WEB DIRECTORY – see page 169...

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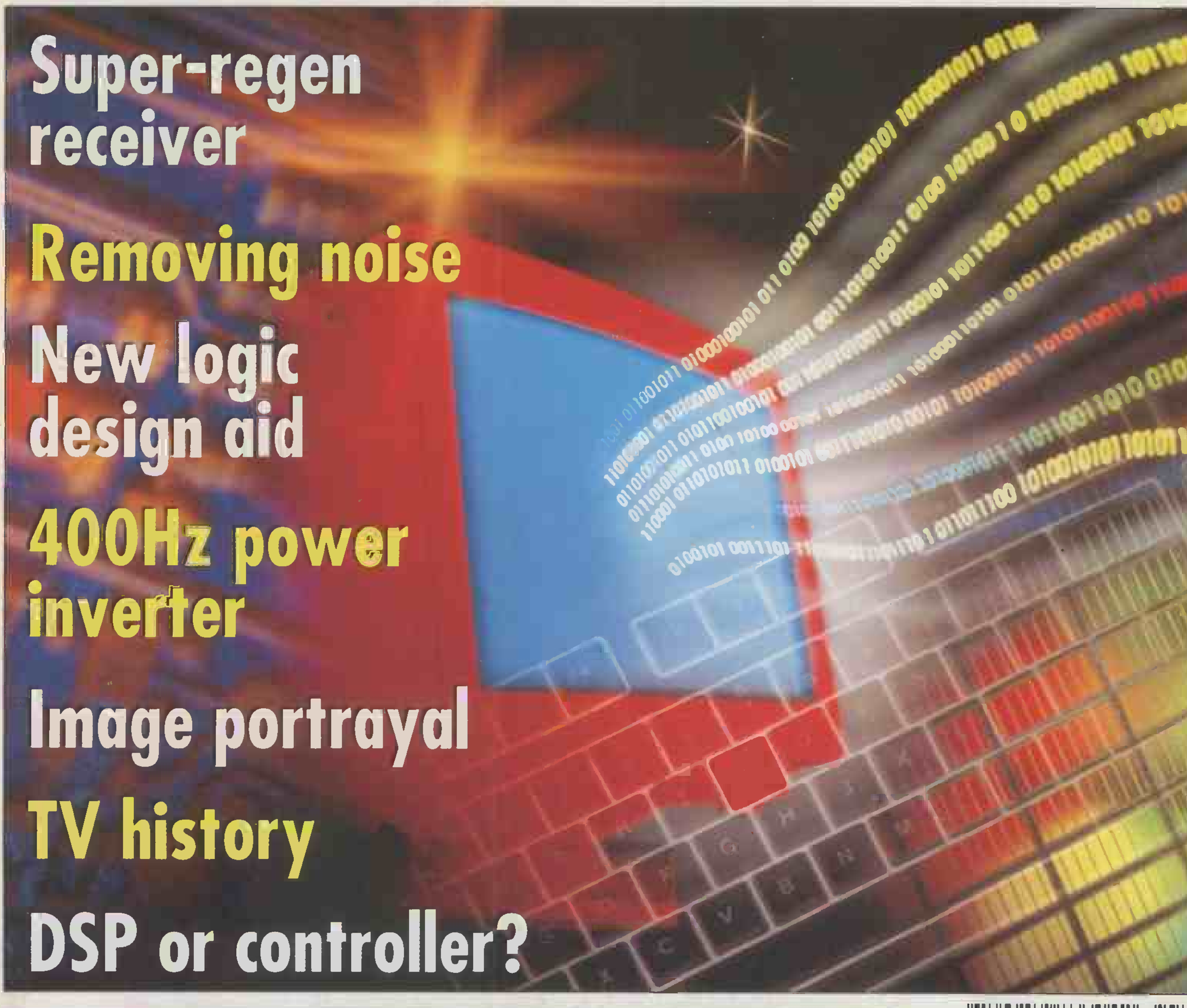

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Recruitment ads start on page 170

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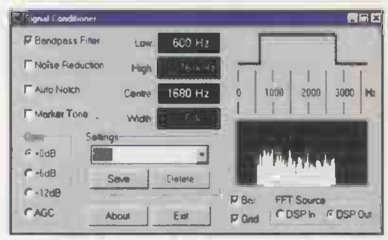

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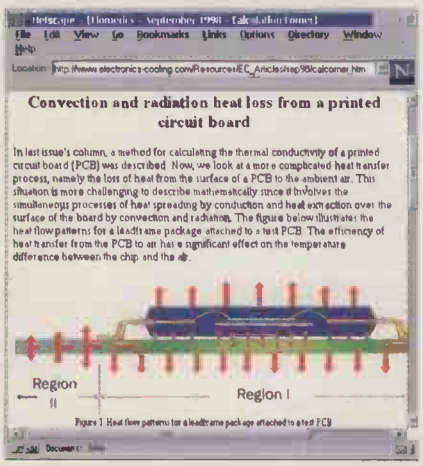


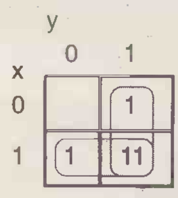
How can the Internet help you solve your thermal management problems? Find out on page 109.

March issue on sale 4 February

Cover photography: *Mark Swallow*

On impact, this 30mm bullet blasts a 10MW pulse – making land mines visible to detectors. Read about it on page 94.

Did Baird get it so wrong? Evidence that he didn't is the Tornado's airborne reconnaissance system. For more see page 160.



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If this means anything to you, you'll find a good read on page 113.

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REED BUSINESS INFORMATION

Copyright, and the right to copy

A recent report in the Daily Telegraph said that television viewers 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 unenforcable 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.

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

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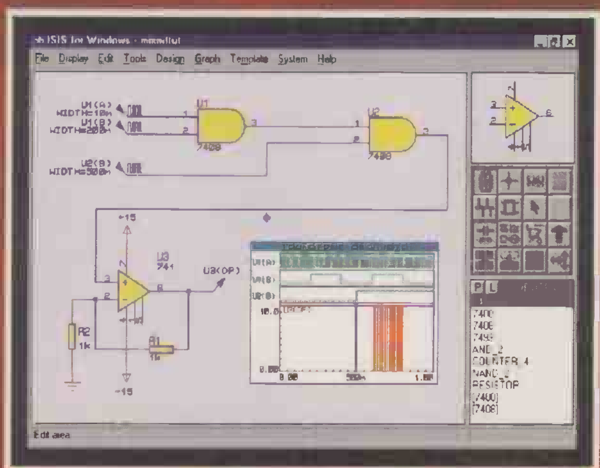

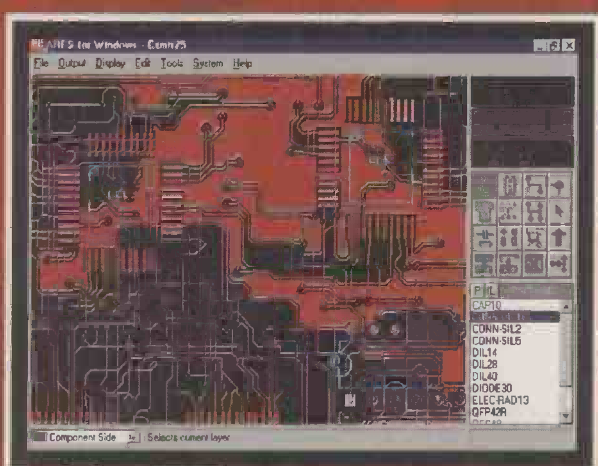

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C&W pips BT in broadband race

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 several megabits per second data rates offered by dsl modems will be disappointed if the operators refuse to support them by providing a dsl service at the exchange end of their telephone line.

BT refuses to say when it will allow customers to take advantage of the twenty times plus improvement in access speeds which adsl offers.

"We are trialling adsl," said a BT spokesman. The trials will last until March 1999. They are consumer trials – the technology has already been proven in technical trials.

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 contenders for a future sub 0.1μm lithography process.

The Semiconductor Industry Association roadmap released in 1997 calls for the first ICs with 0.07μm features to be produced by 2009. For this, commercial tools will be needed by 2008.

Oxford will head group efforts to determine 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.

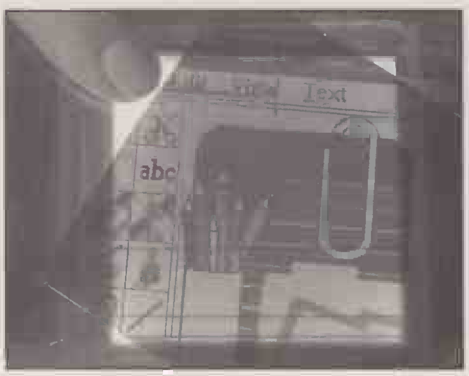
All the red strips are energised simultaneously followed by all the green strips in a repeating cycle.

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 blue LEP has lagged red and green types. "We will be making some announcements about blue LEPs very shortly," said Heeks.

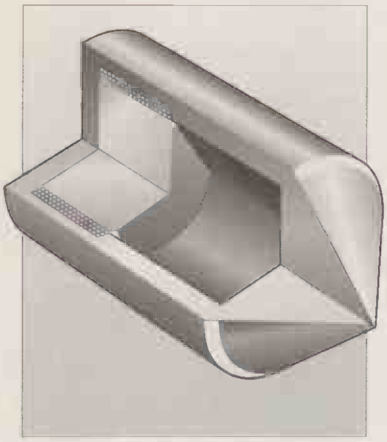


Two display companies, together with the University of Cambridge, have developed a display that combines the strengths of light emitting polymers and ferroelectric liquid crystals to make a limited colour display. The technology demonstrator is 7.5cm square and displays red, green and colours in between.

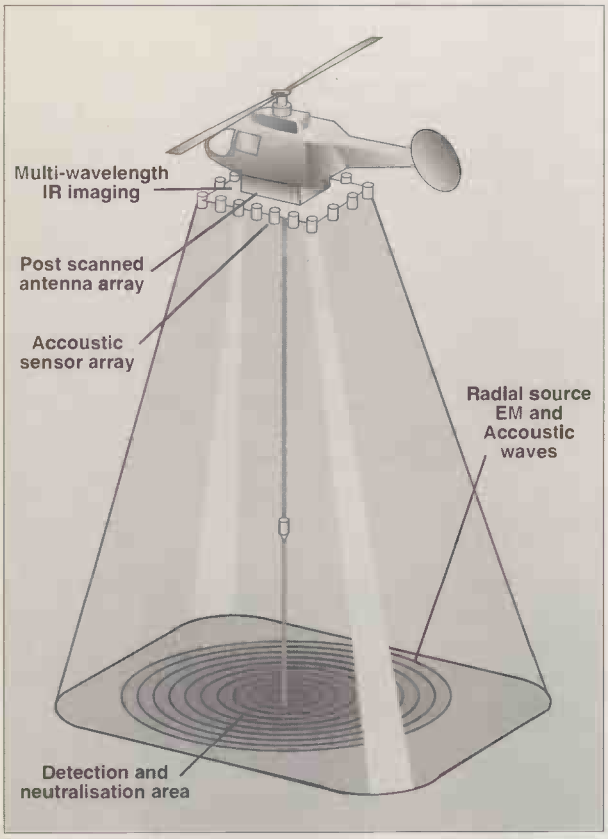
EMP bullet helps detect land mines

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.



Magic bullet... Not a new way of killing people, but a high-tech way of detecting mines. Kinetic energy is converted to an electromagnetic pulse as this projectile buries itself in the ground. The pulse bounces of nearby mines giving away their position.



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 1cm^3 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.

Producing the pulse underground, claims the university, couples far more energy into the locality than an above-ground source, which looses 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 $L_{final}I_{final}^2$.

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

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.

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 closure of two fabs in the UK could have been avoided if pricing had been normal."

Reckless over-investment by the Korean chaebols flooded the market and killed prices. EECA asked the EU to take action against low dumping prices, personally lobbying Brittan, but he refused support.

In the ensuing bloodbath, Siemens Semiconductors lost £400m and is now being put up for sale by its parent company Siemens AG. "The Koreans 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

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PLUG IN AND MEASURE

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.
- 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 WYSIWYG 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 up 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 disposes 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 displays. 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 instument 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 1:1/1:10 switchable oscilloscope probe's, a user manual, Windows and DOS software. The price of the HANDYSCOPE 2 is £ 299.00 excl. VAT.

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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 Javachip.

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 despite strong competition from LCD 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.

Driver's seat... Ford's reconfigurable concept car dashboard.

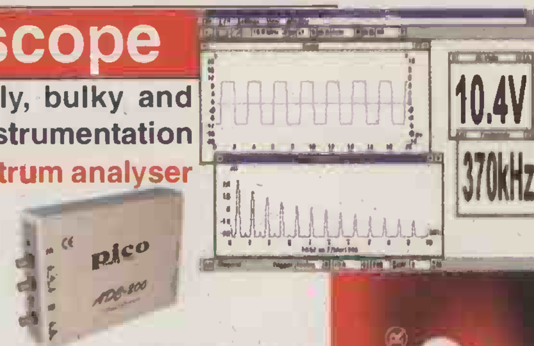
Easy PC, Tina, where?

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



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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.

