in the positive feedback actually reduces the sensitivity, as the following explanation shows.

In any oscillator circuit, the gain of the active device – at the fundamental, i.e. the resonant frequency of the tuned circuit around which reaction is applied – falls with increasing amplitude. This is the mechanism which stabilises the amplitude of oscillation.

In a circuit suitably designed for use as a receiver with reaction, the way the loop gain changes with amplitude is all...
important. Several characteristics are shown in Fig. 1.

Characteristic a) – and even more so c) – is ideal for a high-stability low-noise oscillator. The rapid change of loop gain with amplitude, in the region of unity loop gain, results in low amplitude modulation noise sidebands. The fm noise sideband performance is governed mainly by other factors.

But for a receiver with reaction, characteristic d) is just what is wanted. The shallow angle at which the characteristic cuts the unity gain level makes the oscillator extremely susceptible to influence by any outside factor, such as an incoming signal.

Characteristic b), on the other hand is no good to man nor beast. As an oscillator, it will usually start, being kicked into life by the switch-on transient, but may occasionally fail too. As a reaction-aided receiver, as the degree of reaction is increased, it will suddenly burst into oscillation. It will not stop until the reaction control is wound back down some way, where the gain is low again – an annoying sort of hysteresis effect.

Many ingenious attempts have been made to harness reaction, automating it so as always to be at the optimum level. Older readers may remember the 'Sobellette' small valve table radio from the fifties. This was a superhet, with but one IF transformer and no IF stage! Instead, the usual double-diode triode detector stage was replaced by a pentode leaky grid detector with reaction.

The theory was that, at the fixed IF, a fixed degree of reaction could be applied, achieving gain and selectivity equivalent to a conventional superhet four-valve-plus-rectifier line-up, but with one less valve.

So much for the theory: the output impedance of the frequency changer varied across the band. This changed the damping on the IF transformer, severely limiting the degree of factory-preset reaction that could safely be applied.

The super-regenerative receiver

The super-regen receiver is another attempt at harnessing the gain increase achievable with reaction. Reverse bias on an initially cut-off valve or transistor with feedback is gradually increased, until the stage begins to oscillate. When the oscillation has built up to the intended design amplitude, the beyond-cut-off bias is again applied, and the oscillation dies away again.

There are two ways of implementing the periodic cut-off of the device.

In the externally quenched super-regen, a separate quench oscillator is used, resulting in a fixed quench frequency, Fig. 2. This is usually in the supersonic or low-rf range, typically 50 to 100kHz.

Alternatively, the oscillator can be provided with self biasing, with an over-long time-constant, so that it "squegs". This results in bursts of classic operation, each burst cutting off the device until the reverse bias dies away again sufficiently for oscillation to recommence. The self-quenching frequency is again typically in the range 50 to 100kHz in the absence of an incoming signal, but will increase somewhat in the presence of a signal.

The arrangement is usually similar to Fig. 2, but with the time-constant CR increased, and the separate quench oscillator replaced by a short circuit.

External versus internal quenching

Figure 3 shows the build-up of amplitude of rf oscillation, lower trace, in sympathy with the quench waveform, middle trace, in the absence or presence of an incoming signal, top trace. The external quench waveform is shown as sinusoidal, but in the case of a self-quenching circuit, it would be the typical sawtooth waveform of a squegging oscillator.

In the absence of an incoming signal, the oscillation has to build up from the level of the noise floor in the circuit. With an on-tune incoming signal, the build-up starts from a higher level. Consequently, the amplitude reaches any given level sooner than would otherwise be the case.

Thus in the externally quenched case, the burst of oscillation is longer, as in Fig. 3, while in the self quenched case, the amplitude reaches the level needed to cut off the circuit sooner, Fig. 4. Either way, the current drawn from the supply increases, and as in Fig. 2 this may be taken as the detected signal level.

Whether self or externally quenched, a super-regenerative receiver can be designed to run in either of two modes. In the linear mode, each newly started burst of oscillation is quenched before ever reaching its maximum possible value. The result is a detected signal which varies linearly with the incoming signal level, over a wide range.
Alternatively, the amplitude of oscillation may be designed to reach almost the maximum possible for the given supply rail, before being quenched. This 'logarithmic mode' provides the greatest sensitivity to the smallest signals, giving a kind of limiting or automatic-gain control action with larger signals. Thus the dynamic range of the output is compressed to a manageable value, over a wide range of input levels.

**Under the floor**

It is important to note that, whether using linear or log mode, external or self-quenching, the off period must be long enough to allow the amplitude of oscillation in the tuned circuit to die down to below the level of the noise floor in the circuit.

Thus each burst of oscillation starts in a random noise-initiated phase, rather than a phase coherent with the previous burst of rf. Otherwise, the receiver will 'hear' itself, as well as any external signal, with resultant reduced sensitivity.

The super-regen circuit, in common with the reactive receiver, provides great sensitivity with a low component count. But it does not enjoy the other virtue of the receiver with reaction. The reactive receiver shows enhanced selectivity as well as enhanced sensitivity, due to the Q multiplying effect of reaction. But clearly, the faster build-up of oscillation in the super-regen will be caused by any signal within the bandwidth of the tuned circuit.

At this early stage in the process, there is as yet no Q enhancement. As a result, the relevant bandwidth is simply the natural, unenhanced bandwidth of the tuned circuit.

The other main drawback of the super-regen receiver, besides its poor selectivity, is its antisocial behaviour towards other users of the band in which it operates. In addition to being a receiver, the super-regen also acts as a very effective broadband jammer.

The narrow pulses of rf, seen in the time domain in Fig. 4, correspond to a forest of spectral lines, spaced at the receiver's pulse repetition frequency. These appear in the frequency domain...
as in the spectrum analyser display of Fig. 5. The typical appearance shown has earned the super-regen the fanciful, if not entirely inappropriate, nickname of the ‘hedgehog’.

One ingenious scheme to render the super-regen receiver somewhat less obnoxious appeared in the literature a year or two ago. In this, an additional grounded-gate junction-fet stage preceded the receiver proper, in an attempt to prevent the quasi-frequency-modulated rf getting back up the aerial. How effective this was I am unable to report, but the idea does not seem to have caught on.

**Simple, but not a super-regen**

Imagine your boss comes in one lunchtime, saying that he wants a receiver design for the UK low power radio 418MHz licence-exempt band to MPT1340, and he wants it on his desk by the following morning.

For a quick solution, a super-regen might appear to be the answer. But they are tricky things to get right, and there’s not enough time for a superhet design. The answer — ready by teatime and that same afternoon — might be a functional replacement for the super regen, which has recently appeared. This offers the same low component count combined with high sensitivity as the super-regen circuit, but without any of the troublesome stray radiation of the latter.

The **MICRF001** *QuickRadio* is in fact a fully functional superhet receiver, but the level of integration is so great that an absolutely minimal component count is achieved.

Figure 6 shows the internal workings of the device, which comes in either a 14-pin plastic DIL package or a 14 pin SOIC. Both options operate over −40 to +85°C and draw just 6.3mA from a +5V supply. The claimed sensitivity is −95dBm, making it directly comparable with a super-regen receiver.

The design range of receive frequencies is 300 to 440MHz, over which the device handles off-on keying, data rates of 100 up to 4800bit/s. Talking to the Micrel rep. on the company’s stand at the recent Low Power Radio Association Exhibition and Conference, he boasted that the **MICRF001** was the only uhf radio chip you could build into a working radio on experimenter’s plug-board. **A uhf radio on bread board?**

I obtained a sample for evaluation and, decided to put his boast to the test. My circuit was just about the crudest, simplest that one could devise, Fig. 7. Built on the well known *Experimentor* white plug-board, testing commenced as soon as a suitable reference frequency crystal had been procured. This was at 3.1969MHz, which is effectively multiplied by a factor of 130 in the device’s synthesiser to produce a local oscillator frequency of 415.602MHz.

Given the device’s intermediate frequency, which is itself a weak function of the reference frequency, this sets the receive frequency as 418MHz. There’s more on this in the panel entitled ‘The single-chip superhet’. Being temporarily without a uhf signal generator, I connected 18cm of wire to the output terminal of a Leader LSG-16 100kHz to 100MHz signal generator, to act as a quarterwave whip. The receiver, a metre or so away, was similarly equipped. With internal 1kHz AM selected, the signal generator’s output frequency was set to 83.6MHz.

The **MICRF001** receiver picked up the generator’s fifth harmonic, slicing the envelope cleanly to recover what looks like a 010101 data stream running at 2kbit/second, Fig. 8, top trace. This is quite a feat, given the low level of the fifth harmonic. In addition, the modulation depth — barely 20% — hardly resembles on-off keying by a long margin, Fig. 8, lower trace. However, it gave no real indication of the range that I could expect in practice.

Fortunately, an open-site test range on the extensive flat rooftop of a factory, plus a wide range of test equipment, was available to me at the time. This permitted a more quantitative measurement approach. A Marconi 2022D 10kHz to 1GHz signal generator, with its front panel horizontal and standing on a 1m high parapet, was set to 418MHz and 18cm of wire left poking up from its output socket. The output level was set to −33dBm (500nW), with 99% amplitude modulation depth at 1kHz.

**Range testing**

I monitored the receiver’s data output at pin 8 with a crystal earpiece. Walking away with the receiver handheld at about the same 1.5m height, the clear 1kHz tone held out to a range of about 20m. Beyond this distance, it disappeared in the noise. Clearly, this brief test involved no danger of interference with other, off-site users.

The permitted transmitter power in the 418MHz band, per MPT1340, is 250μW, or some 500 times as much as the signal generator was delivering. So taking the optimistic free space loss figure of −6dB per doubling of range would predict a working range of 450m. This assumes a transmitter working within the legal limit of power.

The flat earth loss figure of −12dB PDOR is more realistic than the free space loss figure of −6dB.

**Technical support **

**MICRF001** — Micrel Semiconductor (UK) Ltd., 21 Old Newtown Road, Newbury, RG14 7DP. Tel: 01635 524455, fax: 10635 524454, e-mail: info@micrel.co.uk, Website www.micrel.com

3.1969MHz crystal, Golledge Electronics Limited, Ashwell Park, Ilminster, Somerset, TA19 9DX. Tel: 01460 256100, fax: 01460 256101, e-mail: sales@golledge.co.uk, Website www.golledge.co.uk.

**RF Design**

**Fig. 7. Circuit diagram of a hasty lash-up uhf receiver using the MICRF001 chip.**

**Fig. 8. Upper trace — a 010101 data stream at 2kbit/s, recovered from the fifth harmonic of the 83.6MHz output of a signal generator. 2V/div. vertical, 500μA/div. horizontal. In the lower trace is the signal generator output, showing just 20% amplitude modulation depth, 50mV/div. vertical, 500μA/div. horizontal.**
The single chip superhet

An rf amplifier feeds the mixer, the local oscillator for which is supplied by the synthesiser. The mixer output is fed to an IF amplifier stage, followed by the IF filter.

The filter has a 1MHz bandwidth, centred on 2.25MHz nominal. But as equation 1 shows, the exact value is a function of $F_{ref}$. The IF filter output passes to a final IF amplifier stage, and thence to a peak detector.

A post-detection low-pass filter with programmable cut-off frequency permits selection of the optimum bandwidth for the data rate used. The filter output supplies automatic gain control to the mixer and IF stages, as well as driving the demodulator via a programmable single-pole low-pass filter.

The time constant of this filter is usually in the range 5 to 50ms, its output forming the comparator reference level. The comparator slices the recovered analogue data relative to the reference level, converting it to a 5V logic output. The slicing action, for typical data, is shown in Fig. 10.

The device is designed primarily as a more sanitary replacement for the super-regen receiver. One ‘advantage’ of the super-regenerator is that its selectivity is so poor that it can be used in conjunction with a very cheap transmitter whose frequency, being determined simply by an LC circuit, is poorly defined.

As an example, for operation in the UK’s 417.9 to 418.1MHz band, as specified by MPT1340, operation at 418.000MHz would require an $F_{ref}$ of 3.1969MHz. Manufacturers may use other frequencies in the band, which is intended for a variety of applications including those requiring a wide bandwidth.

In various European countries, the band 433.050-434.709MHz is available for non-specific SRDs, as per CEPT Recommendation CEPT/ERC/REC 70-03, which may be viewed at www.ero.dk

Sweep mode. In sweep mode, the local oscillator sweeps a band centred on the nominal transmit frequency, so that the effective bandwidth is much greater than the IF pass bandwidth $F_{bp}$, as shown in Fig. 11.

In this mode,

$$F_{ton} = F_{ref} \times M$$

and

$$F_{tomin} = F_{ref} \times (M + 2)$$

Thus the sweep range $\Delta F_{sv} = 2F_{ref}$. The resultant coverage is

$$\Delta F_{sv} = (2F_{ref} + F_{bp})$$

In sweep mode, $F_{ref}$ is simply given by,

$$F_{ref} = \frac{F_{ref}}{(M + 1)}$$

So, for example, given $F_{tx} = 387$MHz ±0.5%, including initial tolerance, temperature and ageing, then from equation 6, $F_{ref} = 387/129 = 3.00MHz$ – a standard ceramic resonator frequency.