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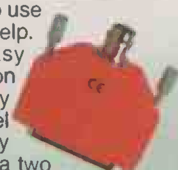

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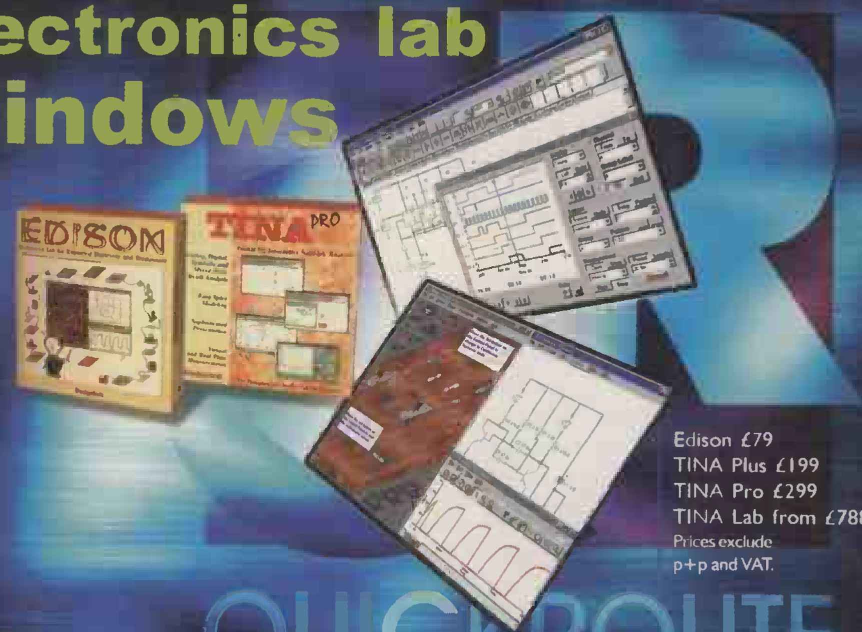

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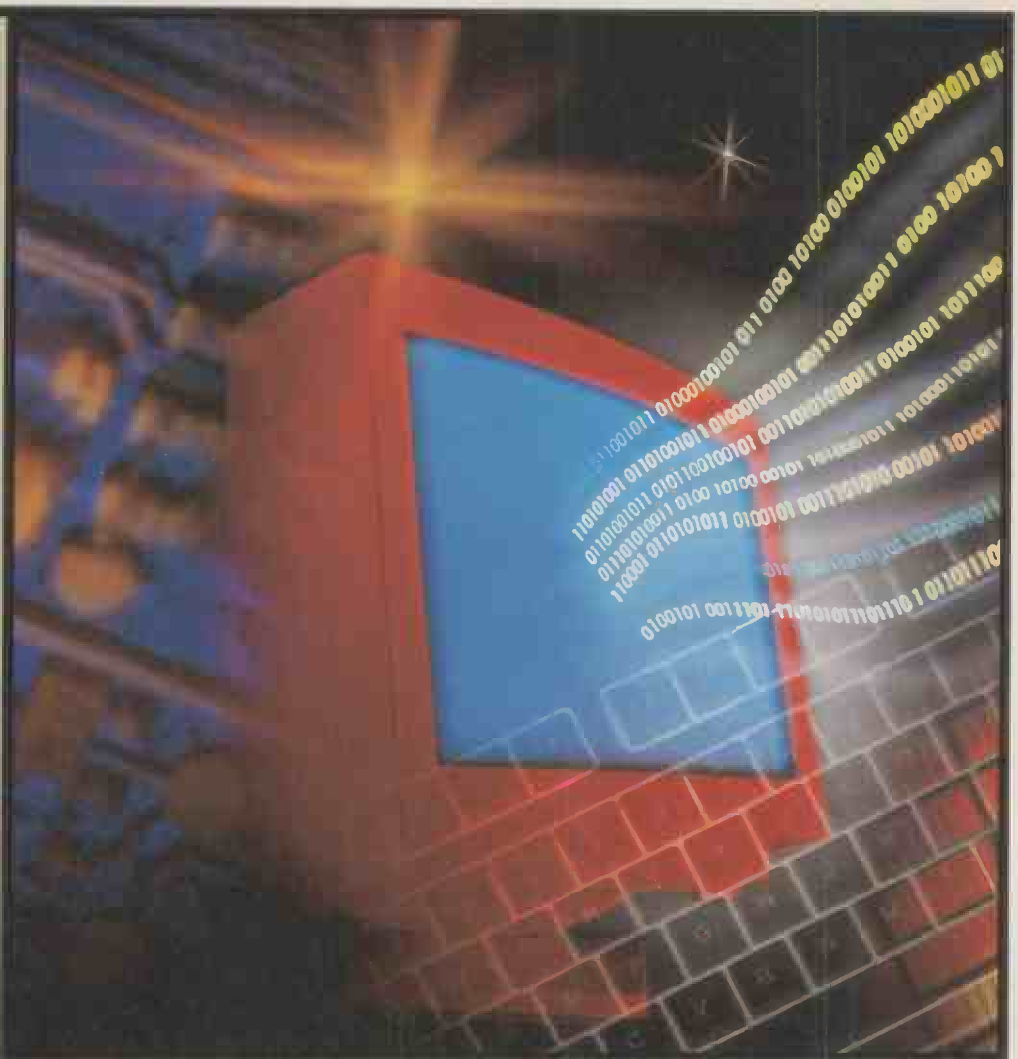
CIRCLE NO.107 ON REPLY CARD

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.



PLDs for all

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.

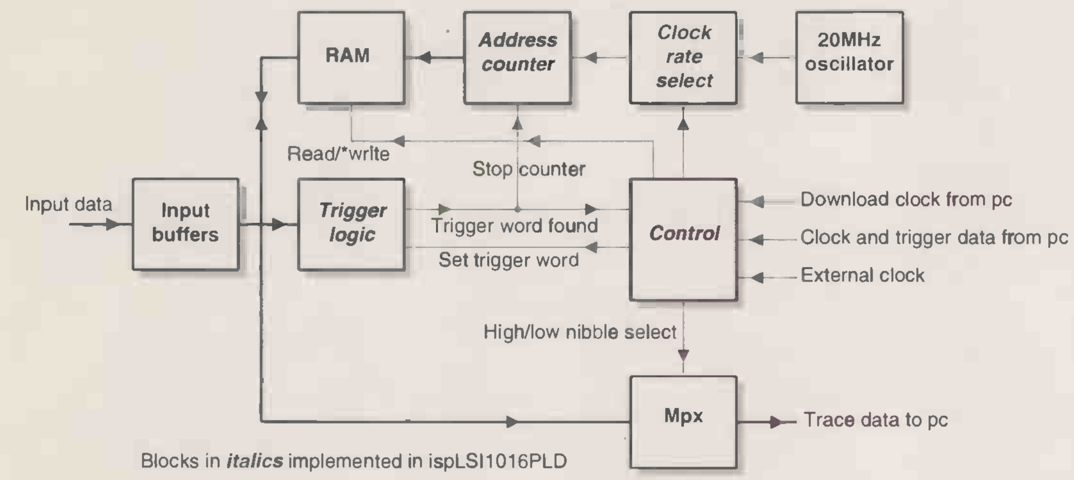


Fig. 1. Outline of a logic analyser, whose job it is to read a sequence of logic levels on an eight-bit bus and display the results on the screen of a pc. Note that asterisks denote active-low signals in this article.

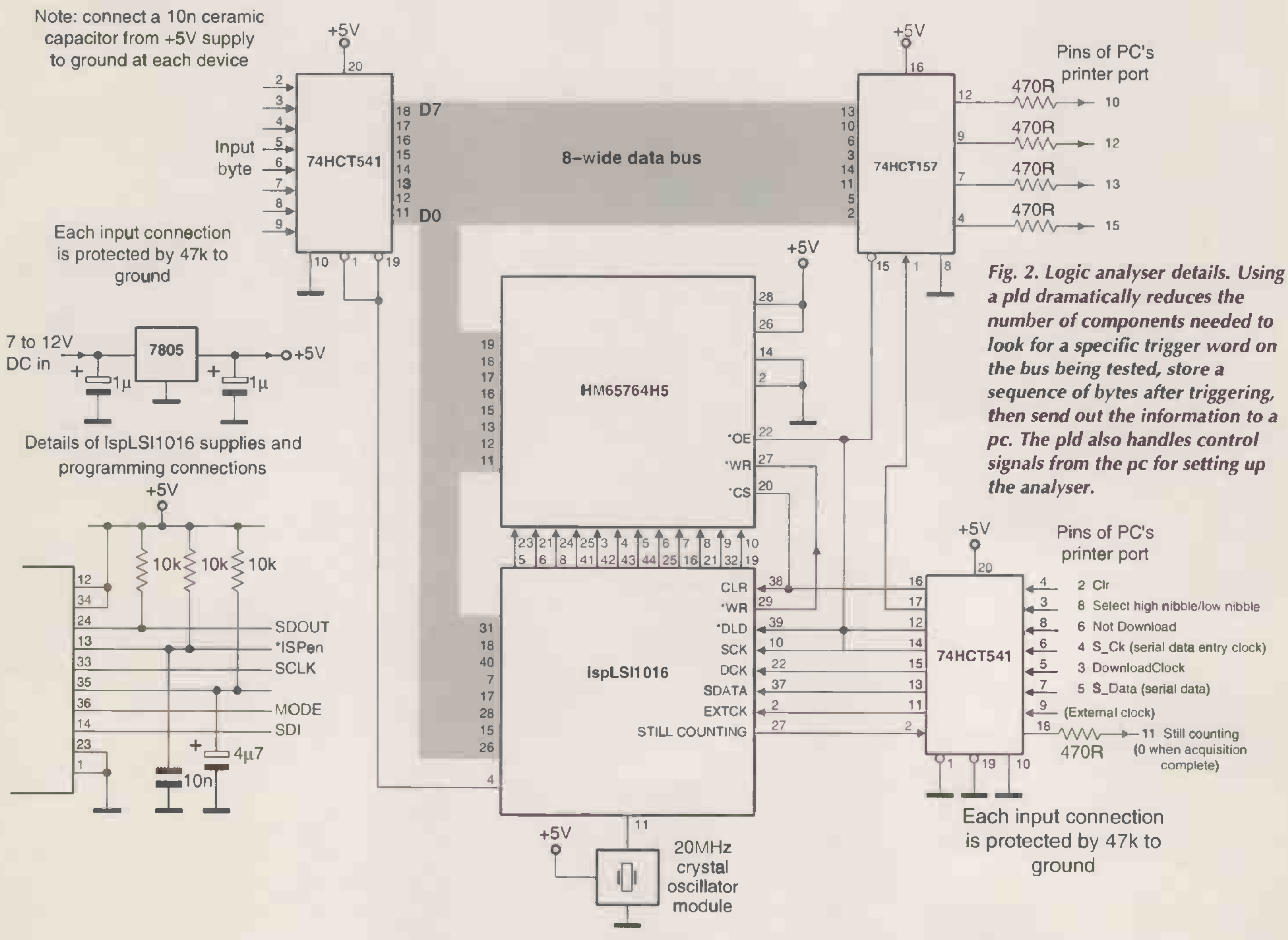


Fig. 2. Logic analyser details. Using a pld dramatically reduces the number of components needed to look for a specific trigger word on the bus being tested, store a sequence of bytes after triggering, then send out the information to a pc. The pld also handles control signals from the pc for setting up the analyser.

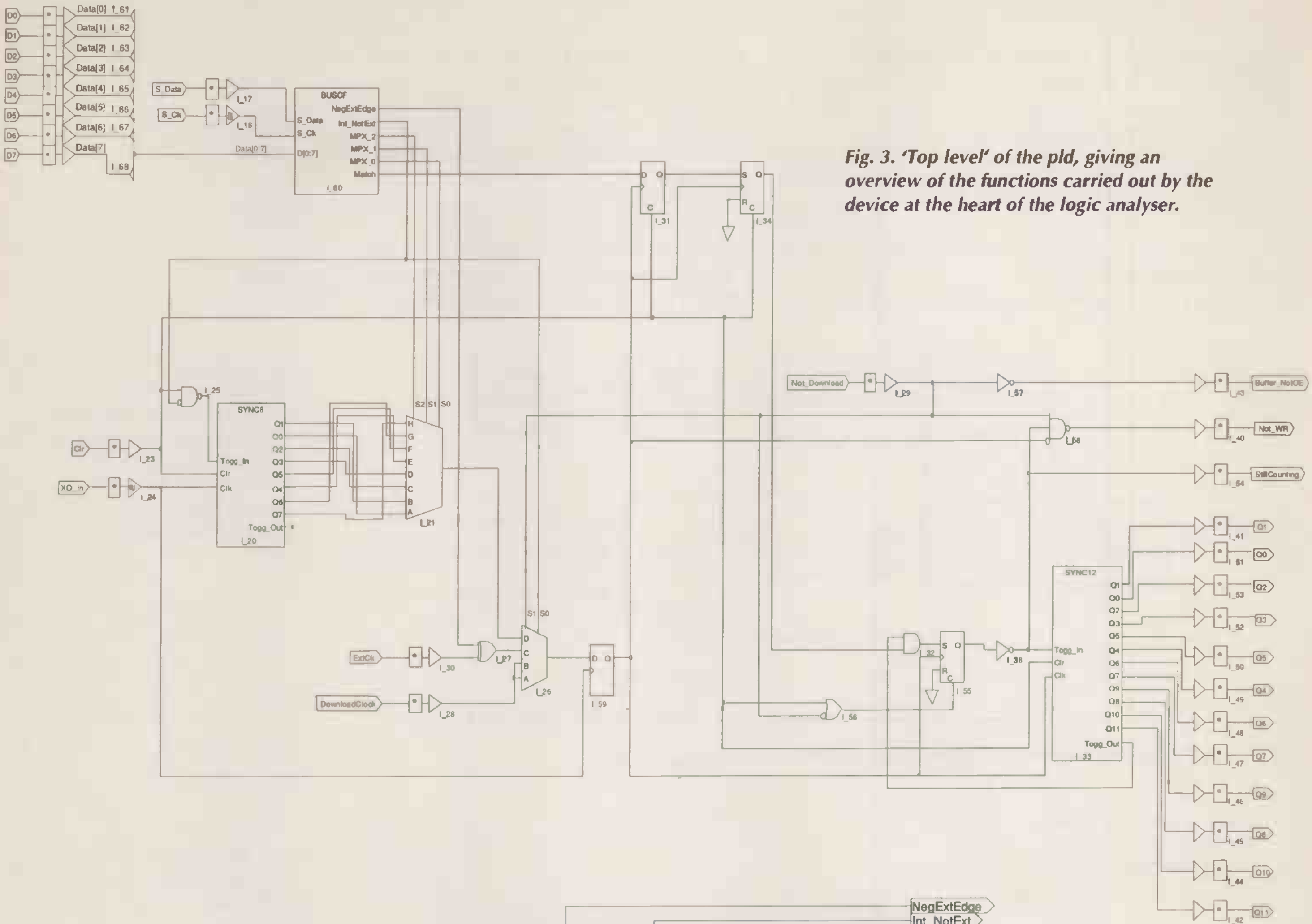


Fig. 3. 'Top level' of the pld, giving an overview of the functions carried out by the device at the heart of the logic analyser.

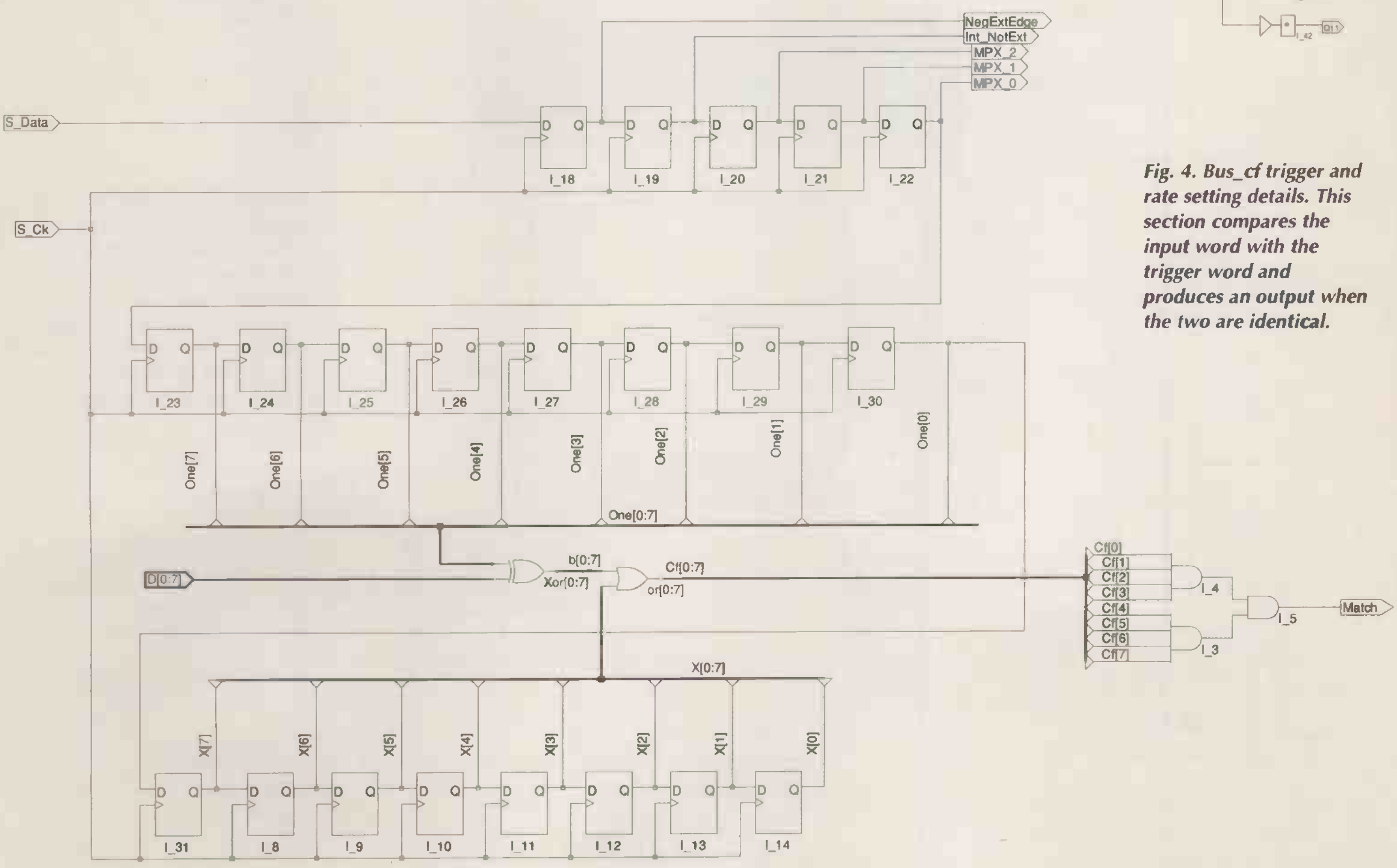
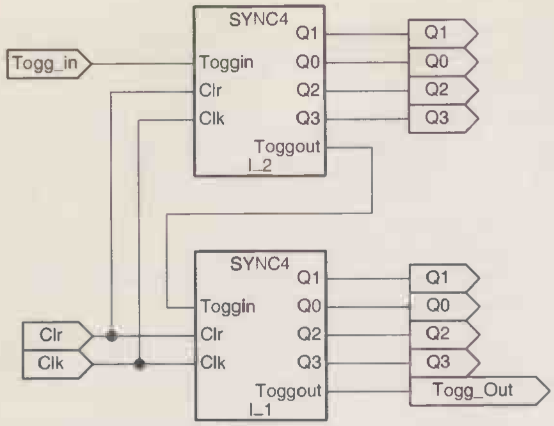


Fig. 4. Bus_cf trigger and rate setting details. This section compares the input word with the trigger word and produces an output when the two are identical.



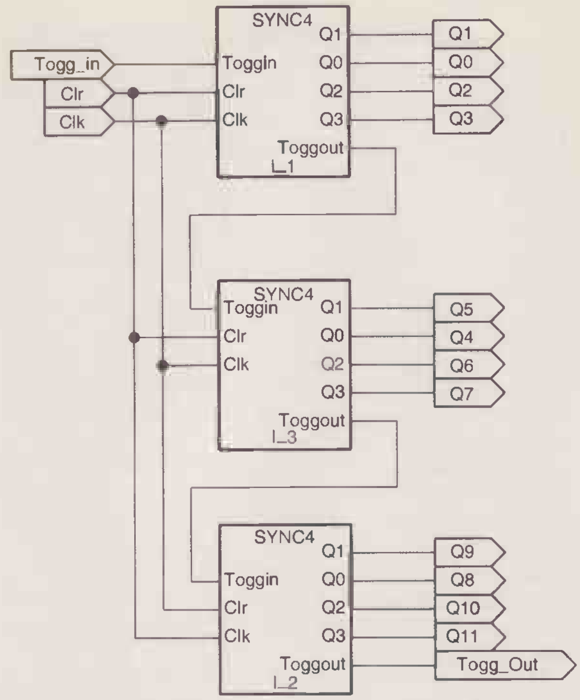


Fig. 6. Clocking counters Sync8 and Sync12 – eight and 12 bits respectively – are made up of cascaded four-bit synchronous counters.

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 BUSCF 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_CF 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

Tip: re-using circuit designs

Suppose you copy a top level circuit by using File/Save As, intending to use it as the basis of a new design project. You will find that, in the Sources window, the sub-circuits are marked with queries. The system doesn't know where to find the subcircuits. Tell it where to look by clicking on an unknown subcircuit and then use Source/Import to import it.

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 deglitching 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 s:r 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, 'ispLSI 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. 5**; 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.

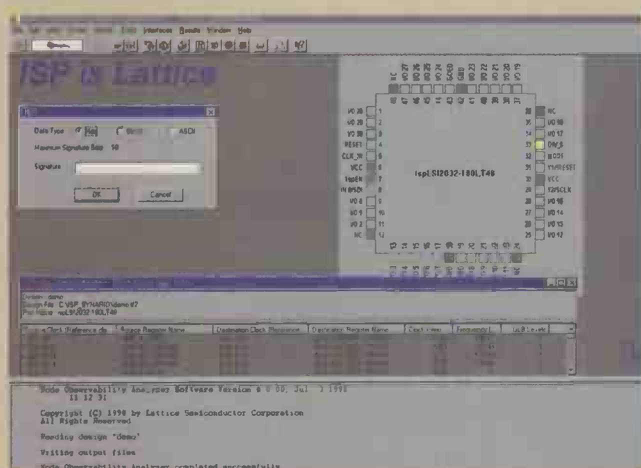
Two items in the centre row of the tools palette let you move components. The centre one lets you click on an individual component and drag it, breaking any connections; the

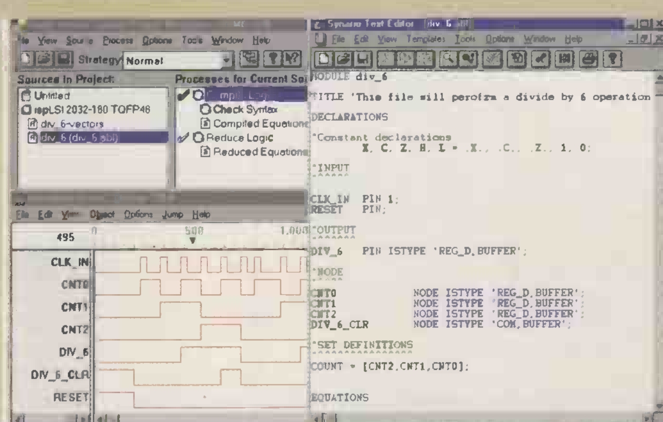
Software download

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 existing lead – to start a wire, click again to anchor at a bend, and click on the destination wire or component lead end.

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/os.

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/os are merely for this section of the circuit, they are not pins on the completed pld.

You can name any wire – not just i/os. 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 V_{CC} 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 for the sync4 counter, which can be imported to future circuits just like any other gate or flip-flop. It will appear in the 'local' section of the Symbol Libraries menu.

To check your work, click the tick mark at the top of the schematic editor. A window listing errors will be opened, and if you click on the error description the error will be highlighted on the circuit diagram.

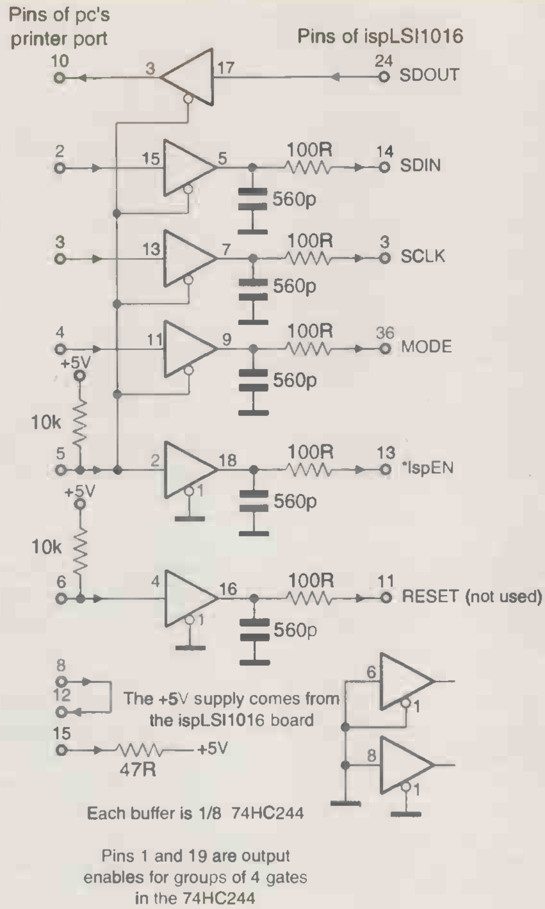


Fig. 7. This is the buffer circuitry needed to program an ispLSI1016 via your pc's printer port. Take great care with directions and power supplies here – particularly if your printer port is an integral part of your mother board. It may be wise to use an add-on i/o card to give you LPT2 and probably two extra COM ports. These are very cheap. Note that this interface handles 5 and 3.3V devices in an isp or JTAP programming chain, but not a mix of isp and JTAG parts. A ready-made cable is available for this task.

Building the pld

The logic analyser uses a 12-bit (sync12) and an 8-bit (sync8) counter; both are made up from sync4 counters.

To make sync12, start a new circuit diagram as for the sync4. Import three sync4s from the 'local' section of the 'Symbol Libraries' menu. Connect them up as shown in **Fig. 6**, add i/os and names, give sync12 a block symbol, check it

ispLSI 1000/E families: overview

The ispLSI(r) 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

Family Member	1016E	1024	1032E	1048E
Density: (PLD Gates)	2000	4000	6000	8000
Speed - f_{max} (MHz)	125	90	125	125
Speed - t_{pd} (ns)	7.5	12	7.5	7.5
Macrocells	64	96	128	192
Registers	96	144	192	288
Inputs and i/o	36	54	72	110
Pin/Package	44-pin PLCC	68-pin PLCC	84-pin PLCC	128-pin TQFP
	44-pin JLCC	68-pin JLCC	100-pin TQFP	128-pin PQFP
	44-pin TQFP	100-pin TQFP	84-pin CPGA	133-pin CPGA

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.

and save it. Repeat this process for sync8.

The bus_cf circuit, **Fig. 6** introduces the idea of busses – i.e. groups of wires – and of iterated components – or components repeated for each line of a bus. Make a bus by drawing a wire and naming it data[0:7] for example. Use the centre icon in the second row of the tools palette, just as you did when naming i/os. The wire thickens to show that it is now a bus.

To add eight exclusive-or gates, import one gate from the symbols library. Now name the instance of the gate, using the left-hand icon of the second row of the tools palette, as x[0:7]. Enter the name, hit return, and click the mouse over the gate. You can now wire the iterated gate to the bus.

Add the iterated Or gate and name it; add the other buses. Note that the connection between the iterated gates must itself be a bus.

To connect individual signals to a bus, use the icon at the top right corner of the toolbox palette. Follow the prompts at the bottom of the schematic editor window, clicking first on the bus and then on the destination connection.