**Fig. 11.** Showing how in sweep mode, the effective bandwidth is increased by sweeping the local oscillator.

---

The antenna

In the typical application circuit of Fig. 9, some simple antenna tuning is incorporated. This provides some selectivity to reduce the possibility of blocking or desensitisation by large out-of-band signals. Matching the antenna into a tap on the inductor would further increase sensitivity.

The arrangement in Fig. 9 provides protection against response to other
transmissions, which may appear on the same channel. It does this by virtue of the coding supplied by the Holtek HT12D address/data decoder shown, and its companion coder in the transmitter.

Data receipt

The receiver only responds to the appropriate one of 64 different codes, providing on receipt up to four different commands which can be decoded from data bits D11 and D12. Note that in Fig. 8, a 3MHz ceramic resonator is used as the reference frequency. This arrangement is possible due to the more generous spectrum allocation and relaxed frequency accuracy requirements for srds (short range devices) in North America and some other countries.

Even allowing for the additional cost of a crystal or surface-acoustic-wave device to provide the greater frequency accuracy demanded by the European market, clearly the device provides a quick and economical answer for anyone needing to design a receiver for the 418MHz or 433MHz licence exempt bands.

Note that while srds transmitters and receivers for these bands are licence exempt as far as the user is concerned, the manufacture must obtain type approval to the relevant specifications for any countries in which he intends to sell his products.

References
2. See an article on the super-regenerative receiver by J. Dent, Wireless World, June 16, 1933
3. Produced by Micrel Inc. 1849 Fortune Drive, San Jose, CA 95131, USA.
CROWNHILL ASSOCIATES LIMITED
The Old Bakery, New Barns Road,
Ely, Cambs. CB4 7PW
Tel: +44 (0)1353 666709 Fax: +44 (0)1353 666710

Low cost professional quality Smart Card Systems

CHIPDRIVE EXTERN

Intelligent programmer for Smart Cards using the International Standard T=0 or T=1 protocols also Memory and Secure Memory using IC, 2-wire & 3-wire interfaces. Supplied with software to read and write to most popular secure smart cards, Inc GSM, PAY PHONE and ACCESS CONTROL cards.

T=0 or T=1 @ 3.579MHz
RS232 @ 9600 - 115200 bps

£69.00
P&P £7.50

Internal Supply / Ni-MH £7.51
Size: 100x70x30mm Weight 660 Gram

Supplied with cardServer.dll API for easy development of SmartCard Applications using Visual Basic, Delphi or C++. Supplied with Sample Memory cards and Secure Smart cards.

CE Compliant

CHIPDRIVE - micro

Fully Compatible with TOOLBOX for application development. Featuring the same functionality as Chip Drive Extern but in a small neat low cost package, similar in size to a smart card. Supplied with cardServer.dll API

£65.00 + £5 P&P + VAT

CE Compliant

CHIPDRIVE Developer Kit

CDK consists of: CD ROM containing cardserver.dll. Applications and Source code examples. CHIPDRIVE-micro a selection of Smart Cards offering protected memory, processor and memory cards. Typical users are Control access, Pay Phone cards and Data transport. PKE cards for the cards are supplied along with data sheets and programming data for use with cardserver.dll. A useful application with source codes shows how the CHIPDRIVE can be used to identify any Smart card inserted, giving manufacturer info, and memory map if available. Applications produced with the developer kit will operate under Windows 3.11/95/NT and are compatible with the whole CHIPDRIVE family. The CDK uses easy to use 16 bit or 32 bit DLLs with just one function call to the 'CardServer' to identify the card or carry out any instruction. Cardserver is a powerful background task which relieves the application programmer from device and card administration. 

- Two chassis including a selection of Sample memory cards and Secure Smart cards.
- User Guide
- Sample Memory cards
- Sample Secure Cards
- Win95 compatible Development API
- DLLs

£85.00 + £5 P&P + VAT

CE Compliant

Antrim Transformers Ltd

Large standard range + custom designs on
15 core sizes approved to EN60742
(KEMA agreement 919691)
Large standard range + custom designs on
23 core sizes approved to UL.506 & C22.2
No.66-1988 (UL file no.E179800)

Medical isolation transformers approved to
EN60601-1

Audio grade, 100V line, valve output &
valve psu transformers

Lead time typically 3 weeks, minimum
batch size of 10 off

Rapid quotation & prototype service

KEMA

100% UK
manufactured

144
NEW PRODUCTS CLASSIFIED

Please quote "Electronics World" when seeking further information

PASSIVE AND ACTIVE COMPONENTS

Connectors and cabling
Heavy-duty connectors. Han Series connectors by Harting are designed for a hard life, during which mechanical strength and tolerance of vibration are needed. They conform to a number of international standards and come in various hood and housing sizes. Mixed contacts provide for the connection of optical fibres, pneumatics and electrical cables and signals in the one connector. Many different termination forms work at different voltage and current ratings.

Cable repeater. For connecting 1394 cables and products in a large network, DDK's 1394 Cable Repeater allows a continuous signal strength to be maintained on all 1394 serial-bus networks over a cable extension of up to 72m. It conforms to 1394 IEEE standards, uses an IBM three-i/o port physical layer chip, may be connected up to 16 hops and gives automatic detection of data transfers up to 400Mb/s.

Enq no 502

Arrays
Memory/logic asics. Samsung now has available new asics based on 0.25um merged memory and logic. Up to 8.2 million gates combine to form three types of device: STD110 standard cell, MDL110 merged dram and logic, and MFL110, which is merged flash memory and logic, allowing users to begin with a logic design, adding dram or flash. Libraries are available for products such as notebooks, cellular handsets and cellular graphics acceleration, all needing low power and high density, a second literary concerns networking and desktop systems needing high performance and somewhat higher power. Samsung Semiconductor Europe Ltd. Tel., 0181 3807200; fax, 0181 3807220. Enq no 501

Digital View Ltd. Tel., 0181 3861112; fax, 0181 3861116; web, www.digitalview.com. Enq no 506

Displays
12.1in avg a tft. A 300000 life, high brightness tft-liquid-crystal display panel from Toshiba, the LTM12C280, is meant for industrial applications and not necessarily for those involving personal computers. It provides wide viewing angles and brightness levels at the top of the screen, with 100% brightness at the bottom of the screen. Since the lighting cdfs are both at the top of the screen, the backlight can be reduced to 100% without losing brightness. The backlight life is 800000 hours. Toshiba Electronics UK Ltd. Tel., 01276 694730; fax, 01276 694800. Enq no 505

Digital RAM. Toshiba Large Memory Systems Corp. offers a new generation of 64M and 72M rambus, which provides a data transfer speed of 800MHz or 1.6GB/s. New generation of 64M and 72M rambus, which provides a data transfer speed of 800MHz or 1.6GB/s. Organisation is 4-word by 18 bits with a 16byte page size. Refresh cycle is 256cycles, voltage supply is 2.5V, power 2.2W, or 260W in standby and 10W asleep. Toshiba Electronics UK Ltd. Tel., 01276 694730; fax, 01276 694800. Enq no 507

Firm. Micron's new fans use vanes within the housing to impart a "turbo" effect, which increases airflow and pressure by 20%. The fans are for low-power working and localised cooling, the airflow being stronger than is usual. Speed is 13000rev/min and operating voltage 12V or 24V. Radialtron Components Ltd. Tel., 01784 430350; fax, 01784 477333. Enq no 509

February 1999 ELECTRONICS WORLD 145
NEW PRODUCTS CLASSIFIED

Please quote "Electronics World" when seeking further information

Small fans. Designed to cool small components such as individual semiconductors, the Model 2009 by Shioch measures 20 by 20 by 8mm and weighs 5.3g. It uses a linear motor on ball bearings and is virtually silent, although airflow is 0.015m³ per minute. It is designed to work from 70mA at 12V dc, but starts working at 7V and still turns at 0.5V. It is suitable for flush mounting on a gasket or metal and insulation resistance is 10MΩ at 500V ac.

Key Electronic Components. Tel., 0118 9351546; fax, 0118 9660294; e-mail, sales@keyelectronic.com; web, www.keyelectronic.com.
Enq no 510

Materials

Conductive paints. IVC has three new paints for use with its Spraycoat process of emi/rfi shielding. They are made using very mild solvents to withstand the higher built-in stresses found in some plastics. They have passed the requirements of the Underwriters' Laboratory. AG1010 contains pure silver particles for the highest shielding performance, providing sheet resistivity of 0.05Ω/square in a 10µm thickness. AGCU120 has blended silver and silver-plated copper particles to give a sheet resistivity of 0.05-0.12Ω/square. In a 15µm thickness, CS725 uses silver-plated copper for plastic surfaces, for which it has excellent adhesion. The paints may be applied selectively to plastic surfaces manually or robotically.

IVC Ltd. Tel., 0121 511 1115; fax, 0121 544 5253.
Enq no 511

Microprocessors and controllers

Micro supervisor Ics. Five microprocessor Ics from IMP contain power management circuitry to switch the power source to a backup battery when the main supply fails. They also have a watchdog function and initialisation to reset the system after failure or lockup. IMP690A/692A and IMP802L-M/805L are equivalent to Maxim devices with the same names but with the addition of thermal and short-circuit protection. Current consumption on the IMP versions is 100µA.

IMP Inc. Tel., 001 408 432 9100; fax, 001 408 434 0335; web, http://www.impweb.com
Enq no 513

64-bit microprocessors. From IDT are two RISCController micros for communications systems. Available in speeds of 180, 200 and 250MHz, they are 3.3V devices tolerating 5V I/O, a TTL Interface and an enhanced write mode to simplify support of synchronous operation. They are also compatible with Windows CE and other op. sys. and deliver a 55MHz performance at 250MHz. Two-way set-associative caches have cache locking and the RCG6474S has a 33-bit interface bus to provide 64-bit processing and low-cost 32-bit memory. The RCG6475 uses 64 bits throughout to give over 1Gb/s bus bandwidth and 4Gb/s system bandwidth.

IDT Europe. Tel., 01372 363399; fax, 01372 378851. Enq no 514

Optical devices

Optical transceiver. When used with low-cost optical fibre of up to 100m long, NEC's NL2100 optical transceiver handles data at between 1Mbit/s and 150Mbit/s. It uses a 650nm led, a silicon PIN detector and a preamplifier. Power supply is 5V, the electrical interface is high-speed and connectors are of the F07 AN type. The unit is contained in a standard 1-9g ip package and the mounting arrangement makes the device suitable for network interface cards and other uses in which it must take hard use. It complies with the ATM Forum standard and the path length may be increased from 100m to 1000m by the use of plastic-clad fibre.

NEC Electronics (UK) Ltd. Tel., 01908 691133; fax, 01908 670290.
Enq no 515

Oscillators

Ovened v-c crystal oscillators. Tele Quartz GmbH has a new range of oven-controlled, voltage-trimmed crystal oscillators. OCOC1000 oscillators are stable to within 0.05ppm over the 0-70°C range, annual ageing being less than 0.1ppm. A cheaper AT-cut type gives a stability of ±0.15ppm over the temperature range and ageing of 0.2ppm/yeae, both types provide Hcmos output. Frequencies lie in the range 10-25MHz, with specific frequencies at 10, 13, 16,384 and 256kHz. The company also has a version designed for use in switching and transmission systems, operating from 3.3V at 350mA. This type has a stability of 0.1ppm at 8.192-26MHz, with voltage trimming. Output is LVHcmos.

Webster Electronics Ltd. Tel., 01460 57166; fax, 01460 57777; e-mail, sales@websterquartz.com.
Enq no 516

Passive components

Chip Inductors. Surface-mounted chip inductors from BI Technologies now come in three standard sizes of 0063, 0805 and 1206, instead of only the last. In the 0805 size, the inductors cover a range of 0.047µH to 33µH, the same as in the 1206 type, in 34 values; maximum and minimum current ratings are 300mA and 5mA. In 0063, the range is 0.047µH-27µH; all are shielded and are compatible with vapour-phase and infra-red soldering.

BI Technologies Ltd. Tel., 0116 2761133; fax, 0116 2761199.
Enq no 517

Chip attenuators. Kamaya PAC16 chip attenuators replace three resistors with the one chip, which measures 1.5mm square by 0.55mm. They take the form of an unbalanced pi section and exhibit a vswr of less than 1.2. Characteristic impedances are 50Ω, 75Ω or up to 100Ω on request, attenuating by 1, 2, 3, 6 or 10dB at temperatures between -40°C and 125°C.

Surtech Distribution Ltd. Tel., 01256 840055; fax, 01256 479785.
Enq no 518

Sensing resistors. Sensors with virtually zero inductance are offered by VTM. Materials are resistance alloys, allowing values down to R0005 to be produced with temperature
coefficients down to 4Oppm/°C. Power
by reference to battery voltage,
slic up to 90V. Programming is done
protection envelope. The devices are
Innovations are for use with
surge protectors by Power
Protection devices
Enq no 521

Protection devices
Surge protection for Ericsson slics. TISPPBL, programmable telecoms surge protectors by Power
Innovations are for use with Ericsson's PBL3xx series of
subscriber line interface circuits; these require a complex voltage/time
protection envelope. The devices are rated for the full voltage range of the slic up to 90V. Programming is done
by reference to battery voltage, providing minimum stress to the slic, regardless of supply. Two models are produced: the TISPPBL1 for
standard use; and the TISPPBL2 for
line currents over 60mA. Two buffer
transistors are used to lower supply
loading and to prevent the slic power
supply being charged.