Name the wire you've added, as you've done before. If you 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 c:\..\GENERIC\IOPADS.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

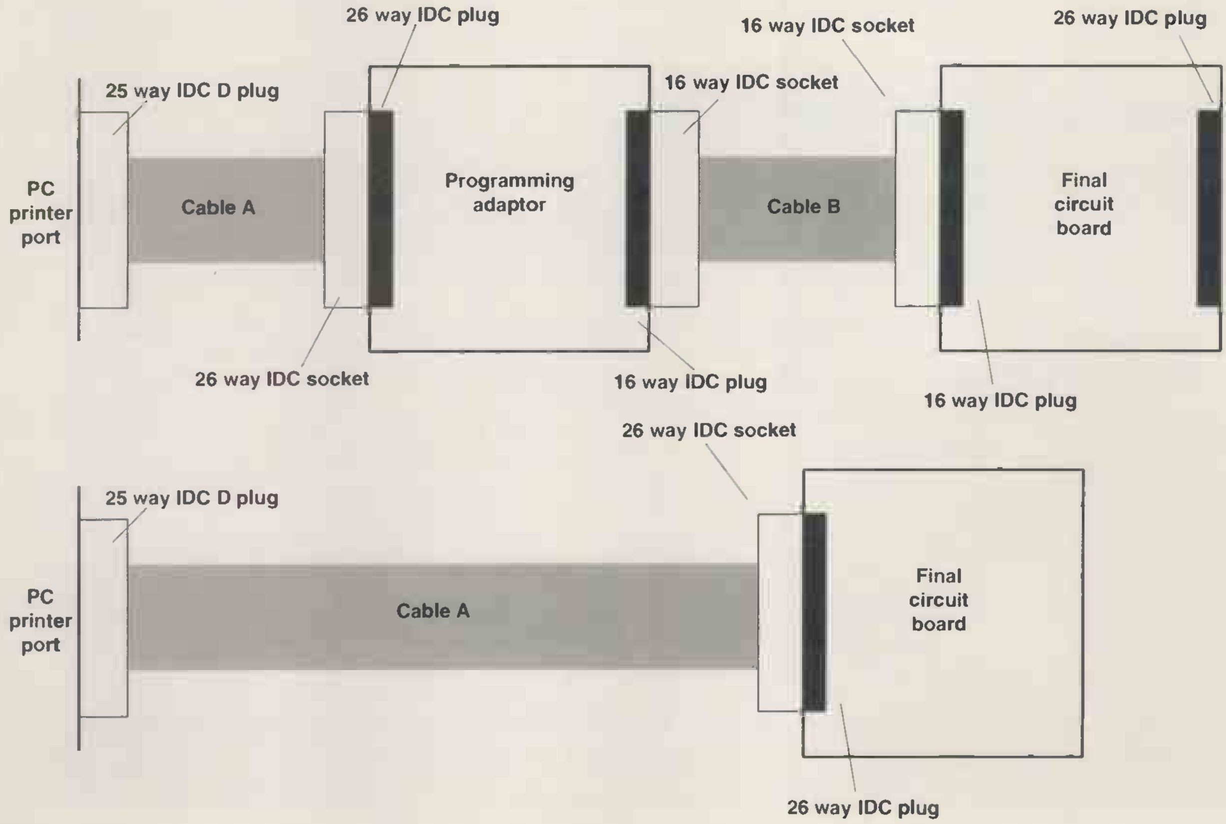


Fig. 8. With a few minor sacrifices, the pld can be programmed in situ. Here, the top diagram shows a development adaptor using two cables. I chose this option, and used one of the programming cables to control the analyser in use.

three entries; the second is named the 'Synario Pin'. Enter the pin number you want in the 'Attribute' window, then click elsewhere in the schematic editor window.

This approach is also useful when you want to make minor changes to an already-programmed device which has been committed to a printed circuit board, where changing the pinout would involve changing the board. You can force the pin numbers to be identical to those of a previous version.

But first I must show you how to find what pin numbers the system allocates when given a free hand.

Making the programming .jed file

In the project navigator window, click the device, in this case, *ispLSI1016-60* PLCC44, in the sources window. Then double-click 'Fitter Report' in the processes window. The process may complete successfully with or without warnings, or may fail if there are errors. In any event, the Report Viewer window will open.

If the process completes successfully, you will see a <projectname>.rpt, with, at the end, a list of which i/os have been allocated to which pins. If errors or warnings arise, they will be shown in a .log file.

Use F2 – the 'Find' function – to examine descriptions of errors and warnings in the .log file.

Programming the device

To program the device, you need a programming adaptor, Figs 7, to go between the pc's printer port and the device being programmed.

Details of the hardware connecting pc, programming adaptor and target *ispLSI1016* are left to the you since there are different implementations to choose from. You will have to decide whether you want a separate programming board for the pld, or whether you will program the device in the final circuit board.

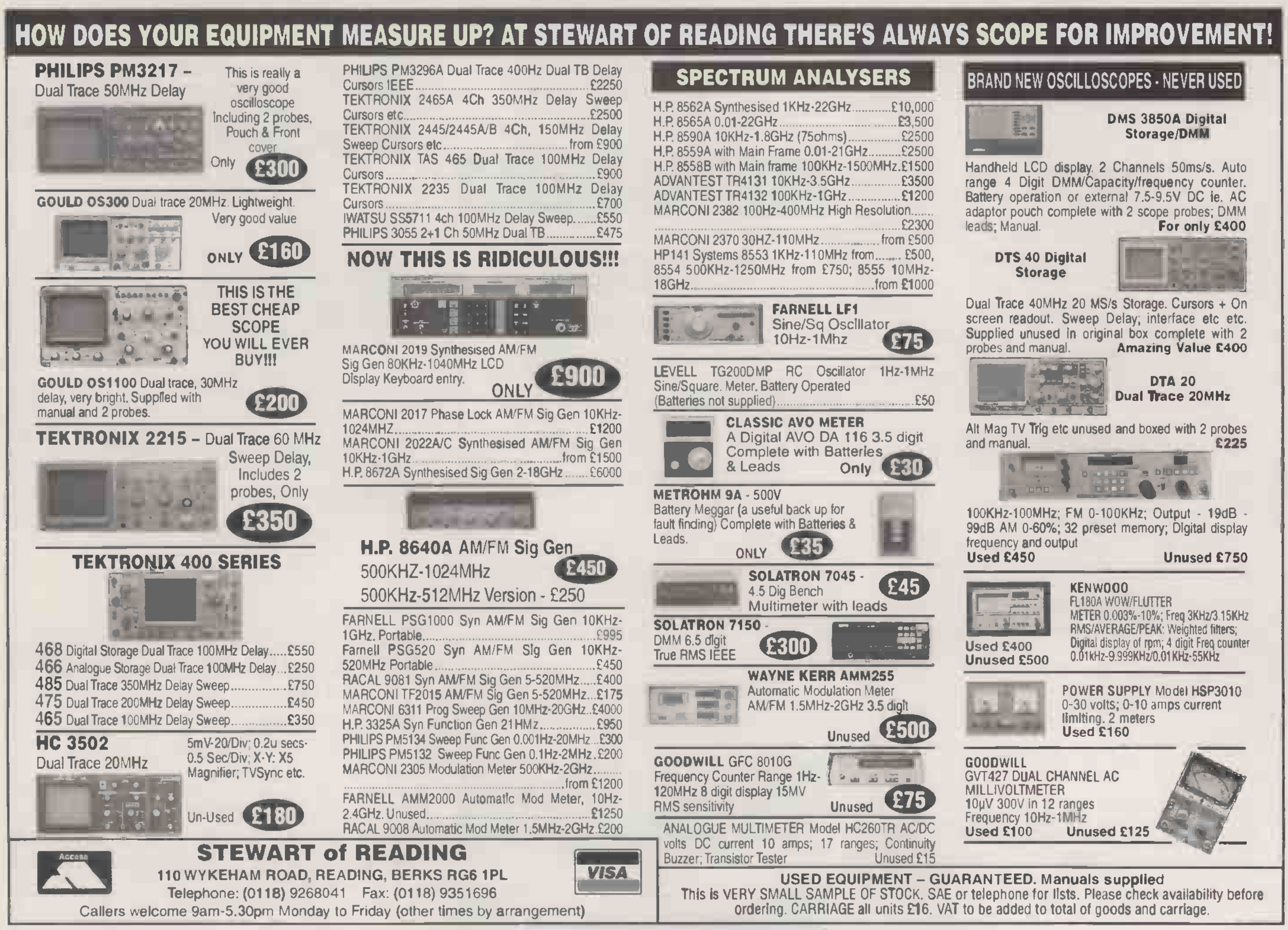
Because my final circuit needed to communicate with the pc via its printer port, I used a 25-way D to 26-way IDC cable to connect the printer port either to the programming adaptor or to the final circuit board. I then used a 16-way IDC cable between programming adaptor and final circuit board, **Fig. 8**.

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 <projectname.jed> 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. ■



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LETTERS

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E-MAIL jackie.lowe@rbi.co.uk

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, obviously. 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 £4000. 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 allude 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

Watt exposé

I read Lawrence Woolf's article 'RMS watt, or not?' with particular interest. I had just bought a pair of small amplified loudspeakers to use with my pc and had been enjoying a boggle at the numbers on the box.

The front of the box claimed 50W PMPO, peak music power output. On the back of the box, the specification claimed 10 watts rms (2×5W). But the plug-top power supply included was rated at 6V, 600mA – i.e. 3.6W.

The amplifiers inside consist of eight-pin DIL chips of the type usually rated at 2W into 8Ω using a 12V supply. The speakers are 4in, 8Ω units. Realistically with a 6V supply, I would expect about a watt of output.

They work well and sound about as loud as a portable radio. I am not complaining. They are just what I needed, and were remarkably good value at £6 the pair – new and boxed. Some pc loudspeakers on offer are rated at 400W. I settled for the 50W jobs – fearful of the wrath of my neighbours.

It would be great if we could believe specifications at face value without the chore of trying to understand what's watt. Manufacturers take note: I for one am more impressed by a realistic specification as opposed an unlikely sensational one. But then I expect your marketing people know better.

John Cronk
Prestatyn
Clwyd

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 in 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 appaling.

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 these have been processed a greater number of times.

When combined with a strong accent, 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?

M. Gentle
London

HV fuses?

A friend recently asked me if I could obtain a replacement for the high-voltage fuse in his microwave cooker. 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.

M. Gentle
London

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 S_1 selects the first scale and S_2 the second one. Pressing both switches together allows you to adjust full scale.

Of course there is no current through the battery when neither S_1 or S_2 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

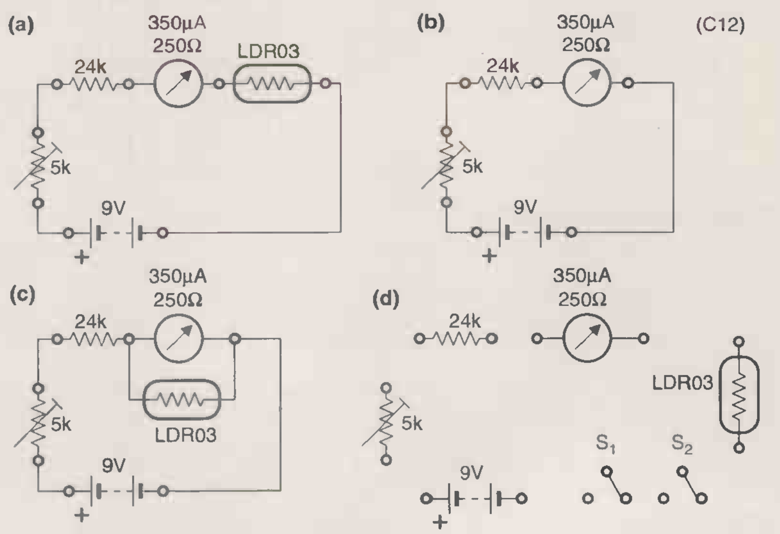


Fig. 1. Luxmeter with two ranges. All you have to do is wire it up so that each switch selects a range, both switches on allows fsd setting and both switches off disconnects the battery.

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 wouldn't be 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 Exploder 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 the current state of research funding I am unlikely to get it upgraded in the near future.

My old system at home had a 2.6Gb drive, and both of these systems are squeezed for hard disk space. I partitioned both drives to minimise the cluster size but even so there is some 80 to 100Mb of lost 'slack space' in a 1Gb partition due to the cluster size – a loss of nearly 10%. Most of this would be reclaimed with FAT 32.

Win 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 Micro$oft 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 for 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, and I believe that the bun fight over Internet Explorer has more to do with that than Microsoft's desire to provide a browser.

In Australia we already have an alliance of Microsoft with one of our biggest media groups (PBL, owned by the Packers), called NineMSN. A friend recently bought a new pc which had '98 loaded, and there were dozens of shortcuts in menus – up to five deep – to various sites for news, sports, movie, etc, owned or operated by PBL, Microsoft, and their associates.

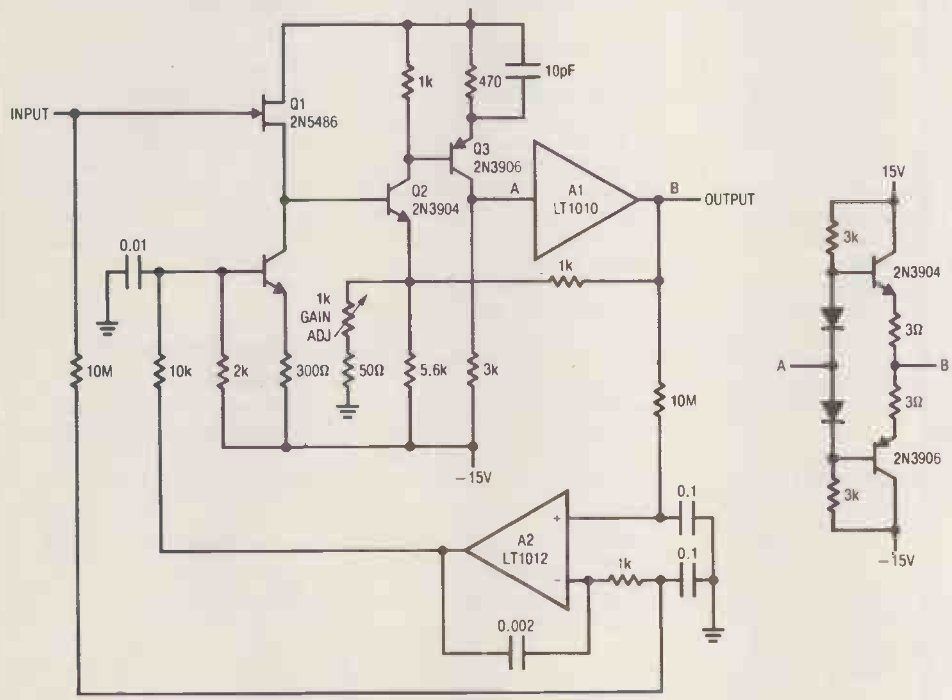
We certainly don't want Bill Gates and Microsoft – or PBL for that matter – to be in a position exercise control over the information we have access to, any more than we want that other well known US citizen, Rupert Murdoch, to. It is essential for democracy that they don't.

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.creativelement.com

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

Definition of Windows95:
Windows95: /win-doz-nin-te-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.



Wide-band fet amplifier

I have some commentary regarding the circuit, 'wide-band, variable-gain FET amplifier,' submitted by Frantisek Michele in your August 1998 issue. In particular, because the *2N5486* fet is outside the feedback loop, the circuit will not follow the gain equation given in the text.

In practice, the fet follower suffers gain loss, although this is correctable by trimming the feedback ratio to achieve the overall desired circuit gain. Also, the feedback path should be returned to Tr_3's emitter, as opposed to Tr_2's.

This circuit is of special interest to me because it is identical to a circuit that appears in the Linear Technology Corporation application note 21, 'Composite Amplifiers' dated July 1986. The sole difference is that our circuit used feedback trimming to avoid the previously mentioned problem.

The circuit also appeared, with LTC's approval, in the January 1987 issue of *EDN* magazine. Your readers and Mr Michele may wish to reference these publications for expanded discussion of this circuit's operations.
Jim Williams
Staff Scientist
Linear Technology Corporation
Milpitas
USA

Hands-on Internet

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 manufacturers 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 applications 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 that 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.com[3] 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.	http://www.news.com/News/Item/0,4,27482,00.html
2.	Cuartango Security WEB Site.	http://pages.whowhere.com/computers/cuartangojc/index.html
3.	EE DESIGN CENTER.	http://www.questlink.com
4.	Electronic Designer Interface.	http://www.info-quick.com
5.	Global Semiconductor Datasheets Library.	http://www.semi.com.tw
6.	Electronics Cooling Magazine.	http://www.electronics-cooling.com/Resources/EC_Articles
7.	Application Note AN-225.	http://www.national.com
8.	Application Note AN28.	http://www.linear-tech.com
9.	Application Note AN-369	http://www.analog.com

Bugs

As features are added, operating system and application software becomes more vulnerable to software bugs and hacker attacks. According to a CINET[1] 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 Cuartango[2] posted on his Web site details of four recent security problems. His demonstration test pages let you confirm whether your system is vulnerable.

Hopefully the last of a year long series of 'scripting' enabled hacks, which could affect Internet Explorer 4 users.

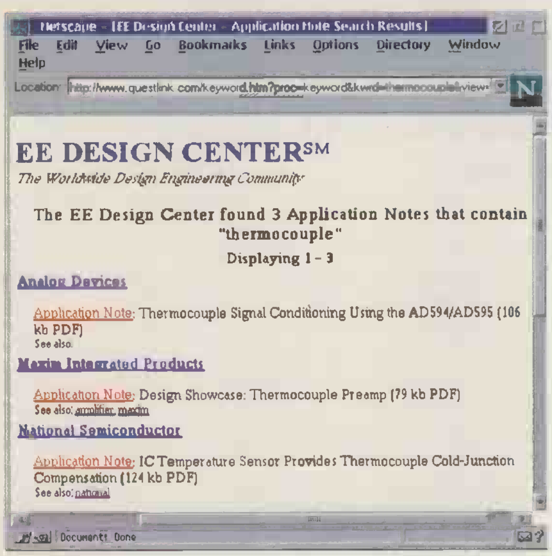


Fig. 1. Result of searching the user friendly QuestLink application notes database, for 'thermocouple' applications.

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 Integrated Products and National Semiconductor, **Fig. 1**.

Info-quick.com[4] I find less useful, mainly because I use Netscape 2. With this early version of the browser, I experience pull-down menu bugs. These are listed in Info-quick'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 site[5] 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 manufacturers 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 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[6] 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 Keltner 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 though, you can quickly understand how to minimise errors for 'in-circuit' temperature measurement of components.

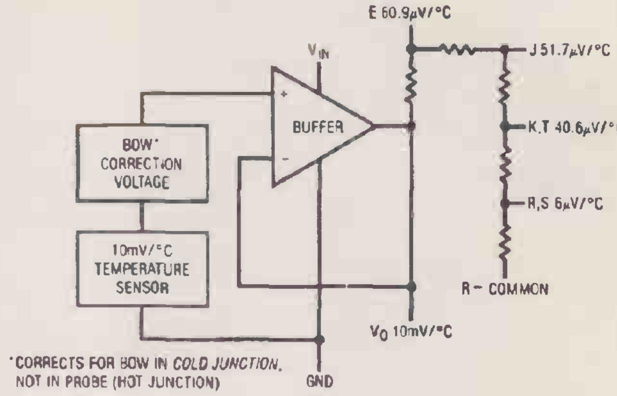
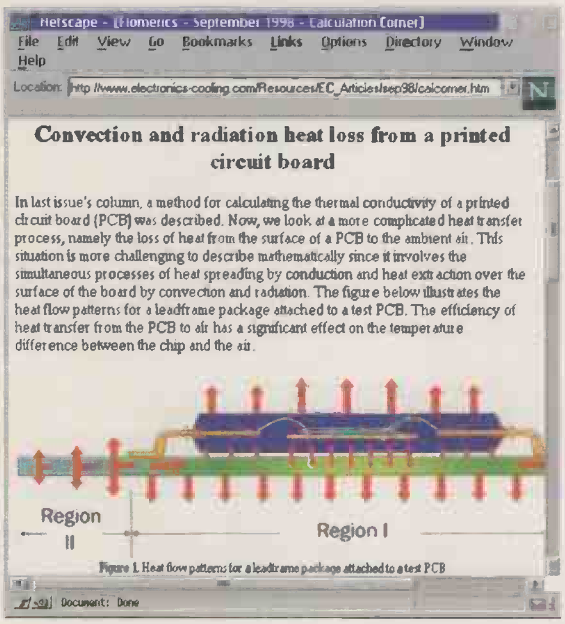


Fig. 5. An integrated circuit method which supplies a switch selectable cold junction compensation voltage, suitable for use with common thermocouples.


Netscape - [Flomerics - September 1998 - Calculation Corner]
File Edit View Go Bookmarks Links Options Directory Window Help
Location: http://www.electronics-cooling.com/Resources/EC_Articles/sep98/calcorner.htm

Convection and radiation heat loss from a printed circuit board

In last issue's column, a method for calculating the thermal conductivity of a printed circuit board (PCB) was described. Now, we look at a more complicated heat transfer process, namely the loss of heat from the surface of a PCB to the ambient air. This situation is more challenging to describe mathematically since it involves the simultaneous processes of heat spreading by conduction and heat extraction over the surface of the board by convection and radiation. The figure below illustrates the heat flow patterns for a leadframe package attached to a test PCB. The efficiency of heat transfer from the PCB to air has a significant effect on the temperature difference between the chip and the air.

Region II
Region I

Figure 1. Heat flow patterns for a leadframe package attached to a test PCB

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Fig. 2. Heat dissipated from printed board mounted components, is a complex combination of heat dissipated by the component, the pcb and its tracks.

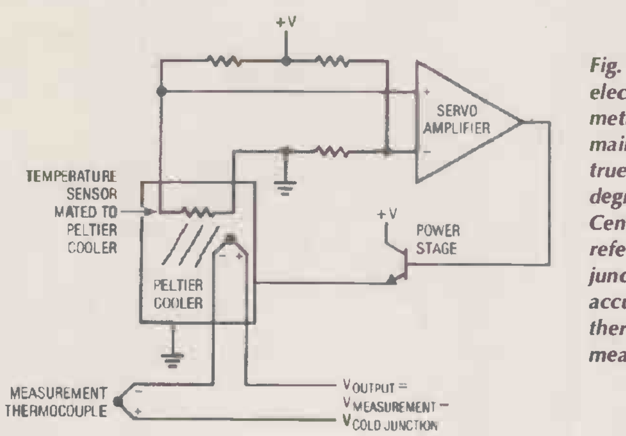


Fig. 3. An electronic method of maintaining a true zero degrees Centigrade, reference cold junction, for accurate thermocouple measurements.

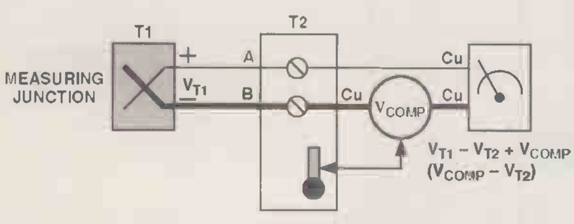


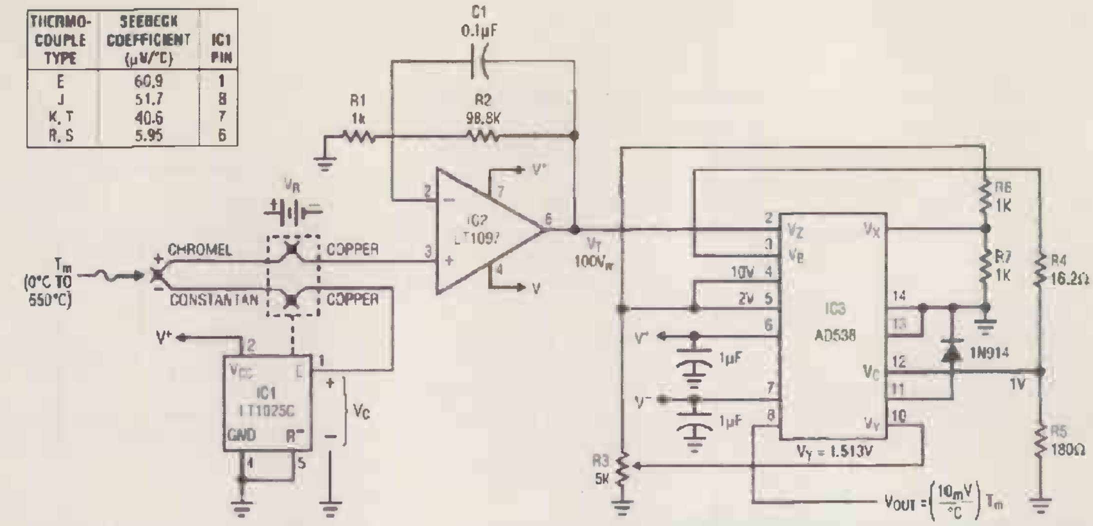
Fig. 4. Electronic voltage compensation methods can be substituted to avoid maintaining a zero degrees Centigrade, reference cold junction.

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.[7] It uses their *LM335* integrated thermometer circuit to measure the



THERMO-COUPLE TYPE	SEEBECK COEFFICIENT (µV/°C)	IC1 PIN
E	60.9	1
J	51.7	8
K, T	40.6	7
R, S	5.95	6

Fig. 6. A totally analogue, continuous function linearisation circuit, which can correct for all thermocouple non-linearities.

cold junction temperature. This circuit then applies a 'best straight line' fit correction voltage.

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.[8] 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.

Analog Devices' application note AN-369 describes a single integrated circuit which combines the required cold junction compensation with an 'in-amp' for signal amplification in the one package.[9] Thermocouple hot-junction linearisation however is not included, so external compensation for this needs to be added. Thin thermocouple wires and junctions are fragile, and this package also includes an on-board broken thermocouple alarm circuit.