Power Innovations Ltd. Tel., 01234
223001; fax, 01234 223000; e-mail:
info@powinv.com.
Enq no 522

Switches and relays
Rubber keypads. Keypads in rubber by Radiatron give a proper response to touch, choice of key styles
and a range of actuation forces. There are also printing choices, backlighting and a number of surface
finishes, including simulated plastic keytops with no tooling cost.
Radiatron Components Ltd. Tel.,
01784 439693; fax, 01784 477333.
Enq no 523

Automotive relay: Matsushita has a range of twin relays designed for vehicle use. CT relays measure 17.4
by 7 by 13.5mm, with twin and H-bridge types double the width. Switching capability is 20A/14V dc per
contact and 2A/28V ac per contact. These package styles are available. There is a single
changeover with spot operation, a dual changeover with a twin-coil relay with two spot operation and an
H-bridge version. This last version is for use where the simultaneous forward and reverse operation of a
motor drive must be avoided, as in electric sunroofs and windows.
Matsushita Automation Controls Ltd.
Tel., 01908 231555; fax, 01908 231599; e-mail, info@macuk.co.uk;

Enq no 524

Solid-state relays. Omron's range of relays provides output currents in the
100mA-40A range. Smallest is the
G3VM mosfet type that switches ac/dc
loads to 350V in spst-no and dpst-no
versions. There are double-throw
variants in 4-pin and single-throw versions. Also in the range are single-
throw types in 4-pin or 6-pin packs, all
including six models with torques of
100mA-40A range. Smallest is the
G3VM mosfet type that switches ac/dc
loads to 350V in spst-no and dpst-no
versions. There are double-throw
variants in 4-pin and single-throw versions. Also in the range are single-
throw types in 4-pin or 6-pin packs, all
including six models with torques of

Electronics World when seeking further information

Radio remote control. Using
RF Solutions' Globemaster
Pager Decoder, one can
operate systems remotely by
making a telephone call. What
happens is that you call a pager
service, which then transmits
the relevant command code to the
Globemaster receiver-decoder,
activating its four high-
current switched outputs. Each
unit has its own identification
code to validate the caller's
identification number. Power
needed is 5V or 12V dc and the
standard outputs at cmos ttl
level may be replaced by relay
outputs. The device is normally
a board-mounted module, but it
is also available as a complete
system in a case.
RF Solutions Ltd. Tel., 01273
488886; fax, 01273 480661; e-
mail icepic@pavilion.co.uk; web,
www.rfolutions.co.uk.
Enq no 538

Transducers and sensors
Small load cell. Wherever a very
small load cell is needed. Control

Transducers' Model ME should fill the
bill, being 12mm in diameter and 5mm
thick. Ranges are 250g to 5kg in 14
steps, errors due to non-linearity,
hysteresis and repeatability combined
amounting to less than ±0.15%. The
units are in the form of a four-arm
Wheatstone bridge using bonded
strain gauges. Overload is 150%
full-scale. A 10V ac/dc excitation is
needed, output is 20mV and bridge
resistance 350Ω.
Control Transducers Tel., 01234
217704; fax, 01234 217083.
Enq no 528

EQUIPMENT

Production equipment
Power screwdrivers. Mains-powered
Model ET screwdrivers from
Toolworld are meant for bench
assembly operations, the power
supply being capable of running
two such tools simultaneously. The
range includes six models with torques of
0.4kgf cm to 20kgf cm, three of them
taking 4mm or 6.35mm hexagonal bits
and the others 6.35mm or 5mm; the
ET-7000R is a right-angled version. A
catalogue is on offer.
Toolworld Ltd. Tel., 01249 821234;
fax, 01249 816723.
Enq no 530

Miniature power tool. New from
Minicraft is the MiniMax 230, a mains-
powered rotary tool turning at speeds
variable from 8000 to 21000rpm/min and taking all the
standard accessories in the
company's range in its four-jaw
keyless chuck. It fits the standard
lathe attachment and drill stand, as
well as those of other makes. The
tool is available on its own or in a
case with a 100-piece set of
accessories.
Minicraft. Tel., 01388 420535; fax,
01388 817182.
Enq no 531

Power supplies
Battery chargers. Hitec battery
chargers by Merlin are flexible enough
to handle a number of different battery
types, keep them topped up or charge
them quickly. They detect
environmental variations that would
result in incorrect charging regimes in
simpler chargers. Switched-mode
charging is used to provide bulk,
absorption and float characteristics for
absorption and float characteristics for
charging is used to provide bulk,
absorption and float characteristics for
charging is used to provide bulk,
absorption and float characteristics for
charging is used to provide bulk,
absorption and float characteristics for
charging is used to provide bulk,
absorption and float characteristics for
charging is used to provide bulk,
absorption and float characteristics for
charging is used to provide bulk,
absorption and float characteristics for
charging is used to provide bulk,
absorption and float characteristics for
charging is used to provide bulk,
absorption and float characteristics for
charging is used to provide bulk,
absorption and float characteristics for
charging is used to provide bulk,
NEW PRODUCTS CLASSIFIED

Please quote “Electronics World” when seeking further information

bench dc supplies, providing outputs of 20V at 36A to 120V at 6A. Light weight and small size have been achieved by the use of combined switching and linear operation. Performance is said to be as good as that of large, high-linearity types. Line and load regulations are both better than 0.005%, transient response time is 100μs and temperature coefficient 100ppm. All have 3.5-digit displays showing voltage and current simultaneously and there is provision for internal GPIB, RS232 or analogue interface. Kenwood UK Ltd. Tel. 01923 655111; fax, 01923 655297. Enq no 533

Low drop-out regulators. Toko's Tr112xx series linear regulators have built-in switching and provide a 2% output. They are available in 0.1V steps from 1.3V to 5V, 5.5V and 8V. Quiescent current is 170μA no load and 1mA with a 30mA load; standby current is 100mA. The internal p-n-p transistor gives a dropout of, typically, 80mV at 30mA. Internal switching is controllable by ttl or cmos levels and there are the usual protective circuits. Cirkit Distribution Ltd. Tel., 01992 444111; fax, 01992 464457; e-mail, enquiries@cirkit.co.uk. Enq no 534

150W dc-dc converters. New to the Artesyn Technologies BX6 family of dc-to-dc converters is 150V series model for use in communications and distributed power applications. These come in the industry-standard half-brick package and have the same footprint as BX85075/100 types, being drop-in replacements to provide increased power. All have remote sensing and adjustment. Operation is permitted to 100°C, heat-sink mounting increasing the limit. Isolation input case and output case is 1500V dc. Artesyn Technologies. Tel., 00353 2425272; fax, 00353 2493510; e-mail, jackie.day@artesyn.com. Enq no 535

Multiple-supply controller. Cherry's CS-51313 synchronous buck controller allows the generation of a number of different supply voltages to power computer motherboard core logic with just the one switching regulator. A 1% internal bandgap reference is taken to an output pin, where it may be used with external components and power transistors to supply various voltages to a Pentium II processor and its support logic. There is also a pair of signals to drive n-channel mosfets supplying the processor core. Transient response is 200ns. There is a range of protective measures. Cherry Semiconductor. Tel., 001 401 885-3600; fax, 001 401 885-5786; web, www.cherry-semi.com. Enq no 536

Radio systems

Downconverter/mixer ic. TQ5M31 by TriQuint is a general-purpose mixer and down-converter ic for use in cellular and PCS mobile 'phones, ISM bands, GPS and pagers. Rf input range is 500-2500MHz and if output 45-500MHz. Very few external components are needed, although the lo buffer amplifier frequency response and If gain response are externally trimmable. Conversion gain is 2-3.5dB within ±0.3dB over a wide temperature range. Input third-order intercept is 9dB minimum at a noise figure of 9.5dB. I/o is 50Ω. TriQuint Semiconductor. Tel., 001 503 615-9000; fax, 001 503 615-8920; web, www.triqunt.com. Enq no 537

Test and measurement

Virtual instruments. National Instruments has a new family of computer-based Instruments, which

BACK ISSUES

Back issues of Electronics World are available, priced at £3.00 UK and £3.50 elsewhere, including postage. Please send your order to Electronics World, Quadrant House, The Quadrant, Sutton, Surrey, SM2 5AS

Available issues

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>January</td>
<td>January</td>
<td>January</td>
</tr>
<tr>
<td>April</td>
<td>February</td>
<td>February</td>
</tr>
<tr>
<td>May</td>
<td>March</td>
<td>March</td>
</tr>
<tr>
<td>July</td>
<td>May</td>
<td>April</td>
</tr>
<tr>
<td>August</td>
<td>June</td>
<td>May</td>
</tr>
<tr>
<td>November</td>
<td>July/August</td>
<td>June</td>
</tr>
<tr>
<td>December</td>
<td>September</td>
<td>July</td>
</tr>
<tr>
<td>1995</td>
<td>1997</td>
<td>1999</td>
</tr>
<tr>
<td>February</td>
<td>November</td>
<td>January</td>
</tr>
<tr>
<td>April</td>
<td>October</td>
<td>December</td>
</tr>
<tr>
<td>May</td>
<td>November</td>
<td>November</td>
</tr>
<tr>
<td>June</td>
<td>September</td>
<td>October</td>
</tr>
<tr>
<td>September</td>
<td>August</td>
<td>December</td>
</tr>
<tr>
<td>October</td>
<td>September</td>
<td>December</td>
</tr>
</tbody>
</table>

Note that stocks of some of the above issues are low and will soon sell out. Please allow 21 days for delivery.

Free copy of Electronics Engineer's pocket book with every order while stocks last

80-channel logic analyser. Thurby Thandar's TA4000 logic analyser series is capable of asynchronous data capture at 400MHz with a memory depth of 9Kword. There are three versions with 32, 48 or 80 channels. An eight-level random branching trigger sequencer provides trace control, each trigger term consisting of up to four words, Or-ed or And-ed, the latter triggering on the absence of a word. All this goes at a memory depth of 8Kword. There are three versions with 32, 48 or 80 series is capable of asynchronous data capture at 400MHz with a

11.1111111.11.1.111.11

| 1.4, 10,= arm. tal=g1 ar-ns gai alit a Ii.
| 1111111
| i64.6
| II.

11111111.11.1.111.11

| 1.4, 10,= arm. tal=g1 ar-ns gai alit a Ii.
| 1111111
| i64.6
| II.

11111111.11.1.111.11

| 1.4, 10,= arm. tal=g1 ar-ns gai alit a Ii.
| 1111111
| i64.6
| II.

11111111.11.1.111.11

| 1.4, 10,= arm. tal=g1 ar-ns gai alit a Ii.
| 1111111
| i64.6
| II.
Please quote “Electronics World” when seeking further information

NEW PRODUCTS CLASSIFIED

Music Engineering by Richard Brice
The Electronics of Playing and Recording

Highly illustrated guide to the technology of music and recording.

Written in an approachable style using examples of well-known songs, this book is a must-have guide for sound recording engineers and electronic engineers.

If you are an electronics engineer who needs specific information about music reproduction, or if you are a sound recording engineer who needs to get to grips with the electronic technology, Music Engineering is for you.

This handy volume is a technical guide to electric and electronic music, including the essential science, but concentrating on practical equipment, techniques and circuitry. It covers not only basic recording techniques and audio effects, kit such as microphones, amps and instruments, but also valve technology, stereo and digital audio, sequencers and MIDI, and even a glance at video synchronisation and a review of electronic music.

Music Engineering lifts the lid on the techniques and expertise employed in modern music over the last few decades. Packed with illustrations, the book also refers to well known classic recordings to describe how a particular effect is obtained thanks to the ingenuity of the engineer as well as the musician.

Richard Brice has worked as a senior design engineer in many of Britain’s top broadcast companies and has his own music production company. He is the only writer who can provide this unique blend of electronics and music.

Contents: Soul Man - Science and sensibility; Good Vibrations - The nature of sound; Stand By Me - Microphones and their applications; Message in a Bottle - Valve technology; Roll over Beethoven - Electric Instruments; Wild Thing - Electronic effects; Pet Sounds - Electronic synthesis; Silver Machine - Sequencers & MIDI; Got to Get You into My Life - Sound recording; Bits 'n' Pieces Digital Audio; Space Odyssey - Stereo and spatial sound; Let's Stick Together - Recording consoles; Unchained Melody - Amplifiers; Shout - Loudspeakers; Synchronicity - Video and synchronisation; Dark Side of the Moon - Electronics and the music of the 20th century.

Inclusive price: £22.50 UK, £25 Europe, £28 ROW.

To order by post, send a cheque or postal order to Jackie Lowe at Electronics World, Quadrant House, The Quadrant, Sutton, Surrey SM2 5AS. Please make your cheque payable to Reed Business Information. Alternatively, fax full credit card details to 0181 652 8111, e-mail jackie.lowe@rbi.co.uk.

ISBN: 0 7506 39032

Paperback, 256pp, 150 line illustrations.