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. ■

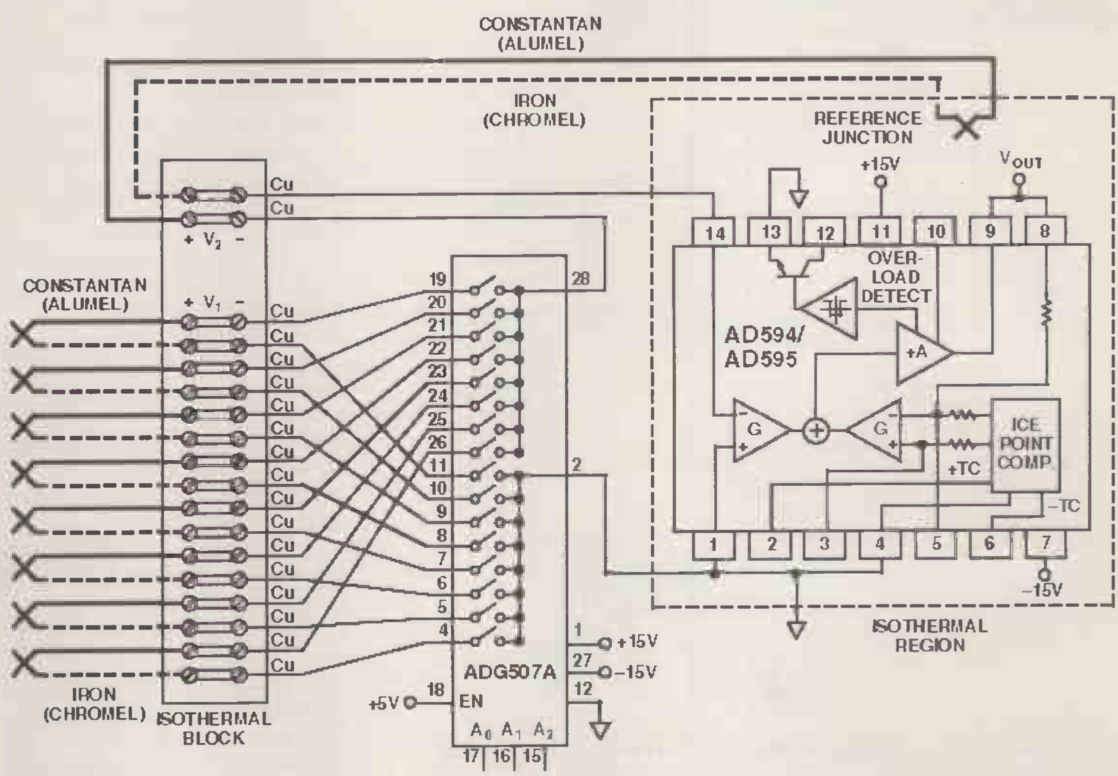
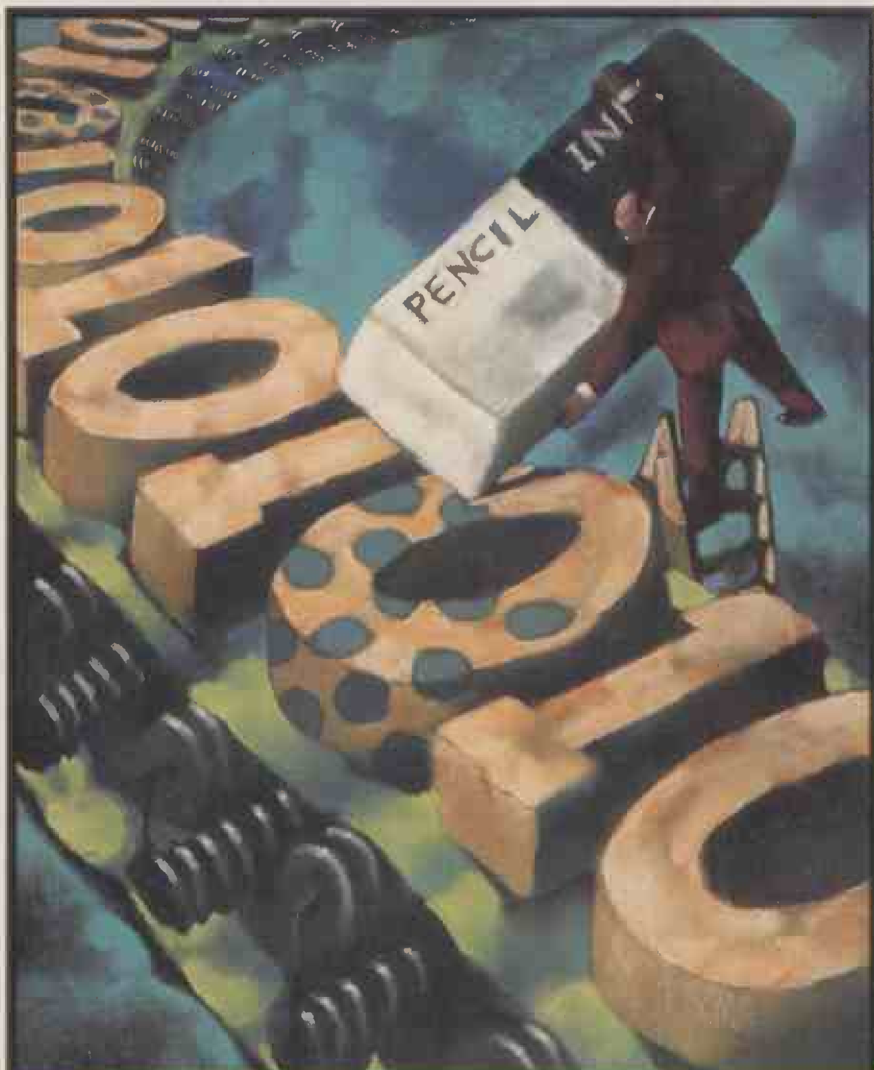


Fig. 7. A modern integrated thermocouple cold junction compensation circuit, used with multiple switch selectable thermocouples, for rapid multi-point temperature measurements.



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.

New logic

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 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

Fig. 1. The familiar elements of AND, OR invert algebra.

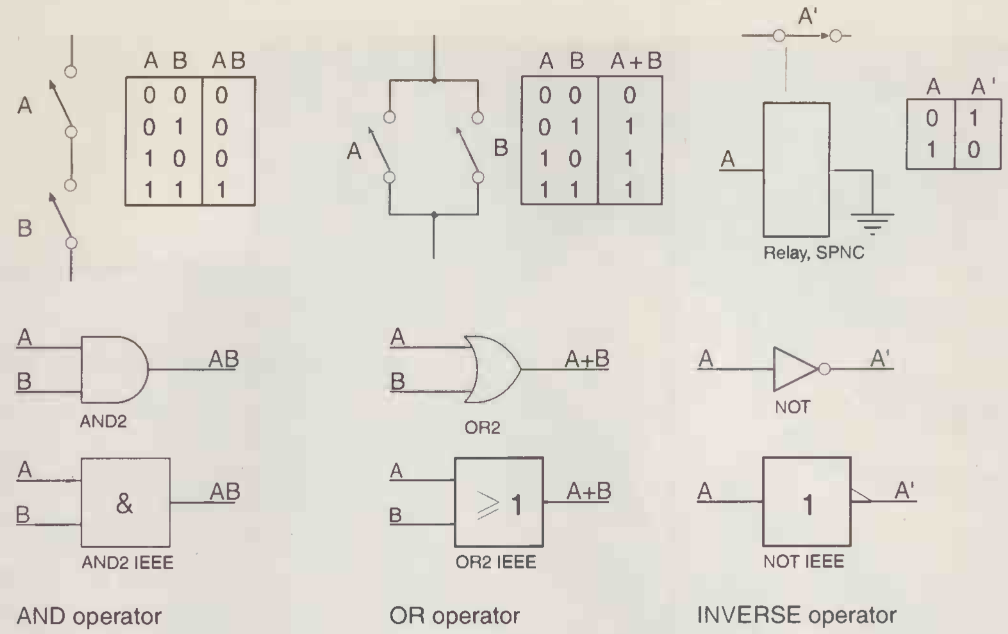


Fig. 2. The 16 possible binary operators and the 4 possible unary operators.

A 0011
B 0101
0000 Open circuit (stuck low)
√ 0001 AND operator
0010 AND operator with B inverted
0011 A
0100 AND operator with A inverted
0101 B
√ 0110 Exclusive OR operator
√ 0111 Inclusive OR operator
√ 1000 NOR operator
√ 1001 Exclusive NOR operator
1010 Inverse of B
1011 OR operator with A inverted
1100 Inverse of A
1101 OR operator with B inverted
√ 1110 NAND operator
1111 Short circuit (stuck high)

A 01
00 Open circuit
01 No inversion
√ 10 Inversion
11 Short circuit

thing such as 'true and false', 'high and low' or 'on and off'.

The algebra was the same whatever names you used, but the application of the algebra could vary depending on what you wanted to apply it to. You have constants and variables in this algebra, but they take on only one or the other of the two values that you have assigned to the algebra.

Some of the early books that I bought were written by Post Office engineers and applied to relay circuits. I discovered that in a digital design problem, you could separate the logical analysis or synthesis of a problem from the implementation of the final hardware solution. The algebra was just as applicable to logic gates, and diode gates as it was to relay circuits.

Another thing I discovered was that after the initial bit of thinking to get used to the new algebra and concepts, it was quite easy to understand and use for practical problems. Just a little persistence was needed to get used to the new way of thinking.

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 plds. 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 cplds are reprogrammable. 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 bigger, 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 inverter 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 Figure 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.

Basic theorems

	A&0 =0	A+0 =A
	A&1 =A	A+1 =1
	A&A =A	A+A =A
	A&A'=0	A+A'=1
Commutative law	AB=BA	A+B=B+A
Associative law	A(BC)=(AB)C	A+(B+C)=(A+B)+C
Distributive law	A(B+C)=AB+AC	A+BC=(A+B)(A+C)

DeMorgan's theorem:

The inverse of a logic function can be obtained by replacing all + operators with & operators, replacing all & operators with + operators, priming all unprimed variables and unpriming all primed variables.

Simplification relationships:

A+AB=A   A+A'B=A+B

Fig. 3. Summary of AND, OR, Invert Boolean algebra theorems.

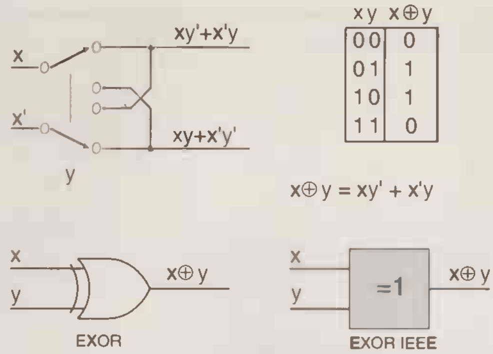


Fig. 4. Truth table and circuit diagrams for the exclusive-OR operator.

Next the three laws are dealt with – namely the associative, commutative and distributive laws. These allow you to perform manipulations with parenthesis and with rearrangements. Next, inversion is dealt with, given by DeMorgan's theorem for AND, OR Inverse algebra.

Finally, two simplification results are included with the theorems. When you derive the exclusive-OR algebra you would of course expect to find some new or different results.

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 therefore 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⊕y   = xy'+x'y
T1.   x⊕x   = xx'+x'x  =0
T2.   x⊕x'  = xx+x'x'  =1
T3.   x⊕0   = x1+x'0   =x
T4.   x⊕1   = x0+x'1   =x'
```

where ⊕ 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.

Fig. 5. Derivation of the inversion theorems.

x y	(x ⊕ y)	(x ⊕ y)'	x' ⊕ y	x ⊕ y'
0 0	0	1	1	1
0 1	1	0	0	0
1 0	1	0	0	0
1 1	0	1	1	1

T5. (x ⊕ y)' = x' ⊕ y = x ⊕ y'

x y	x ⊕ y	x' ⊕ y'
0 0	0	0
0 1	1	1
1 0	1	1
1 1	0	0

T6. x ⊕ y = x' ⊕ y'

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.

```
T5.    (x⊕y)' = x'⊕y = x⊕y'
T6.       x⊕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.

Commutative, 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.

```
T7. x⊕y      = y⊕x        Commutative law
T8. (x⊕y)⊕z  = x⊕(y⊕z)    Associative law
T9. x(y⊕z)   = xy⊕xz      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⊕h and gh=0, then f= g + h. Disjunction theorem T10 can be proved as follows:

```
f  = g⊕h = gh'+g'h
   = gh'+g'h+gh
```

since gh=0,

```
   = g(h+h')+h(g'+g)
   = g+h
```

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 ⊕ 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 ⊕ 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:

C1. $f(abc)=\alpha_0 a'b'c'\oplus\alpha_1 a'b'c\oplus\alpha_2 a'bc'\oplus\alpha_3 a'bc\oplus \alpha_4 ab'c'\oplus\alpha_5 ab'c\oplus\alpha_6 abc'\oplus\alpha_7 abc$

where α is 1,0 depending on whether the *i*th term is present or not. Expressions like this are sometimes referred to as exclusive-OR sum-of-products or ESOPs in the literature.

An alternative canonical form is found by expanding primed variables with T4 (x'=x⊕1) multiplying out and cancelling duplicate terms with T3 and T1. It is:

C2. $f(abc) = \beta_0 \oplus \beta_1 a \oplus \beta_2 b \oplus \beta_3 c \oplus \beta_4 ab \oplus \beta_5 ac \oplus \beta_6 bc \oplus \beta_7 abc$

where β is 1,0 again depending on whether the *i*th term is present or not.

The canonical expansions imply that any Boolean function can be expressed in terms of the AND and exclusive-OR operators. Exclusive-OR algebra is therefore a complete Boolean algebra.

The majority function

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

$$ab \oplus ac \oplus bc = ab + ac + bc$$

Alternative representation of basic theorems

Equations T1-4 are dual theorems and are frequently labelled to reflect this property.

Alternative expressions for T1 and T3 are:

T1a. $x \oplus x \ldots \oplus x = 0$,

for an even number of x,

T3a. $x \oplus x \ldots \oplus x = x$,

for an odd number of x,

T1b. $x \oplus y \oplus z \ldots = 0$,

if an even number of variables x, y, z... have the value 1

$x \oplus y \oplus z \ldots = 1$,

if an odd number of variables x, y, z... have the value 1.

Alternative systems

Equations T1 to T10 are a system of exclusive-OR-AND logic. A dual system of Exclusive-OR-OR logic is also possible. In such a system T9 would have to be replaced by the following:

T9′ $x(y \oplus z) = (x'+y) \oplus (x'+z)$

This follows from applications of the distributive law, DeMorgan's theorem and T6.

The exclusive-OR operator can be thought of as a second addition operator, known as modulo-2 addition, giving switching circuit algebra two addition 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 theorems.

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 $f = g \oplus h$, then $g = f \oplus h$ and $h = g \oplus f$.

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

$$f \oplus h = g \oplus h \oplus h = g$$

since $h \oplus h$ disappears due to T1 and T3. As a result, $g = f \oplus h$. Similarly, $h = g \oplus f$.

By means of this theorem any given term or expression can be made to be a part of any other expression of the same variables.

For example, let $x = ac' \oplus a'bc$ and suppose that the term $h = ac$ is to be made a part of this expression. Now,

$$g = x \oplus h = ac' \oplus a'bc \oplus ac = a(c' \oplus c) \oplus a'bc = a \oplus a'bc$$

So,

$$x = g \oplus h = a \oplus a'bc \oplus ac$$

As a check, this could have been obtained in this simple case directly from the given expression for x by replacing c′ with $1 \oplus c$ and expanding by T9 the distributive property.

You might want to use this idea if you want to find out if a single variable, with a single exclusive-OR operator will give an expression with fewer product terms than the original expression. Let p be the single variable in function f, then evaluate $g = f \oplus p$. If this expression or its inverse has fewer product terms as required then g is the required result. i.e.

$f = g \oplus p$ or $f = g' \oplus p'$

You would need to evaluate $g = f \oplus p$ for each variable in turn and take the best result, or you might stop with the first good result if any.

Another example of the use of this theorem is to find a Gray code to binary code converter circuit, given the circuit for a binary code to Gray code converter. It is known that the Gray code is constructed from the binary code by the exclusive-OR of adjacent binary bits. You can see this from **Fig. 6**. For four bits:

$$g_0 = b_0 \oplus b_1, \quad g_1 = b_1 \oplus b_2, \quad g_2 = b_2 \oplus b_3, \quad g_3 = b_3$$

The most significant bit, b_3, is the same for both the Gray code and the binary code.

If you want a Gray-to-binary code converter you can simply apply T11 to the above equations to get,

$$b_0 = g_0 \oplus b_1, \quad b_1 = g_1 \oplus b_2, \quad b_2 = g_2 \oplus b_3, \quad b_3 = g_3$$

Or by substitution,

$$b_0 = g_0 \oplus g_1 \oplus g_2 \oplus g_3$$
$$b_1 = g_1 \oplus g_2 \oplus g_3$$
$$b_2 = g_2 \oplus g_3$$
$$b_3 = g_3$$

Exclusive-OR operator on a Karnaugh map

Take the problem of expressing the function,

$$f = ac + b'c + a'bc'$$

in exclusive-OR form.

If you are observant you could solve this problem as follows:

$$f = ac + b'c + a'bc'$$
$$= c(a + b') + a'bc'$$
$$= c(a'b)' + a'bc'$$
$$= c \oplus a'b$$

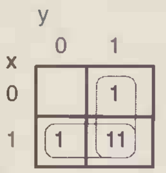
There are many cases like this for functions of three variables. Often though, this approach may not be so easy to carry out. Fortunately the K-map technique can be readily adapted for the purpose.

First consider the exclusive OR function plotted on a K-map as in Fig. 7. The K-map technique for the exclusive-OR function depends on T10 and the extended forms of T1 and T3. This leads to the relatively simple and more conclusive method I mentioned earlier.

Plotting the variables x and y individually on the map results in minterm xy being plotted twice, consequently by the extended form of T1, this term will disappear from the exclusive-OR form.

$b_3b_2b_1b_0$	$g_3g_2g_1g_0$
0000	0000
0001	0001
0010	0011
0011	0010
0100	0110
0101	0111
0110	0101
0111	0100
1000	1100
1001	1101
1010	1111
1011	1110
1100	1010
1101	1011
1110	1001
1111	1000

Fig. 6. Binary to Gray code conversion.



$x \oplus y = xy' + x'y$

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

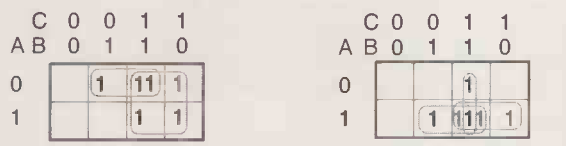
Similarly by the extended form of T3, where the minterm is plotted once or an odd number of times it will be retained.

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.

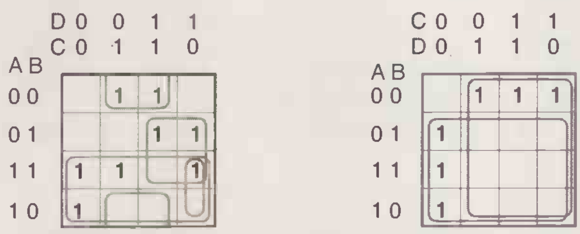
Fig. 8. Examples of exclusive-OR forms of logic equations.



The function:
$A'BC' + AC + B'C = C \oplus A'B$

The function:
$ab \oplus ac \oplus bc = ab + ac + bc$

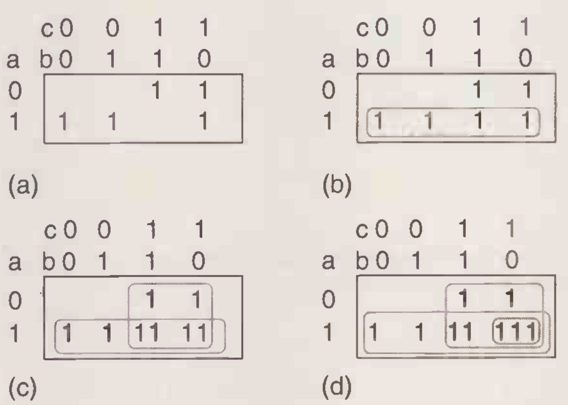
Fig. 9. Four variable examples of exclusive-OR functions.



$f1 = a'b'c + a'cd + bc'd + ac'd' + abd'$
$= a \oplus b'c \oplus bd \oplus ac'd$

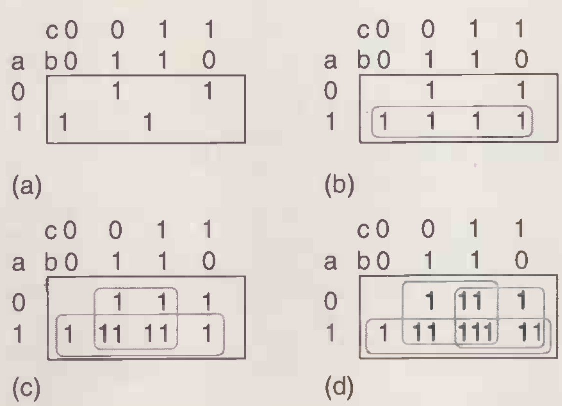
$f2 = (a+b) \oplus (c+d)$
$= a'b' \oplus c'd'$

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



$y = a \oplus c \oplus ab'c$

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



$y = a \oplus b \oplus c$

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 shows 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 a'bc and a'b'c 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:

$$y = a \oplus c \oplus ab'c$$
$$= a \oplus c(1 \oplus ab')$$
$$= a \oplus c(ab')'$$
$$= a \oplus c(a' + b)$$
$$= a \oplus (a'c + bc)$$

or,

$$a' \oplus (c(ab')')'$$

for NAND gate implementation. Remember that a NAND gate has the form (ab)'.

Another example is shown in Fig. 11. The same steps are taken as for Fig. 10. The function is shown plotted on a Karnaugh map at **11a)**. As before, you start by plotting variable a as in **11b)**, since this looks like a suitable starting point. This covers two of the ones in the function but introduces two additional ones.

Next you plot variable b as shown in **11c)**. This cancels one of the unwanted ones introduced in 11b) but also cancels one of the ones that need to be kept and introduces an additional one at a'bc.

Finally, add the plot for variable c. As you can see this restores the one at abc covers the one at a'b'c and cancels the unwanted ones at a'bc and ab'c. The final well known result is shown under the K-map at **11d)** as it was in Fig. 10. The 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=ac'd'+abc+ab'd+b'c'd+a'b'cd'
```

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⊕(b'cd'+abc'd+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.

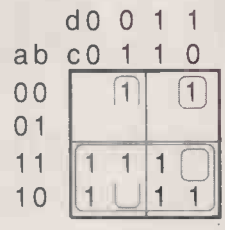
In summary

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. ■

David is based in Adelaide, South Australia where he pursues his interest in the theory and design of digital circuits. Some of the material in this article is already in use in Technical and Further Education Institutes in South Australia.



y=a⊕(b'cd'+ abc'd + a'b'c'd)
= ac'd' + abc + ab'd + b'c'd + a'b'cd'

Fig. 12. Confirming the identity of these functions with a Karnaugh map.

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

```
T1. x⊕x=0                          T2.x⊕x'=1
T3. x⊕0=x                          T4.x⊕1=x'
T5. (x⊕y)'=x'⊕y=x⊕y'               T6.x'⊕y'=x⊕y
T7. x⊕y=y⊕x                 Commutative law
T8. (x⊕y)⊕z=x⊕(y⊕z)         Associative law
T9. x(y⊕z)=xy⊕xz            Distributive law
T9' x(y⊕z)=(x'+y)⊕(x'+z)    Distributive law with OR function
T10.If:   f=g⊕h and gh=0, then f=g+h
```

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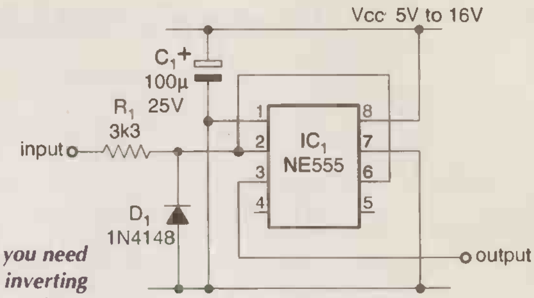
Make sure that the input cannot exceed the supply voltage. If there is no risk of negative input excursions, the diode can be left out.

K Samson
Thornton Cleveleys, Lancashire C8

Too trivial to publish? Yes, unless you need a very cheap and simple inverting buffer/driver with 200mA switching.



Capacitance bridge

ADC42 Winner

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, $R_yC_y=R_xC_x$ and $C_x=R_yC_y/R_x$ where C_y 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 IC_{3a}.

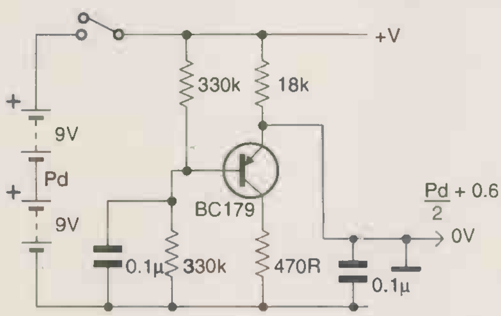
Output from IC_{3a} drives the indicator amplifier IC_{3b}, which illuminates 'high' and 'low' leds. In the out-of-balance state, one of the integrators will have too long a time constant and lower amplitude than the other, the leds indicating the fact.

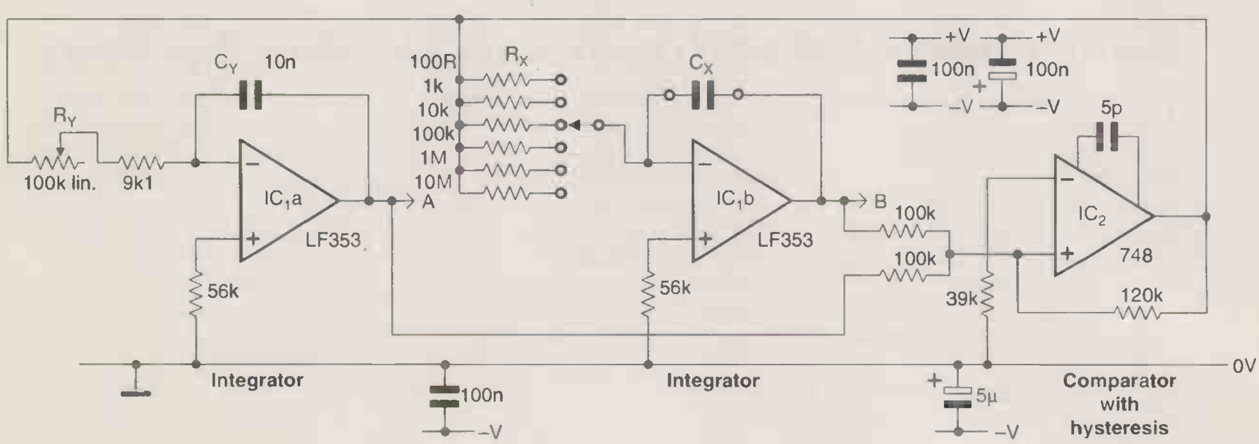
Since only relative values are important, the only components whose absolute values need care are the range-selecting resistors and C_y, which may be selected to match a known calibration capacitor. Frequency of the waveform depends on the setting of R_y and remains within 500-5000Hz to keep the error detection simple.

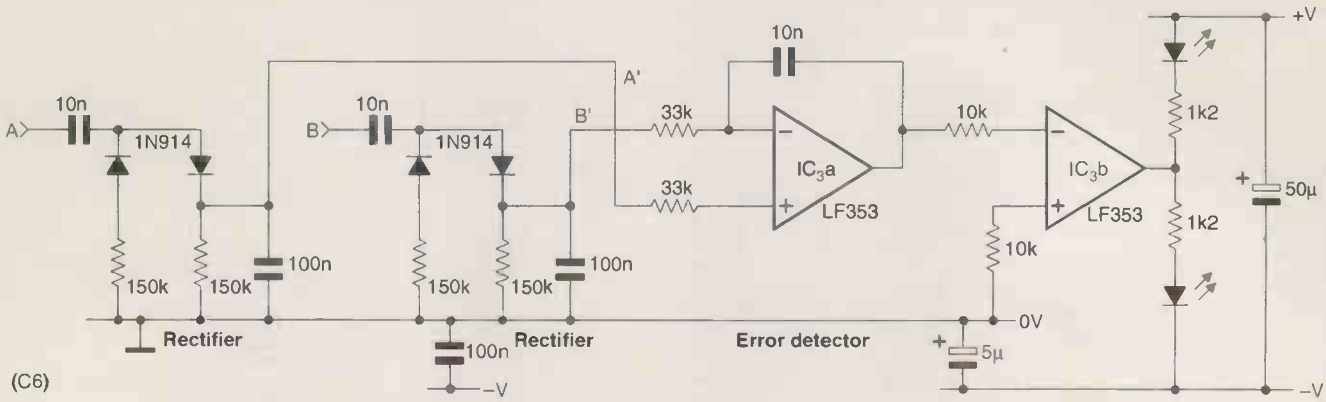
The zero volts line is obtained from a divider and p-n-p transistor to give a voltage close to the centre of the *LF353* comparator; it tracks as battery voltage falls and allows the use of a single on/off switch.