Copies of Richard’s previous book, Multimedia and Virtual Reality Engineering, are still available, inclusive hardback price: £27.50 UK, 29.50 Europe, £32 ROW.
Posters
Free EMFI wall chart. Schaffner EMC has produced a wall chart on EMC emissions, which provides information on a variety of test topics including the scope and required test equipment for common world-wide commercial standards. It also covers technical data such as field-strength conversion tables.
Schaffner EMC. Tel. 0118 9770070; fax, 0118 9792969.
Enq no 546

Software
TriCore development. TASKING offers the first programming package for the Siemens TriCore processor and its derivatives. It consists of the Nucleus PLUS real-time kernel, ANSI C and C++ compilers, a macro assembler, linker/locator and Crossview Pro debugger. All elements together form the Embedded Development Environment, which provides a Windows-based facility for the generation of TriCore applications software. Features include additional data types for fractional numbers and the automatic generation of multiply/divide operations; the C++ package also has a set of dsp classes for fixed-point data types.
Tasking Software BV. Tel., 0031 33 4558584; fax, 0031 33 4550033.
Enq no 545

Catalogues
Switches. Catalogue No 4 from Mec is available, in which are described process-compatible/sealed switches and surface-mounted types, together with full specifications.
Quiller Switches Ltd. Tel., 01202 436777; fax, 01202 421255.
Enq no 547

Application notes
Flexible circuits. Designers' Guide to Flexible Circuit Technology is published on a cd-rom by Flextronic and provides technical data on almost every aspect of flexible circuit design (the word being used here in the sense of 'bendy'). There are sections on materials, applications, markets, sculptured circuits, interference, and economical design. A hypertext form of presentation is used to give an easy path through the information.
Flextronic Ltd. Tel., 01243 784515; fax, 01243 774376; e-mail, flextronic-sales@diaipex.com.
Enq no 548

FM Embedded Controllers
at a ground breaking price!

The range of 'FM-Controllers' provide most of the features required for embedded control at a very low cost.

FEATURES FM-200 Controller
- 68K Micro-Controller 16 MHz clock
- 512 Kbytes Flash EEPROM
- 512 Kbytes SRAM Battery Backed
- 2 RS232 Serial Ports
- 1 RS232/RS485 Serial Port
- Real Time Calendar Clock (Y2K Compliant)
- Watchdog & Power fail detect
- 10 Digital I/O Lines
- 2-16 bit Counter/Timers
- P/C Bus or M-Bus
- Expansion Bus
- Size 100 x80 mm

OPTIONAL EXTRAS
- Up/Download removable card for data logging and/or re-programming
- SPI BUS, 68000 and PC Interface
- Designed, Manufactured and supported in the UK

CAMBRIDGE MICROPROCESSOR SYSTEMS LIMITED
Units 17-18, Zone D, Chelmsford Road Industrial Estate, Great Dunmow, Essex UK CM6 1XG Tel. +44 (0) 1371 875644 Fax: +44 (0) 1371 876077

CIRCLE NO.127 ON REPLY CARD

FM Embedded Controllers

C95 each
PER 100 UNITS
EDWin NC BASIC: Schematics, PCB Layout Basic
Autorouter, manufacture outputs, Max. 100 component database, 500 device Library

<table>
<thead>
<tr>
<th>Product</th>
<th>Price (£)</th>
</tr>
</thead>
<tbody>
<tr>
<td>EDWin NC De Luxe 1: BASIC + Professional Libraries and unlimited database</td>
<td>£79.00</td>
</tr>
<tr>
<td>EDWin NC De Luxe 2: BASIC + Professional Libraries and Mix-mode simulation</td>
<td>£79.00</td>
</tr>
<tr>
<td>EDWin NC De Luxe 3: BASIC + Professional Libraries, unlimited database, Mix-mode Simulation and Arizona Autorouter</td>
<td>£115.00</td>
</tr>
<tr>
<td>EDWin NC De Luxe 4: De Luxe 3 + Thermal Analyser, EDSpice Simulation, EDCoMX Spice model kit</td>
<td>£199.00</td>
</tr>
<tr>
<td>EDWin NC De Luxe 5: De Luxe 4 + ED-EMA (EMC Analyser) ALL FOR ONLY</td>
<td>£235.00</td>
</tr>
</tbody>
</table>

Plus Post & Packing UK £5.00; Rest of World £10.00 (only one charge per order)

I wish to order:
- EDWin NC BASIC: £49.00
- EDWin NC De Luxe 1: £79.00
- EDWin NC De Luxe 2: £79.00
- EDWin NC De Luxe 3: £115.00
- EDWin NC De Luxe 4: £199.00
- EDWin NC De Luxe 5: £235.00
- Post & Packing UK £5.00
- Rest of World £10.00

(total one P&P charge per order) Total £
Dictionary of Communications Technology

With over 9000 entries and 250 illustrations, this book is an invaluable reference work for anyone involved with electronics and communications. Dictionary of Communications Technology provides comprehensive coverage of data and communications and has entries on PC laser, the Internet, communications testing and client-server applications - in 500 pages.

Over 20 major companies helped prepare the Dictionary of Communications Technology, including AT&T, IBM and Digital Equipment Corporation.

Gilbert Held, author of Dictionary of Communications Technology, is an internationally author who has used his enormous expertise to make this work one of the most comprehensive sources of telecommunications information.

** Price includes delivery and package **

Dictionary of Communications Technology

Please supply the following title:

** DICTIONARY OF COMMUNICATIONS TECHNOLOGY **

Total

Name

Address

Postcode

Telephone

Method of payment (please circle)

Access/Mastercard/Visa/Cheque/PO

Cheques should be made payable to Reed Business Information

Credit card no

Card expiry date

Signed

Please allow up to 28 days for delivery
This month, John Watkinson looks into the basket - the chassis part of an electromagnetic loudspeaker that holds everything together - and explains how it can affect reproduction quality.

A loudspeaker's chassis or basket is a part which is often taken for granted, but it can have an effect on performance. At a basic level, the chassis provides mounting points, so that the drive unit can be fixed in an enclosure, and it supports the cone and the magnet assembly. A little thought shows that the chassis material and construction can affect the magnetic and thermal properties of the speaker, as well as being a potential source of colouration.

Take the example of a woofer, Fig. 1. This shows that the cone is supported in two planes. The first is the plane of the surround which serves as a flexible pressure seal between the moving cone and the stationary chassis. The second is the plane of the 'spider' or centring device which supports the neck of the cone.

The cone is located within the spider plane so that it can only move axially, and a (sometimes) linear restoring force is provided against cone travel to keep the cone in the centre of its range of travel.

Figure 1 also shows that the magnet assembly is supported by the chassis. Magnets and steel pole pieces are inevitably heavy, and the chassis has to be rigid enough to ensure that the relationship between the spider and the pole pieces is held constant. If this is not achieved, the coil may rub on the pole pieces.

In many applications it has to be accepted that the loudspeaker will be dropped or handled roughly. The chassis has to withstand very high transient forces from the magnet under these conditions.

Benefits of rare earth

In addition to the audible advantages of rare-earth magnets already advanced in this column, we now have a non-audible advantage. This is that the lighter rare earth magnet will place less stress on the chassis during rough handling, giving a distinct reliability advantage in applications such as PA, as well as making the unit easier to move.

When the cone is driven forwards, the magnet assembly experiences the Newtonian reaction backwards. It is often heard that the chassis of a loudspeaker has to be incredibly rigid to withstand the reaction of the magnet. This is a myth. If the relative masses of the cone and the magnet assembly are considered, it is clear that with a ratio of about 1000:1 the magnet isn't going anywhere.

Figure 2a) shows what really happens when the cone is driven forwards. The pressure in the enclosure goes down, and atmospheric pressure flexes the front of the enclosure inwards, actually moving the entire drive unit.

Some designers install the tweeter in a separate enclosure which is mounted on springs so that its position is not modulated by any enclosure flexing caused by the woofer. This is a near-plausible argument which justifies a high price tag on 'high-end' hi-fi equipment. But if such an approach results in an audible improvement, this must be an admission that the woofer enclosure isn't rigid.

Brace it

The solution is properly to engineer the enclosure for rigidity, a technique which is actively avoided in traditional wooden box speakers. A useful improvement can be obtained by bracing the rear of the woofer magnet against the opposite wall of the enclosure with a suitable strut.

Figure 2b) shows that the atmospheric pressure forces cancel at the magnet which stays put. Unfortunately it is difficult to be hyperbolic about an invisible block of wood, and so in certain markets it has no advantage at all.

Chassis can be made from a wide variety of materials, but the choice is far from obvious and depends upon the production volume and power handling requirement. Candidates include cast alloys, pressed steel and injection moulding.

With ferrite magnets, a steel chassis can increase flux leakage, requiring a larger magnet for the same performance. Alnico and rare-earth designs do not have this problem. Aluminium or plastic chassis avoid flux leakage in ferrite magnets.

The high strength and ductility of steel means that chassis can be made in quantity by pressing from a relatively thin sheet with a very low material cost. For rigidity, thin sheet cannot be left flat over any significant area and so the pressing will need to be complex to ensure that every edge is flanged. The press tool also has to punch out holes to allow the pressure from the back of the cone to escape. This results in a loss of strength, and many pressed steel chassis tend to err
on the side of plenty of metal rather than freedom of air movement.

Thermal considerations

For high-power speakers, thermal considerations are usually uppermost. The coil dissipated a lot of heat, most of which has to be removed through the magnet.

Mounting the magnet on a substantial cast aluminium chassis is a good way of losing that heat with minimum temperature rise. Casting allows the complex ribbed structures needed for rigidity to be replicated with ease. For volume production, die-casting is a natural technique. The die tools may cost thousands of pounds, but the unit cost is very low.

Cast chassis will also be found on low-volume, prototype and special-purpose drive units. These may be sand cast because the tooling costs are quite low, requiring only very basic wooden patterns, although they are well within the scope of the home builder. Sand casting is, however, labour intensive and tends to be poor thermal conductors.

In production engineered active speaker designs, one casting may form the entire front of the speaker, having integral woofer and tweeter chassis, mountings for the power transformer and also acting as the heat sink for the amplifier.

Advances in composite materials have meant that chassis can practically be moulded. It is easy to mould in any required details, and as plastic is non-conducting, the connecting tags can be mounted directly in the plastic, rather than on a separate tag strip. Plastics tend to be poor thermal conductors though, so their use is limited to drive units of moderate power.
“We never expected PCB Layout power at this price...”

Easy-PC For Windows is the latest evolution of one of the most popular affordable CAD systems available. With powerful new features and a true Windows graphical user interface, it is also one of the easiest to learn and use. Using full manufacturing outputs using Gerber, Windows printers and pen plotters it is one of the most complete systems.

Run multisheet schematics, PCB layouts and library managers in the multiple document interface and switching between each is simply case of selecting it with the mouse.

Runs under Windows 95™ and Windows NT™

Number One Systems
The Electronics CAD Software Specialists
Call 01684 773662 for more information or fax 01684 773664
Sightmagic Ltd, Oak Lane, Bredon, Tewkesbury, Glos GL20 7LR UK

Number One Systems is now a trademark of Sightmagic Limited
My last article looked at the characteristics of the eye and introduced the concepts of the optic-flow axis and dynamic resolution. When examined using these concepts, the shortcomings of interlaced video scanning were revealed.

This article continues the theme by examining the performance of film and then looks at how progress can be made across all image portrayal systems.

Making films
Good dynamic resolution is essential for realism, and will only be achieved if the motion portrayal is accurate. Accurate motion portrayal requires that the optic-flow axis is reproduced without distortion.

Figure 1a) shows how movie film is shot. Originally a frame rate of only 18 frames per second was used, for economy reasons. The optic flow axis is correctly preserved on the film for moderate motion. However, 18 frames per second is below the critical flicker frequency of human vision and is unwatchable.

The traditional palliative was to present each frame three times. The projector had a three-bladed shutter which produced three flashes of light for each frame pull-down.

Development of the 'talking picture'
meant that an optical soundtrack was added to the film. The resolution of the sound-head optics was such that the film speed at 18 frames a second was too low and so the speed was raised to 24 frames a second to improve the audio bandwidth. Now a two-bladed shutter could be used to produce a flicker frequency of 48Hz.

Figure 1b) shows that this corrupts the optic flow axis because there cannot be motion between the repeated frames. The eye tries to track the motion the best it can, but the optic flow axis of the film now oscillates with respect to the retina as shown in Fig. 1c).

Unlike interlace - which is worst on vertical movement - this effect is equally powerful in all directions. To a tracking eye, the two identical versions of a frame appear in different places on the retina. For slow movements, this results in an aperture effect which damages dynamic resolution. For rapid movements, the result is visible as judder or multiple images.

Assuming the film has a thousand lines of static resolution, dynamic resolution will be halved by aperture effect when a speed of one picture height in 40 seconds is reached. This is too slow to be useable, so the best dynamic resolution achieved by film hardly ever reaches half the static resolution that the film is capable of.

The best that cinematographers can do is to mount cameras on very solid and smooth supports and move them slowly to avoid judder. Rapidly moving objects of interest must be panned. Quality films are shot like this because the film makers know the restrictions.

Background strobing

In my last article, the concept of background strobing was described. When a tracking eye follows a moving object of interest, the background is presented in a different place on each frame. In television the background is at 50 or 60 different places per second, whereas in film there can only be 24 background locations per second. In other words the background strobing is twice as bad.

As a result, good cinematographers use shallow depth of focus in order to blur the background and disguise the effect of background strobing.

The damaging effect of picture repeat in film means that although film manufacturers have dramatically improved the static resolution of film in recent years, the improvement cannot be seen by the movie-goer in the presence of even very slow motion. As I have shown, there is more to moving picture quality than static resolution.

The picture repeating of film projection is carried over into telecine machines which convert film into television signals. To produce 50Hz video in Europe, the 24Hz film is run at 25Hz and two fields are made from each frame.

Figure 2a) shows the traditional 'flying-spot' telecine which uses a crt as a light source and a photocell behind the film to produce the video signal. The film moves at constant speed, driven by a capstan.

To produce a progressive scan picture the crt would only need to scan from side to side in a line. However, to produce an interlaced scan, the crt

**Fig. 1. Frame repeat damages optic flow axis.**

**Fig. 2. Telecine basics. The 'flying-spot' telecine, a), uses a crt to develop a two-dimensionally scanned spot which is focussed onto the film. The vertical scan of the crt allows interlaced fields to be created in real time from steadily-moving film. In the more modern line-scan telecine, b), vertical scanning is based solely on film motion. The film is focussed onto the line sensor. Interlace is achieved by reading alternate lines from a frame store.**

**Fig. 3. To obtain 60Hz video from 24Hz film, a process called 3:2 pull-down is used. Resultant demolition of the optic flow axis causes judder.**
requires vertical deflection as well so that it can scan each film frame twice in succession even though it has moved to a different location in each scan.

Figure 2b shows the more modern line-scan telecine. The light source illuminates the whole gate and a ccd line sensor is used. The steady motion of the film performs a vertical progressive scan, but the signal is stored in a frame-store. To obtain an interlaced output alternate lines of the frame-store are read out to produce two fields.

**Producing 60Hz video**
The production of 60Hz video from 24Hz film in USA requires 3:2 pull-down, where one frame is made into three fields and the next is made into two fields. Pull-down with a 3:2 ratio has a devastating effect on the optic-flow axis, as shown in Fig. 3. With respect to a tracking eye, images are portrayed in three places, leading to serious judder.

Figure 3 shows that the action of the interlaced telecine is to display a frame, sampled at one point in time, as fields at two (or three) separate times. In the presence of motion, the optic-flow axis turns and these fields no longer superimpose.

The shift of the fields with respect to one another causes an aperture effect which reduces the visibility of interface aliasing. Consequently a motion artifact of film has the result of concealing an interface artifact in video.

Bearing this in mind, using 24/25Hz film material to test or demonstrate hdtv systems must be a very suspect practice indeed, and the results are meaningless. The dynamic resolution of the television system under test could be – and often is – quite poor yet the artifacts due to film judder could well conceal the fact.

The damage done to the optic-flow axis by 3:2 pull-down is bad enough, but there is an even worse option, and that is to convert 3:2 pull-down 60Hz telecine video to 50Hz video in a standards converter. This is known in the industry as the 'Dallas' effect after the television soap opera which first tried it out – briefly.

**Film and MPEG**
MPEG is a set of standards for video compression, i.e. bit-rate reduction, which will be used for services such as digital television broadcasting and digital-video disc, or dvd. Figure 4 reveals that MPEG achieves much of its compression by sending only the differences between pictures. In the case of motion, an MPEG coder can send motion vectors telling the decoder how to shift a previous picture to make it more similar to the current picture.

In an MPEG environment, the damaged optic-flow axis from telecine causes compressors a lot of trouble. The field repeating means that motion vectors are zero between repeat fields but of doubled amplitude elsewhere. This alternating vector data means that the data available for picture differences fluctuates, causing quality loss.

The current approach to MPEG compression of telecine video is to use a preprocessor which de-interlaces the fields back to progressively scanned frames. In 3:2 pull-down systems, the third field is entirely redundant and is discarded. The adoption of progressive scan at the same frame rate as the film material allows MPEG to work at its most efficient as the vector data is more stable from frame to frame.

Set-top boxes receiving MPEG film frames at 24/2Hz have no trouble accurately decoding the frames, but display them by reading the output frame-store at 50Hz using interface and at 60Hz using interlace and 3:2 pull-down. This interlacing process recreates the damage to the optic-flow axis which took place in the original telecine material.

Telecine machines are actually standards converters because the input and output picture rate is different. It is obvious that the only way to overcome the poor motion portrayal of the telecine machine is to use motion compensation in the conversion process. In this way, the optic flow axis is not distorted. A telecine which does not do this cannot be regarded as having high definition.

The advantage of the motion compensated telecine is that the output video has the same motion characteristics as video from cameras. As a result, it doesn't need handling differently by MPEG. Motion-compensated telecine machines are currently almost unknown, but will come to prominence in due course.

There is an enormous archive of 35mm 24Hz film material which will be heavily used to attract customers to new television services. The advantages of a high quality television system will be lost if primitive field repeating telecines are used.

**High-definition film**
Traditionally, film and television were in competition and incompatibility was often quite deliberate. With the convergence of technologies though, these traditional incompatibilities have become an obstacle to progress and an holistic solution is required.

The clear solution is to use modern technology to remove the compromised motion portrayal of both film and television and to make them truly interchangeable and compatible with computer imaging.

Anamorphic optics are frequently used with film cameras to get widescreen pictures. Effectively, the magnification of the camera lens is different horizontally and vertically so that a wide picture is squeezed into a regular-shaped frame. This is a lossy non-perceptive technique which is inefficient.

Resolution of the film – and that of the eye – is axi-symmetrical. The result on the screen with anamorphic film is that the vertical resolution is in excess of the horizontal resolution. The eye judges quality on the worst axis so that vertical resolution – and film and money – is wasted.

**Anamorphic optics**
Practical anamorphic optics are not ideal and cause further loss of quality. Non-axi-symmetrical systems are inefficient and sub-optimal as the input to an MPEG compression system.

There is a worse case than that. Pass anamorphic film with impaired horizontal resolution into an interlaced telecine machine which has impaired
vertical resolution. Pay for 35mm film - and get the resolution of 16mm film. Consequently if film is being used as the source for an advanced imaging system, it should use axisymmetrical lenses (note the similarity with the use of square pixels giving the same vertical and horizontal resolution in graphics). In film this means that the greatest efficiency or the lowest film cost is achieved when the aspect ratio of the film frame is the same as that of the screen, just as in video the number of horizontal pixels should be given by the number of vertical pixels multiplied by the aspect ratio.

The 24/25 frames per second rate of conventional film corrupts motion portrayal and is incompatible with television and computer displays. The use of anamorphic optics is inefficient. Both problems can be solved instantly by adopting 2-perf 35mm film frames running at 50 or 60 frames per second for television filming. This doesn’t change the film speed, so running costs are unchanged.

Judder and aperture effect are eliminated by correct motion portrayal so that the dynamic resolution will be extremely good. A further advantage of 2-perf is that by halving the height of the frame it is automatically given a wider aspect ratio. Now spherical optics can be used. These are lighter and cause less resolution loss.

Technicolour introduced 2-perf years ago as Techniscope, but running at conventional frame rates for economy. All that is proposed here is to run it at a more appropriate speed. There is no technical problem whatsoever in using 50 or 60Hz as a film frame rate, especially as the pull-down distance is halved.

Existing telecine machines can easily be adapted to use 2-perf. Existing optics and transports are suitable. Telecine machines are naturally progressive scanning devices and have to go to great lengths to obtain interface. Disabling the interlacing processes yields a simpler machine.

Oversampling

People seem to think that high-definition television needs lots of lines. But that’s a myth. Cameras and displays need lots of lines to overcome aperture effects and to render the raster invisible, but the transmission medium between does not.

In the early days of television the capture, transmission and display formats had to be identical for simplicity, but that is no longer true or desirable.

A 525 line camera cannot give 525 lines of resolution, but a 1050 line camera with down-conversion can. Effectively the camera is using oversampling.

Although oversampling has totally dominated digital audio because of its obvious merits, it is harder to use it in conventional television because of interface. Interface puts half the picture data at another time and reduces the performance of spatial resamplers. Once interface is dispensed with, oversampling becomes an obvious and attractive technology.

Oversampling overcomes practical limitations in optical filters. In a ccd camera, the sensor elements sample the image spatially. The sensors are large for maximum light sensitivity and so a serious aperture effect is experienced. Ideally, an optical anti-aliasing filter is needed between the lens and the sensor. Unfortunately it is difficult to make a filter which has a sharp cut-off and it is usually necessary to compromise between visible aliasing and picture softness.

Using oversampling makes this compromise unnecessary. Figure 5 shows that in an oversampling camera, the spatial sampling rate must be increased by using a larger number of pixels in both dimensions – i.e. use a high-definition camera. The optical anti-aliasing filter then only needs to prevent aliasing at the higher sampling rate.

Output of the ccd element is spatially low-pass filtered and decimated to produce a television signal with the target pixel count. It will contain no spatial aliasing, but will not suffer loss at the band edge.

As a crt is a sampled device, breaking the picture up into lines, it should ideally be followed by an optical filter. As before, this is not done because in order to eliminate the raster it would intrude into the passband.

Removing the raster

Oversampling can also be used to render the raster invisible. Once more a form of standards converter is required, but this now increases the number of input lines using interpolation. The aperture effect of the display filters out the raster, leaving the passband unaffected.

Oversampling can also be used in the time domain in order to reduce or eliminate display flicker and background strobing. A different type of standards converter is necessary, which increases the input picture rate by interpolation. Such an oversampling converter must use motion compensation. If it doesn’t, moving objects will not be correctly positioned in an interpolated picture and the result will be judder.

The adoption of progressive scan allows spatial oversampling to be easily implemented in both camera and display. The number of lines needed in the channel between is then quite moderate.

Progressively-scanned sensors and displays having 700 to 1000 lines connected by a 480p channel are all that is required to deliver a truly high definition television service. The up-converter in the display is optional and lower cost receivers could omit it. Equally, large expensive receivers could incorporate motion vector steered frame rate up-conversion to reduce background strobing.

John Watkinson is an independent international consultant on audio and video technology. He is a Fellow of the AES and a Chariot Information Systems Practitioner. John is currently writing a book on helicopters. His web address is www.culinaire.se/JWA.
Digital visions

Is digital television new? Maybe not, but Baird’s television system was certainly a pig in a poke: wasn’t it?
Don McLean has some new evidence.

The much-hailed start of digital television may not be quite the giant leap you think. Digital television broadcasting – converting programme distribution to a fully digital environment – is just one small step in a steady ‘technology refresh’.

A new view on the past
To be objective about early television, what we need – and have not had up until now – is evidence. Without it, historians have had to rely on written or eyewitness accounts, some of them made decades after the event and most of them dismissive and derogatory.

In 1996 and early 1998, hard evidence turned up in the form of home video recordings made from BBC tv programme transmissions in the thirties. Until then, the entire mechanically-scanned era of television was thought to be devoid of any such recording. These digitally restored
recordings now challenge the long-established view.

To understand why this is so, let us fast rewind to just after Baird’s experimental period of the years around 1930.

**BBC chooses Baird’s 30-line system.**

In 1932 the BBC chose Baird’s 30-line standard for its television service, despite higher definition being available. It was chiefly the lack of suitable wide-band transmitter hardware that forced the BBC into using an existing solution.

The 30-line video signal was low enough in bandwidth to be transmitted on an existing BBC medium wave frequency normally used for audio. The public simply used their existing radio for the audio channel and a second radio receiver for the video channel. Only the display had to be bought — or in some cases built.

Baird’s mature 30-line system — developed in the late twenties — provided the BBC with an exceptionally low-cost engineering solution that exploited their existing broadcast infrastructure to the full.

No recordings? If the BBC or the Baird Company ever attempted recording their programmes, there is today no record of it. Fortunately for us, a few enthusiastic viewers made crude video recordings on their domestic audio equipment, Fig. 2, from BBC broadcasts. They had been inspired by Baird’s attempts to make a practical videodisc player in the late twenties and were encouraged by articles describing how to do it.

Recently, Jon Weller, a collector of old electronics equipment, retrieved a collection of direct-cut aluminium discs from a house clearance. The discs were previously owned and possibly recorded by Marcus Games, a keen amateur movie enthusiast. Jon later discovered that several discs in that collection had unusual material on them, Fig. 3.

**What are the recordings of?**

Although the discs were recorded at different speeds, the starting point was that the signal matched Baird’s 30-line video standard. Without a date to go by, I had to rely on comparing the video content with knowledge of the development of 30-line television in order to determine whether they were authentic or recent.

**The evidence**

Once restoration started, the clues began to appear. In the collection, there are eleven separate recordings of 30-line video. Each recording is a fragment from a programme and lasts no more than a minute. There were two types of programme — one type featuring four individual singers and the other containing what may be material from children’s programmes.
Scanning options

Two main types of mechanical scanning were used for 30-line cameras and displays: Nipkow disc and mirror-drum. The Nipkow disc—a spiral ring of apertures around the outer edge of the disc—created a curved image that was scanned in an arc. The mirror drum, shown in Fig. 4, however scanned in straight lines with a slight ‘bow-tie’ distortion.

The BBC transmitted its images from a mirror drum camera system, yet most viewers used receiver-displays based on the Nipkow-disc. They were cheaper and easier to make. Viewers accepted the minor distortion—just as today they surprisingly accept a normal television picture stretched to fit a wide-screen display.

The digitally restored images from the set of discs do not show the distortion caused by arc-scanning. The only alternative camera was one based on a mirror-drum.

Mirror-drum cameras for 30-lines had a fixed vertical field-of-view of just over 20°, excluding blanking. Hence the singers who we see in medium shot were around 9-10 feet, i.e. 2.7-3m, from the camera.

With the bottom of the back wall of the studio in shot, the images show that the studio was large and the camera system was sensitive. Showing camera features common with the 1933 ‘Looking In’ recording, the quality of camera-work appears superior, implying a later date.

Relative to what amateurs today achieve and relative to a genuine 30-line re-make of a 1930 play, the inherent quality of the vision signal is excellent. With no detectable image errors, the mirror drum camera was a precision-built mechanism. Lighting, camera-work and production have all been perfectly matched to the 30-line system.

Allowing for the almost ‘dictaphone’ recording quality, the home-recorded discs show details that have been talked about before, but not seen.

BBC’s first television service

These then are undoubtedly recordings made from the first BBC television service of 1932-35. The clues above suggest the transmissions came from the BBC tv studio at Portland Place between 1934 and ‘35.

With the 1933 programme, ‘Looking In’, we now have the total complement of video recordings of broadcast television—at least in the UK—before the fifties. Since they were discovered and restored only in the last two years suggests that more material may yet appear.

Singer without the song

Only one of the singers is easily recognisable by her distinctive features and hair-style—Betty Bolton, Fig. 5. As an accomplished contralto, she recorded many dance-band songs in the late twenties and early thirties.

Between 1929 and 1935 she performed well over a dozen times on 30-line broadcasts including being the first performer on the opening night of the BBC Television Service in August 1932.

Betty’s performance exudes professionalism. Here is a highly accomplished performer, perfectly natural in front of a television camera. When I showed the images to her, she immediately recognised herself from her appearance and actions.
The glossy shine of her hair, the glint of her tiny silver hair-clasps, her gem necklace and the pattern on her dress are all remarkably clear. A well-defined dark streak either side of her nose and dark eye shadow seemed to be the only make-up. Betty confirmed that only her eyebrows, nose and lips had been enhanced in dark-blue.

The other recordings of singers, Figs 6, 7, 8, are not distinctive enough to be identified. Hence it is difficult to establish when the recordings were made.

For the first time ever, we can truly appreciate something close to the original scene quality from a 30-line broadcast. The only surviving Baird Company engineer described these digitally restored pictures as about as bad as they got.10

The first commercial video disc...

In mid-1935 – rather late in the day to be of much use – the first video disc was offered for sale. It was a double-sided 30-line vision-only test disc, bearing a ‘Major Radiovision’ label, Fig. 9. It comprised a series of twenty still cartoon images – ten per side of the disc.

These stills are slid in, left for about twenty seconds, then pulled out. They are transparencies – lantern-slides – February 1999 ELECTRONICS WORLD
because one of them is slid in twice, the second time backwards. The recording shows the characteristic distortion from using a Nipkow disc as a camera - at a time when cameras used mirror-drum.

Back in the early twenties, people laid down rules to establish what was and was not 'television'. They decided that 'true' television should encompass the ability to see subjects in reflected light. For many years before Baird's successful demonstration of 'true' television in 1926, the early pioneers demonstrated video pictures of silhouettes and shadows. Here, an intense light was shone on the scanning area with the photocell behind it. Animated silhouettes, Fig. 10, a Maltese cross, even waggling fingers were all 'subjects'. However this was not 'true' television. Likewise, the 'Major Radiovision' test disc, made in that way is not 'true'. Although sold as a test disc, the whole recording is marred by a 5kHz 'ringing' on transitions, Fig. 11. The fact that these are stills without movement means that the full capability of the 30-line system is not realised, Fig. 12.

There is a 'sister' disc of stills, made in the same way as the 'Major Radiovision' disc but containing different subject matters. Strangely, whilst the recording is clear, none of the lantern-slides are even remotely recognisable, Fig. 13.

The new television system
Low definition TV had virtually national coverage with at least eight thousand viewing sets. After the last of 1,500 programmes was transmitted on 11 September 1935, these viewers found that their 30-line TV receivers had become obsolete. The new high definition service began a year later.

True revolution. Unlike digital television today, the transition from the 30-line service to the new high definition service was not an enhancement, it was a total revolution. Thirty-line tv was designed to use existing radio channels intended for audio broadcasting. The BBC had used mature technology for its 30-line television studio. It had also used its existing audio distribution channels and radio frequencies for vision transmission, leaving the public to buy or even build their own receivers.

In sharp contrast, a totally new infrastructure supported the high definition system. Virtually everything had to be developed from scratch - cameras, cables, distribution amplifiers, routers, transmitters, receivers and displays.

The investment was enormous but the time was right and the public were crying out for a full television service. The potential returns for the right solution made the investment appear secure.

Trial by television
When test transmissions started in 1936 from RadioOlympia, the price of receivers, full of the latest technology, left the public far behind. Much like the start of BBC Choice in September...
1998 on the digital service, hardly any of the public had the new receivers to watch it. Television coverage shrank from most of Britain to London and the immediate vicinity. Initially, television sets had to be dual-standard: the choice between the Baird Company’s totally new 240-line progressive scan system and rival Marconi-EMI’s 405-line interlaced system was to be resolved on-air. Dual standard reception made the first electronic televisions even more costly. By January 1937, the all-electronic 405-line system had been selected.

Viewers outside the London area, who switched off their 30-line receivers for the last time in 1935, had to wait more than fifteen years for television to return. It took until 1952 for coverage to reach Scotland and Wales and 1953-54 for prices of receivers to become affordable to the average working family.

But what of Baird?

John Logie Baird, Fig. 14, has easily earned the acclaim of Britain’s foremost television pioneer. His list of achievements is legendary. He developed, demonstrated and patented almost every aspect of television including colour, infra-red, 3D, and video recording. He introduced and funded a broadcast television service. His 30-line system was adopted — and hence sanctioned — by the BBC for their first television service. That he lost the prime competition for supplying the BBC’s high definition service to Marconi-EMI in 1936 is unfortunate — the all-electronic system was simply better. This does not detract from his remarkable achievements and innovations throughout the dawn of television and, indeed, for the rest of his life.

Baird received only one honour — honorary Fellowship of the Royal Society of Edinburgh. If we recognise comedians and retired politicians and their secretaries through our country’s honour system, then the time is long overdue to bestow proper honours on John Logie Baird.

Acknowledgments. I would like to thank Jon Weller, the owner of aluminium discs described here and to Elliot Levin of Symposium Records, who freely gave up his time to transfer the discs expertly and professionally. Final thanks go to Betty Bolton, the earliest video star, who has charmed me both on disc and in person.

References
1. BBC, “The Discovery of Television”, Documentary celebrating 25 years of Television, 1961
4. Practical Television, “Canned Television”, Barton Chapple, November 1934
6. NBTVTA - Narrow Band Television Association — uses low definition TV as an alternative amateur radio mode
7. Remake of “The Man With The Flower In His Mouth”, 1967, ILEA, produced by Lance Sieveking (the original 1930 producer) and filmed entirely in 30-lines by Bill Elliott.
11. A tape copy of this disc was supplied by Doug Pitt, NBTVTA, 1982. The source of this tape is unknown.

Don will be describing his work in a lecture to be given at the IEE, Savoy Place, London on 11 May 1999 at 6pm. Admission is free and open to non-members. The multimedia presentation will rely heavily on the video restorations and will be entitled “Restoring Baird’s Image: the restoration of the world’s earliest-known television recordings.”
DSPs at the bottom end of the market are finding themselves used in an ever increasing number of applications. But how will they compete against the likes of Risc and microcontrollers? Steve Bush reports.

With hugely powerful super-scalar digital signal processors grabbing the limelight, it is easy to forget the bottom end of the market—the 16-bit fixed-point processors that sell in increasing numbers into products as unlikely as video baby alarms and fridges.

It is a highly competitive sector which is also the target of Risc processors and microcontrollers. What are chip manufacturers doing to keep their share—or even increase it?

Jean-Marc Darchy is Texas Instruments’ European dsp spokesman. He said: “There is still a lot we can do. The first thing is that dsps will be adopting the latest production technology. With an 0.18 or 0.15μm process, you can deliver for $5 three to four times the performance compared with a dsp from two to three years ago. For instance, our 5402 [due to sample next month] will deliver 100Mips for $5. There will be a variety of products on the market at this performance.”

With 100Mips for $5, dsps will become more attractive in a market that is awash with Risc processors, microcontrollers, and existing dsps.

In some cases, fast dsps will have an inherent advantage. “DSPs will be better than microprocessors for voice coding and data transmission,” said Darchy.

According to Darchy, there is a second factor that will affect forthcoming sales. “To win against microcontrollers, dsps will become more specialised and will focus on an application, or a cluster of applications, with specific on-chip peripherals. This will need a good understanding of the market and the products that will use the processors.”

An example he cites is motor controllers, where TI, Analog Devices and Zilog already have dedicated dsp products. “This is a success. It was a pure microcontroller market which is now switching to medium performance dsps because the on-chip peripherals, pulse-width modulators and timers, focus the product on the application,” said Darchy.

Applications likely to receive the attention of dsp makers in the near future, according to Darchy, include: point of sale terminals, payphones, imaging systems and remote data acquisition. “One dsp could handle all of the usual functions in a sales terminal, plus implement a modem to communicate with the store computer. It could perhaps do some voice recognition as well. For data logging, you will be able to measure parameters, perform calculations and transmit the results down a phone, all with a $5 dsp.”

One company that already incorporates a wide range of peripherals on its dsps is Zilog. “Typically a dsp has hardly any i/o,” said Adam Provis, an application engineer with Zilog. “We add the sort of peripherals found in microcontrollers. For instance: a phase-locked loop to allow the chip to run from a low-cost 32kHz crystal, counter-timers, SPI serial port, 8-bit a-to-d converter and i/o ports.”

He sees this as an advantage in simple consumer products. “Typically, a microcontroller cannot handle voice compression for storage into flash memory or for transmission, whereas a dsp can. In walkie-talkies, baby alarms and similar products, you can choose to use a dsp for compression and a microcontroller to handle the housekeeping.
DSP chip makers are not blind to this and are taking steps to drop power consumption even as performance increases. "Because of the processes used," said Analog Devices' Andrew Lanfear, "in some cases 32-bit dsps can cost less than 16-bit alternatives."

This can make the 32-bit device look attractive, even when the application only demands 16-bit capability. "But the 16-bit dsp is likely to consume less power in the application," said Lanfear.

As an example of low power consumption, he puts forward the ADSP2189. "It is a 75Mips device that can run two V.90 [56kbit/s] modems simultaneously. But it consumes only 0.4mA/Mip at a core voltage of 2.5V."

The core behind the ADSP21xx family has been around for a while now, constantly increasing in performance. Now at 75Mips, "we expect it to top-out at 100Mips," said Lanfear. "In future we are looking at a new instruction set architecture and a new core. This will be further down in power consumption and with much higher performance. But we are not releasing dates yet."

Analog Devices and TI are the 'big two' in dsp. Is TI looking at architectural changes for its low-end processors? "I suspect not," said TI's Darchy. His argument is largely financial: "Going to smaller, faster processes is quickly moving low-end dsps towards top-end microprocessors. A $40 to $50 dsp three years ago is only $10 now." There is also a reason why moves to new architectures are actively undesirable. "Keeping the same architecture is a more robust, efficient and economic way to get the best out of a company's existing software base and tools," said Darchy.

Up-to-date semiconductor processes, combined with microcontroller peripherals are pushing 16-bit fixed-point dsps into applications formally reserved for microcontrollers. Power is going down and speed is going up. The likely result is 'high-tech' consumer goods that feature voice and video compression; speaker phones, security products and baby alarms are the kind of products that should benefit.
Vann Draper is offering 30% discount to readers of Electronics World on two of their professional quality, battery/mains powered, bench digital multimeters.

The APPA 201 normally sells for £139.83 but for readers of EW the price is only £99 fully inclusive of vat and delivery. The APPA 203 is normally priced at £175.08 and is available to readers of EW for just £125 fully inclusive.

Both models are supplied ready to use complete with test leads, mains lead, carrying strap, operating manual, and a 12 month guarantee.

To order simply post the coupon to:
Vann Draper Electronics Ltd at Unit 5, Premier Works,
Canal Street, South Wigston, Leicester LE18 2PL.
Alternatively tel 0116 2771400, fax 0116 2773945
or email sales@vanndraper.co.uk

APPA 201 specification
Display: 2000 count, back lit lcd
Ranging: Auto and manual
DC voltage: 200mV, 2, 20, 200, 1000V Accy 0.5%
AC voltage: 2, 20, 200, 750V Accy 1.5%
DC current: 200uA, 2mA, 20, 200, 10A Accy 0.8%
AC current: 200uA, 2mA, 20, 200, 10A Accy 1.5%
Resistance: 200, 2k, 20, 200, 2M, 20M Accy 0.8%
Continuity test: Threshold less than 50ohm
Diode test: Test current 1.0mA
Additional functions: Data hold
Power requirement: 120/240Vac or 6 x AA batteries

APPA 203 specification
Display: 4000 count, back lit lcd
Ranging: Auto and manual
Bar graph: 42 segment
DC voltage: 400mV, 4, 40, 400, 1000V Accy 0.4%
AC voltage: 4, 40, 400, 750V Accy 0.8%
DC current: 4mA, 4, 40, 400, 10A Accy 0.7%
AC current: 4mA, 4, 40, 400, 10A Accy 1.3%
Resistance: 400, 4k, 40, 400, 4M, 40M Accy 0.6%
Capacitance: 4nF, 40, 400, 4uF, 40uF
Frequency: 100Hz, 1KHz, 10, 100, 1MHz
Continuity test: Threshold less than 50ohm
Diode test: Test current 0.6mA
Additional functions: Min, Max, Hold, Relative, Delay hold
Power requirement: 120/240Vac or 6 x AA batteries

Use this coupon for your order
Please supply me:

- APPA 201 meter(s) at £99 inc vat and del
- APPA 203 meter(s) at £125 inc vat and del

Name:
Address:
Tel No:
Total: £
Cheques payable to Vann Draper Electronics Ltd or debit my visa, mastercard or switch card:
Card type:
Card No:
Expiry date: Switch iss no:
Signature:
Overseas readers can still obtain this discount but carriage charges vary according to country. Please telephone, fax, email or write to Vann Draper.
Aquila Vision specialises in supplying and supporting embedded microprocessor development products from PICs to DSPs. We also stock robotics boards, Linux and general interest CD-ROM's.

AQUILA VISION
http://aqula-vision.co.uk

BF COMPONENTS
http://www.bfcomponents.co.uk
Visit the site for Milgray-Bell in the U.K. Full e-mail facility with instant links to Bell and Milgray web sites for stock interrogation.

CAMBRIDGE MICRO PROCESSOR SYSTEMS LIMITED
http://www.cms.uk.com

COOKE INTERNATIONAL
http://www.cooke-int.com
e-mail: info@cooke-int.com

CROWNHILL ASSOCIATES LTD
http://www.crownhill.co.uk
Crownhill supply low cost development tools for use with Micro-Controllers and Smart Cards. Products include Smart Card development tools, Smart cards, Micro Development tools and Bespoke Card development tools, Smart cards, Smart Cards. Products include Smart tools for use with Micro-Controllers and

ELECTRONICS WEEKLY
HYPERACTIVE
http://www.electronicsweekly.co.uk
DISPLAY ELECTRONICS
http://distel.co.uk

FELLER UK
http://www.feller-at.com
Feller (UK) Ltd. manufacture Fully approved cordsets (Modulised mains plugs and connectors) and Power Supply Cables for all industrial Countries to National and International Standards

FLASH DESIGNS LTD
http://www.flash.co.uk
Portable Easy-ICE - The world's fastest, Lowest Cost, Real-time Emulator + Starter kits with unique ICE MODE for ATMEL AT89C51, AvrMega103/603, MC651, Dallas 80C320, Hitachi H6 + ISP programmers + 'C' Compilers

LOW POWER RADIO SOLUTIONS
http://www.lprs.co.uk
LPRS markets low power radio transmitters, receivers and transceiver modules manufactured by ourselves, Radiometrix, Circuit Designs, RDI and Micrel. Applications for telemetry, video and remote control.

MICRO CALL
http://www.microcall.memec.com
Micro Call is a distributor for the following: Galileo, IDT (Integrated Device Technology).

MITRONICS
http://www.mitronics.com
Visit Mitronics, the leading stocking distributor of obsolete and difficult to find Motorola parts. We carry electronic components, integrated circuits, and semiconductors, plus much more.

NEWNES - BOOKS FOR THE ELECTRONICS WORLD
http://www.newnespress.com
Over 300 books and information packages for those working with electronics and engineering technology. Visit our site for a free catalogue and downloads.

NATIONAL INSTRUMENTS
http://natinst.com.uk

OMEG POTENTIOMETERS
http://www.omeg.co.uk
Omeg 16mm and 20mm potentiometers and switched potentiometers with conductive polymer tracks. Web site has full product details, latest news, company contacts, stockists and distributors.

PCA:PHILIP COLLINS & ASSOCIATES PTY. LTD
http://www.pca.cc
PCA manufactures Radphone 2000DX remote control systems for shortwave broadcasters and government agencies wanting worldwide control of communications receivers and transceivers from any time phone.

RALFE ELECTRONICS
professional test & measurement
www.ralfe-electronics.co.uk

SUPRA AUDIO CABLES
http://www.jenving.se
Jenving Technology AB is the manufacturer of Supra Audio Cables. OEM productions are also accepted.

VANN DRAPER ELECTRONICS LTD
http://www.vanndraper.co.uk
Test equipment from Grundig, Kenwood, Hitachi, Fuks, Avo, Glassman. Advance in a comprehensive site including oscilloscopes, multimeters, power supplies, generators, counters, soldering, digital tv etc.

VUTRAX PCB DESIGN SOFTWARE
http://www.vutrax.co.uk
VUTRAX electronic schematic and pcb design system for Windows 95, 98 and NT. Limited Capacity FREE version downloads available, all upgradeable to various customised levels.

WOOD & DOUGLAS
http://www.woodanddouglas.co.uk
Wood & Douglas Ltd is the leading independent British designer and manufacturer of quality radio products for International telemetry, data,voice & video wireless communications.

ZETEX PLC
http://www.zetex.com
Data sheets, Application notes, Spice models, Distributor details and more are all available on the Zetex website. CD-ROM version available free by request to info@direct@zetex.com.
Hardware

ASIC/FPGA/VHDL

- SUNY Gate Array, VHDL, ASIC
- S-183K
- Design/Manufacture
- M. E. S. U. E.
- VLSI, UVM, VPi, ASIC
- S. W. B.
- VLSI, UVM, VPi, ASIC
- S. W. B.
- VLSI, UVM, VPi, ASIC
- S. W. B.
- VLSI, UVM, VPi, ASIC

FIRMWARE ENGINEERS

- C. 6. 3K + PENSION & BENS
- New position for Hardware Engineer to join one of the world leaders in the design and manufacture of PCs and PC peripherals.

SYSTEMS ENGINEERS - SATELLITE

- £40-35K
- M4 CORRIDOR

RF DESIGN ENGINEER

- £14-20K
- E. ANGLIA
- A company with over 20 years experience in the design and manufacture of Isolators and circulators.
- A company involved in the development of the "3rd generation network" - UMTS - is seeking a Standards Engineer. You will be responsible for developing network architectures for UMTS, representing the company at standards meetings, etc. You should have at least a degree in electronic communications engineering with a minimum of five years experience in the telecommunications industry. Interested? Tel: 01442 231555 Fax: 1442 212555

STANDARDS ENGINEER - UMTS

- £20-35K
- BERKSHIRE

POWER

SUPPLY/ANALOGUE

- W. London
- DC-DC, Magnetics 100K
- Kent
- S. M. S. D. Designer
- Sussex
- Power/Analogue, Medical
- W. Sussex
- Power, Ball, vars.
- Essex
- Switch Mode PSUs
- Midlands
- Switch Mode PSUs
- Herts
- Power Elec., Motors
- Staffs
- Power Elec., GTO

ANAL/DIG/FPGA/ASIC

- SOUTH WALES £18-30K
- New positions for 5 Engineers with experience to be flexible to Digital or FPGA/VHDL/ASIC design work to experience of a new major project developing Secure Networkers.

MEDICAL ELECTRONICS

- W. SUSSEX £25K - £30K
- Senor design role with a British company who are at the forefront of medical electronics in the field of high dose radio, brachytherapy used for internal radiation therapy treatment.

RF/ANALOGUE DESIGN

- £20-27K
- E. ANGLIA
- A world leader in the supply of advanced electronic systems, is seeking an RF/Analogue Design Engineer to carry out the design and development of very high speed Military Electronics equipment.

MICRO/ANTENNA DESIGN

- £14-20K
- E. ANGLIA
- A company with over 20 years experience in the design and manufacture of Isolators and circulators.

RF/Comms

RF Design Engineers x 3

- WALS £20-40K
- A company who manufacture and develop wireless products, software and support for the services providers within the mobile communications industry require Senior/Principal RF Design Engineers. You will be responsible for control loop, power amplifiers, receiver and transmitter design and will require knowledge of GSM systems architecture. With a flexible approach to problem solving you should be able to work on all the above cross-functional teams. Interested? Tel: 01442 231555 Fax: 01442 212555

SOFTWARE

HARDWARE & MUSIC

- CAMPS TO £34K
- Do you have an interest in Music, and would you like to progress your career designing digital electronic systems for the music business?

DIGITAL DESIGNERS

- ISLE OF WIGHT £25K
- New positions for Digital Design Engineer to join one of the largest expanding companies who are a major force in the defence electronics industry.

RF Systems Engineers

- £40-35K
- M4 CORRIDOR

SYSTEMS ENGINEERS - SATELLITE

- £40-35K
- M4 CORRIDOR

RF Test Engineer

- £14-20K
- E. ANGLIA
- A company with over 20 years experience in the design and manufacture of Isolators and circulators.

Contact - Alison Jones 01442 405522
# Radio Communications

**RELIABILITY ENGINEER** – Bristol to £26k+

We're looking for an individual to shake, rattle and roll this company's wireless products ready for the demanding environments they'll be working in. The successful applicant will be the 'first in' in this type of role and our client seeks someone to bring in the necessary expertise. A background in radio technology would be a distinct advantage. Quote WW9801-53.

Contact Mark Wheeler for more information.

**TEST ENGINEER** – Surrey to £25k

Working within a group responsible for the design of switching software for UMTS mobile comms infrastructure, you will be involved in setting up and undertaking complex test and systems integration processes. Ideally HNC qualified, it would be useful if you had experience in mobile, cellular, GSM, etc and an appreciation of switch signalling. Quote WW9808-86.

Contact Malcolm Masters for more information.

**PRODUCTION ENGINEER** – Bristol to £30k

A sound knowledge of small to medium volume production and manufacturing techniques is required here. Experience of liaising with small multi-disciplined R+D teams and being able to pro-actively work with outside contractors is essential. A general electronics background is required, ideally with radio communications experience. Quote WW9811-54.

Contact Mark Wheeler for more information.

**RF STANDARDS ENGINEER** – Surrey to £30k

Working within a new group, you will be ultimately responsible for developing national, regional and international mobile equipment standards. This role is ideal for someone with a proven background in 3rd generation mobile technology. Quote WW9808-82.

Contact Malcolm Masters for more information.

**RF IC DESIGN ENGINEER** – Bristol to £45k

Make a mark for yourself and be the first IC designer in this established and fast growing Radio Systems Design House. You'll be working alongside a very fine multidisciplinary team of Engineers involved in some of the most stimulating projects around. Competent hands on skills are required including experience up to 3GHz together with some good ideas. Quote WW9712-17.

Contact Mark Wheeler for more information.

**DIGITAL DESIGN ENGINEER** – N. Wiltsh to £35k

Contact Malcolm Masters for more information.

**RF PA DESIGN EXPERTS** – Bristol to £40k

Involved in projects that seem to go on forever? Stuck in a corner working on the bit your boss says you have to do? Then your salvation is at hand with this fast growing Wireless Communications company where your talents can be truly realised. Accomplished design skills up to 3.5GHz in high power PA's ideal, receiver and synthesiser development experience very useful. Quote WW9709-56.

Contact Mark Wheeler for more information.

**BENCH TECHNICIANS** – Notes £10k - £22k

Component level expertise? Board level diagnostics? Shiny new technical qualification? This leading cellular maintenance organisation wants you!! You don't have to have communications product experience (although it would help), but you'll be keen to keep abreast of the latest technology. All this in a positive, friendly environment too! Quote WW9703-37.

Contact Mark Wheeler for more information.

**SERVICE REPAIR TECHNICIANS** – Surrey £18k

This is a great opportunity for a keen RF technician to work in a lively atmosphere for a major manufacturer of PAM equipment. You'll need to be able to service and repair to component level and have relevant mobile comms involvement. Some Band 3 and installation experience would be desirable but is not essential. Quote WW9811-52.

Contact Rich Wootten for more information.

**DSP SOFTWARE ENGINEER** – Bristol to £34k

For this one, you'll need to bring to the table at least a year's expertise in DSP Algorithm development, real time embedded software and an understanding of hardware design. You would be working on radio modems, linear amplifiers and many other interesting and challenging projects. A radio background is desirable but not essential. Call us today if it sounds like you. Quote WW9804-30.

Contact Mark Wheeler for more information.

**PRODUCT SUPPORT ENGINEER** – Berks to £25k

Our client is at the forefront of mobile telecoms, having released several of the most popular products on the market. Now it's your turn to get a slice of the action. You'll need to be able to support the introduction of complex mechanical parts into manufacture and maintain build standards in a demanding industry. A general electronics and electro-mech background required. Quote WW9811-09.

Contact Rich Wootten for more information.

For more vacancies visit our website http://www.mdm.co.uk
UK – Wide Vacancies

Graduate Electronics Engineer – Hampshire. Qualified to degree level, to work with the design team developing and proving new hardware and software for engine management and power conditioning systems. Training in various disciplines including embedded micro-controller design and power electronics systems to 250kW. Salary negotiable.

Test & Repair Engineer – Hampshire. Minimum of HNC with at least 2 years experience of fault diagnosis of analogue and digital circuits to component level. Computer literate, familiarity with Windows packages and able to work under pressure. Salary negotiable.

Project Manager – West Yorks. RF/Microwave. To ensure a development project is delivered in line with customer prototype commitments and that the product is developed to enable cost effective manufacture in volume. To £35k.

Test Design Engineer – Hampshire. Minimum of HND and knowledge of Visual Basic and/or C in a Windows environment to design, maintain and document test procedures, systems and software using PCs and telecommunications test equipment. Familiarity with telecommunications protocols and report writing ability would be helpful.

Electronics Engineer – Cheshire. Embedded Controllers. To develop electromechanical devices for the test of PCBs using embedded controllers, analogue instrumentation and PC based software (VB, C++, Win NT/95). Must be able to fault find complex electronic systems with at least 2 years experience in a related field.

Software Development Engineer – Hampshire. For low power embedded systems using C and assembly languages. Knowledge of NEC 75X, 75XL 4 bit and 78K/0 8 bit microprocessors and digital or analogue hardware design ability would be useful. To £28k.

Senior RF Development Engineer – Hampshire. Development of low power RF circuitry up to 1Ghz and experience of LNA, oscillator, mixer and IF design. Experience of synthesiser design and low power transmitter work would also be useful. Supervision of junior engineers and project management is also envisaged as part of the role. Salary to £32k.

Electronics Design Engineer – Cheshire. Development of high frequency analogue circuits (to 500MHz) Degree qualified with a minimum of 2 years experience of analogue circuit design. Exposure to DFM issues and PCB design using Cadstar. £Neg.

For details of these and other electronics vacancies telephone Roy Parrick on 01703 237200 or fax on 01703 634207. Alternatively E-mail to southtech@kellyservices.co.uk

ADVERTISE FREE OF CHARGE

Subscribers* to Electronics World can advertise their electronics and electrical equipment completely free of charge

Simply write your ad in the form below, using one word per box, up to a maximum of twenty words.

Remember to include your telephone number as one word.

You must include your latest mailing label with your form.

* This free offer applies to private subscribers only. Your ad will be placed in the first available issue.

Trade advertisers – call Joannah Cox on 0181-652 3620

All adverts will be placed as soon as possible. However, we are unable to guarantee insertion dates. We regret that we are unable to enter into correspondence with readers using this service, we also reserve the right to reject adverts which do not fulfil the terms of this offer.

Please send your completed forms to:
Free Classified Offer: Electronics World, L333, Quadrant House, The Quadrant, Sutton, Surrey SM2 5AS
Calling all Radio Engineers

We have excellent opportunities within Research, Design and Test for Radio Engineers to work at all levels in the fields of:

GSM
Fixed Radio Access / WLL
Military CIS
PMR DECT TETRA
Satellite Communications
Mobile Switching

John Prodger Recruitment
Connecting people with opportunities

We would be glad to focus our efforts on securing your next move.
Please call John Darby, ref 2984H.
Tel: 01727 818704 Fax: 01727 838272
Email: johnd@jprecruit.com

JPR, The Courtyard, Alban Park, Hatfield Rd, St Albans, Herts AL4 0LA.
ARTICLES WANTED

TOP PRICES PAID
For all your valves, tubes, semi conductors and IC's.
Langrex Supplies Limited
1 Mayo Road, Croydon
Surrey CR0 2QP
TEL: 0181 684 1166
FAX: 0181 684 3056

VALVES WANTED
Courteous, Professional Service
Ask for a free copy of our wanted list.
BILLINGTON EXPORT LTD
Billinghurst, Sussex
Tel: 01403 784961
Fax: 01403 783519
Email: billingtonexportltd@btinternet.com
VISITORS PLEASE PHONE FOR AN APPOINTMENT

WANTED
Valves & Semiconductors
All types e.g. Discrete & IC's
GOOD RATES PAID
CHELMER VALVE CO.
130 New London Road
Chelmsford, Essex
Tel: 01245 265865
Fax: 01245 490064

PLEASE MENTION ELECTRONICS WORLD WHEN REPLYING TO ADVERTISEMENTS

ARTICLES FOR SALE

RF DESIGN SERVICES
All aspects of RF hardware development considered from concept to production.
WATERBEACH ELECTRONICS
TEL: 01223 862550
FAX: 01223 440853

RHODE & SCHWARZ, Anritsu, Racal, W1, Dynamic Sciences, Flexray Rx's, HP, Advantest
Spectrum Analysers. WTB: MW or SW Broadcast 1ks. Tel/Fax/Email for list 01908 565726 - BigMike@pewm-freeerve.co.uk

TEKTRONICS 145/148, SPJ test, Waveform generators, all manuals, rated space hence bargain price £1,200. Telephone 01908 365726 - BigMobile@g4zow.freeserve.co.uk

PHILIPS 5390S
1GHz RF SYNTHESIZER WITH SERVICE MANUAL
£1099 + VAT
100kHz to 1020MHz, -125dBm to +13dBm
Unique video modulation + sound at 4.55, 6.0, 9.15MHz or 1250kHz or FM (to 254kHz)
RF sweep - 8 settings memories - IEEE Interface
Anode Laboratories Ltd
Tel: 01353 649412
Fax: 01353 648128

POWER SUPPLY DESIGN
Switched Mode PSU
Power Factor Correction
Inverter
Tel/Fax: 01243 842520
e-mail: eugen_kus@cox.co.uk
Lomond Electronic Services

APPOINTMENTS

ELECTRONICS, COMPUTING AND AARDMAN MOTION CONTROL ENGINEER
Bristol
Salary - Negotiable
A world leader in 3D model animation is looking for an Electronics Engineer to join their busy team based in Bristol.
Applicants must have a thorough knowledge of electronics - preferably applied to film, video and motion control equipment. Candidates should also possess design and small scale manufacturing experience and ideally, will have experience in processing microprocessors.
Good problem solving skills are essential. Candidates should also be comfortable working on their own initiative in a pressured environment and to strict deadlines. The post will be based in Bristol, although occasional travel may be necessary.
If you would like to be considered for this post, please send your CV, with covering letter, to The Personnel Department, Aardman Animations, Gas Ferry Road, Bristol BS1 6UN.
Closing date for applications - Friday 15 January 1999.

FOR THE PICK OF THE TOP UK DIGITAL ANALOGUE & RF DESIGN

APPOINTMENTS... PhD, MSc, 1st, 2.1 Honours? then visit www.ecmsel.co.uk or call 01638 742244

February 1999 ELECTRONICS WORLD
MACCONI 2022A synthesized signal generator 10kHz-16Hz
KEITHLEY 192 programmable digital multimeter £2500
IFR A-7550 1GHz portable spectrum analyser with receiver options
FLANN precision rotary waveguide attenuator 22110 0-70db 26.40GHz
EIP 575 source locking frequency counter 186Hz GPM option
ORANETZ 626-PA -6006 ac neutral monitor, c/W TR2018 clamp
DATRON 1061 voltmeter
ANRITSU MN95D fibre-optic attenuator 0-65db
ANRITSU ML93A optical power meter with MA96A power Mbit/sec £150
ANRITSU ME518A pcm error-rate test set 1kbit/sec-150
RHODE & SCHWARZ URE rms digital voltmeter IEEE
RHODE & SCHWARZ UN 5, 55 -digit multimeter IEEE
RACAL -DANA 1995 option 01, 200MHz universal counter/timer
PHILIPS PM5580 I.F. modulator (PAL 1) 'PIC'
ALL equipment sold calibration-checked by independent laboratories
AND SPECIAL BARGAIN DISPOSAL DEALS PLEASE CHECK OUR WEBSITE FOR EXCLUSIVE ACCESS TO OUR COMPLETE STOCK INVENTORY
SPECIAL PURCHASE SO WE BELIEVE WERE THE INTERFACE, and 2960 cellular adaptor included!!
MARCONI 2955 MOBILE RADIO TEST SETS wider with a w

Contact Joannah Cox on 0181 652 3620

1999 Measurement and Automation Catalogue
National Instruments
Phone: 01635 523545
Fax: 01635 523154
Website: www.ni.com/uk

1999 Measurement and Automation Catalogue
National Instruments
Phone: 01635 523545
Fax: 01635 523154
Website: www.ni.com/uk

CABLING SOLUTIONS FROM THE LCD EXPERTS
Trident Microsystems' new LVDS system, provides the cabling solution to overcome all the problems associated with driving Digital TFT over long distances.
Trident’s new LVDS system now allows for digital drive of up to 20 metres in length.

Further details call Trident today
Tel: 01737 780790
Fax: 01737 771908

INDUSTRIAL COMPUTER PRODUCTS
The latest ICP catalogue featuring a comprehensive range of CPU boards and enclosures, complete with interconnects, is now available from Wordsworth. Further details from:

Tel: 01732 861000
The Affordable Solution for 8051 & AVR™ Microcontroller Support Tools

**DISTRIBUTORS FOR IAR SYSTEMS**

IAR Microcontroller Development Tools
C-Compilers, Assemblers, Simulators

8051, Atmel AVR, Hitachi H8

**MICRO-PRO DEVICE PROGRAMMER**

The complete programming solution!

Supports:

- **MICROCONTROLLERS**
  - Atmel 89C, 89S, 90S(AVR)
  - Generic 87C, Dallas 87C820

- **FLASH MEMORY**
  - Atmel 29C, 39C

- **SERIAL/PARALLEL EEPROM**
  - Atmel 24C, 25C, 95C, 96C, 28C

- **CONFIGURATORS**
  - Atmel 17C, Xilinx XC17

Not all devices may be supported within each family.

**WRITE IN BASIC RUN IN A FLASH**

**AVR BASIC**

- Compiled BASIC generates tight AVR™ machine code
- Not a Run-Time Interpreter; NO code overhead!
- Target speeds comparable with assembler
- Breaks the cost barrier for small projects
- Ideal for educational, hobbyist and professional use

**THE ULTIMATE 8051 TOOL SET**

- Optimising Ansi-C Compiler
- Macro Assembler
- Linker
- Software Simulator
- Integrated Editor
- Hex Creator

Starters Systems supplied with 2K Toolset & Development Systems supplied with 8K Toolset are available for Atmel, Dallas, Siemens, Texas 8051 microcontroller derivatives

**FLASH 8051 Professional Starter System**

System Contents
- Combined Serial & Parallel Device Programmer
- Evaluation module for 8, 20 & 40-pin DIL devices
- In-System Programming (ISP) Cable
- Keil PRO-128 Development Environment (2K code limit)
- Evaluate Assembly, Linker, Hex Creator, Editor & Simulator
- Mains Power Supply Adaptor
- PC Serial Cable (Connects to PC COM Port)
- One AT89S8252 40-pin DIL Microcontroller

**WRITE IN BASIC RUN IN A FLASH**

**KEIL SOFTWARE**

- µVision Integrated Development Environment for Windows™
- dScope Software Simulator & Target Debugger

**FLASH 8051 Professional Starter System**

System Contents
- Combined Serial & Parallel Device Programmer
- Evaluation module for 20 & 40-pin DIL devices
- In-System Programming (ISP) Cable
- Keil PRO-128 Development Environment (2K code limit)
- µVision Assembler, Linker, Hex Creator, Editor & Simulator
- Mains Power Supply Adaptor
- PC Serial Cable
- Atmel CD-ROM Datbook
- One AT90S1200 DIL Microcontroller

Compiled BASIC generates tight AVRTM machine code
Not a Run-Time Interpreter; NO code overhead!
Target speeds comparable with assembler
Breaks the cost barrier for small projects
Ideal for educational, hobbyist and professional use

**Software Simulator & dScope 6.3**

Available for Atmel, Dallas, Siemens, Texas 8051 microcontroller derivatives

**Write In Basic Run In A Flash**

**THE ULTIMATE 8051 TOOL SET**

- Optimising Ansi-C Compiler
- Macro Assembler
- Linker
- Software Simulator
- Integrated Editor
- Hex Creator

Starters Systems supplied with 2K Toolset & Development Systems supplied with 8K Toolset are available for Atmel, Dallas, Siemens, Texas 8051 microcontroller derivatives
Dataman-48LV

**[Analysis]**
- Plugs straight into your parallel port of PC or laptop.
- Programs and verifies at 2, 2.7, 3, 3.3 and 5 V
- True no-adapter programming right up to 48-pin DIL devices.
- Free universal 44-pin PLCC adaptor.
- Built-in world standard PSU – for go-anywhere programming.
- Package adaptors for TSOP, PSOP, QFP, SOIC, and PLCC.
- Optional EPROM emulator.

**Support**

**[Analysis]**
- 3 year parts and labour guarantee.
- Windows/DOS software included.
- Free software updates via BBS/Internet.
- Free technical support for life.
- Next day delivery – always in stock.
- Dedicated UK supplier, established 1978.

Dataman S4

**[Analysis]**
- Programs 8 and 16-bit EPROMs, EEPROMs, PEROMs, 5 and 12V FLASH, Boot-Block FLASH, PICs, 8751 Microcontrollers and more.
- EPROM emulation as standard!
- Rechargeable battery power for total portability.
- All-in price includes emulsion leads, AC charger, PC software, spare library ROM, user-friendly manual.
- Supplied fully charged and ready to use.

**S4 GAL Module**

**[Analysis]**
- Programs wide range of 20 and 24 pin logic devices from the major GAL vendors.
- Supports JEDEC files from all popular compilers.

**Truth — Claim Verified**

**[Money-back 30-day Trial]**

Secure for own use without delay. Order via credit card hotline – phone today, use tomorrow. Alternatively, request more detailed information on these and other market-leading programming solutions.

Orders received by 4pm will normally be despatched same day.
Order today, get it tomorrow!