J D Gray
London
C6

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







(C6)

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 to close tolerance, any drift and offset drift is cancelled, i.e:

$V_{even}=k(+V_{in}+V_{offset})$

$V_{odd}=k(-V_{in}+V_{offset})$.

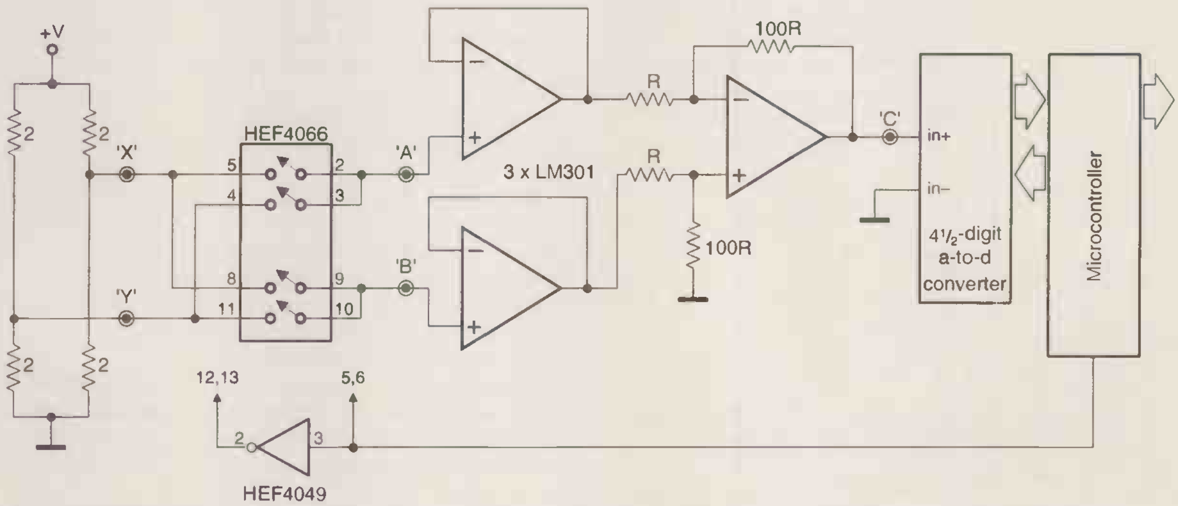
Subtracting,

$V_{out}=kV_{in}$.

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 Iancu
Bucharest
Romania
C17



Stabilised instrumentation amplifier using a cmos chopper ic and software filtering.

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.

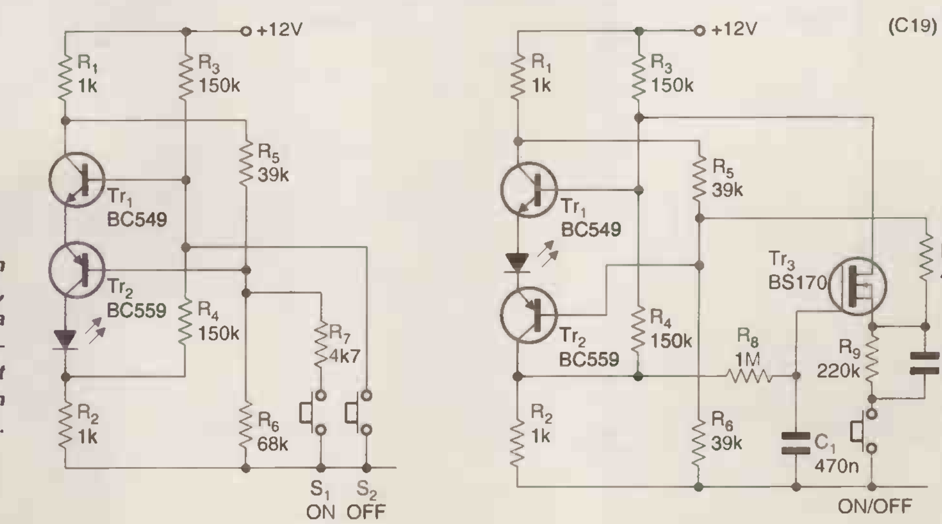
At (a) is the set/reset type, which has separate switches for each state and which may have a relay instead of S_1 or S_2. For lowest off state current, R_5 may be 150kΩ and R_6 270kΩ, off current being 65μA and current in the on state 4mA – a ratio of more than 60:1.

Circuit (b) is a bistable arrangement, in which the same switch triggers both states. Cycling rate is slow at about 100ms with C_1 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 $R_{1,2}$ 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.

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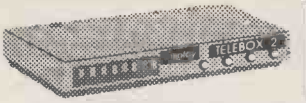

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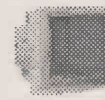

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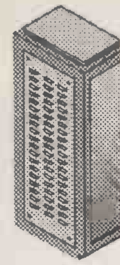

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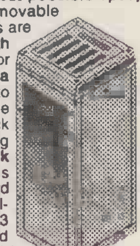

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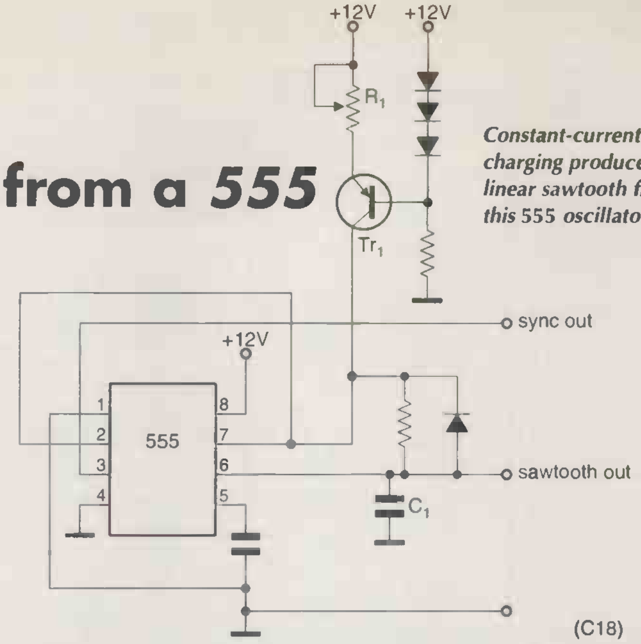
Linear sawtooth from a 555

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 C_1 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

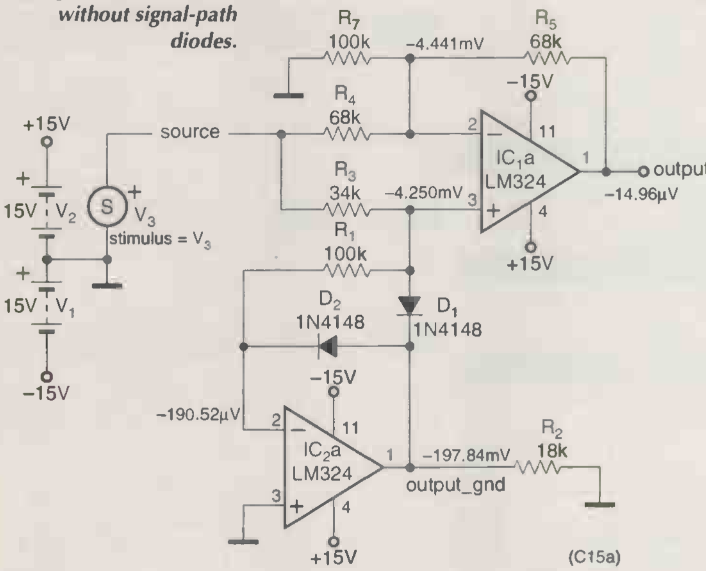


Constant-current charging produces a linear sawtooth from this 555 oscillator.

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.

Fig. 1. Signal rectifier without signal-path diodes.



Looking at the circuit diagram in Fig. 1, diode D_1 does not conduct during negative half-cycles and $R_{1,3}$ form a potential divider, pin 2 of IC_{2a} being held at ground by its feedback through D_4. Loss of amplitude in the divider is compensated in IC_{1a} by the addition of R_7 to change it from a unity-gain follower to a amplifier.

During positive excursions, D_1 conducts and maintains the non-inverting input of IC_{1a} at ground. As the inverting input is at the same level, the op-amp is now an inverting amplifier, so that the input appears as a negative output with the same amplitude. Resistor R_7 has no effect at this time since both connections are at the same level. Waveforms are shown in **Fig. 2**.

Diode D_4 clamps IC_{2a} 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 IC_{2a} 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

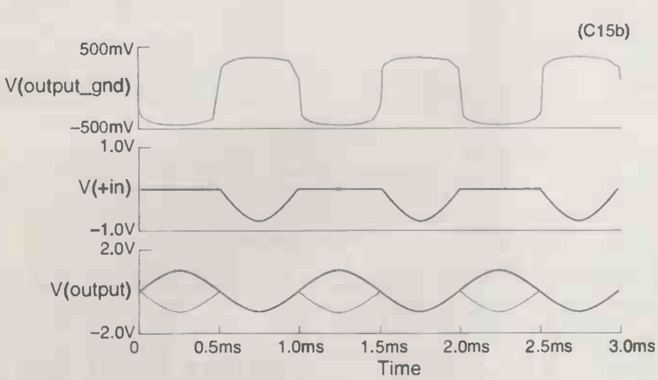


Fig. 2. Waveforms in the circuit of Fig. 1.

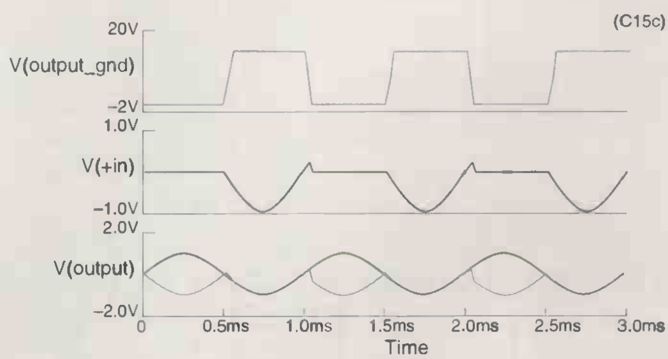


Fig. 3. Without the inclusion of D$_4$, crossover distortion would occur, caused by saturation in IC$_{2a}$.

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Schlumberger Type: S17780 OTDR + S177823 Plug-in
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Kane-May: KM4003 Air Velocity 0-30 In metres/seconds Air Temperature (C) –30 to +200C. Battery Operated.
Portaflow MK11: Portable diagonal beam flowmeter. Made by: Micronics
Bacharach: Combustion Analyzer/Environmental monitor Type: 300NSX.
Kane-May: Combustion Analyzer Type: 9004
Kane-May: Temperature Sensor Type: 1204 c/w 8004
Temperature & Humidity Sensor. GGA-26 Thermo-Anemometer + KM801 Infratrace
Casella: Aerosol Monitoring System Type: AMS950 Ranges: 0-20mg/m 0-200mg/m
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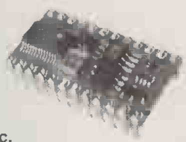

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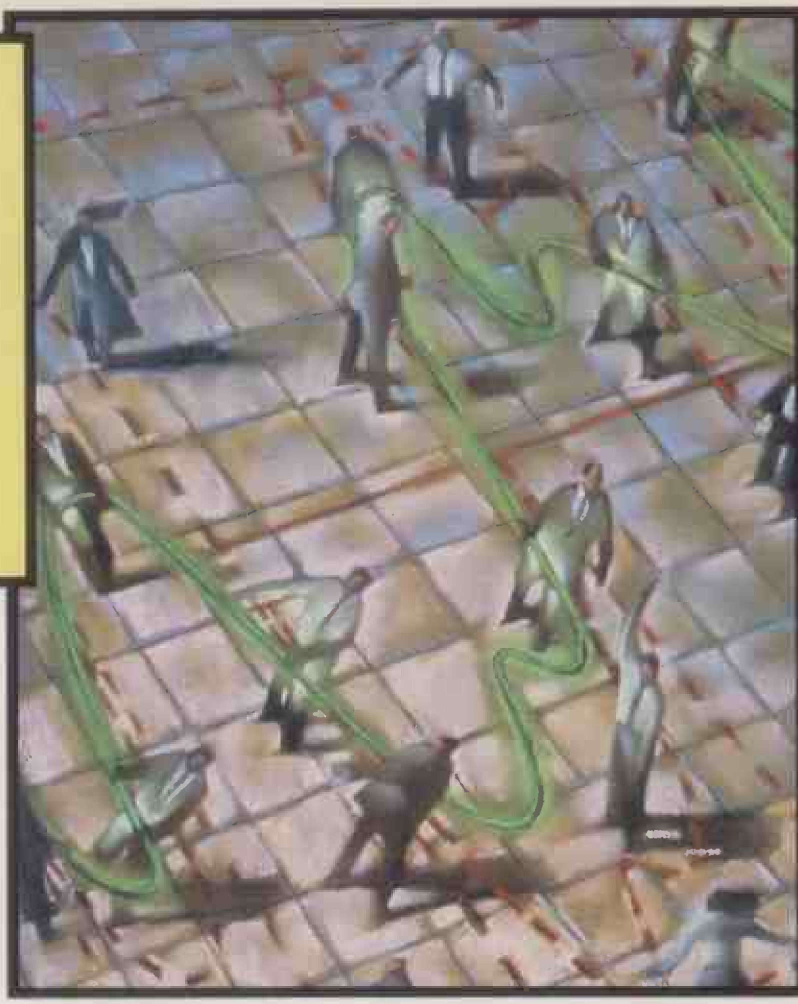
CIRCLE NO.117 ON REPLY CARD

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 Rectifier[1]. 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 *BYW96C* 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.

Packaged inverter

Artificial horizon and motors

Inverter breadboard

phase shifts encoded in the eproms.

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.

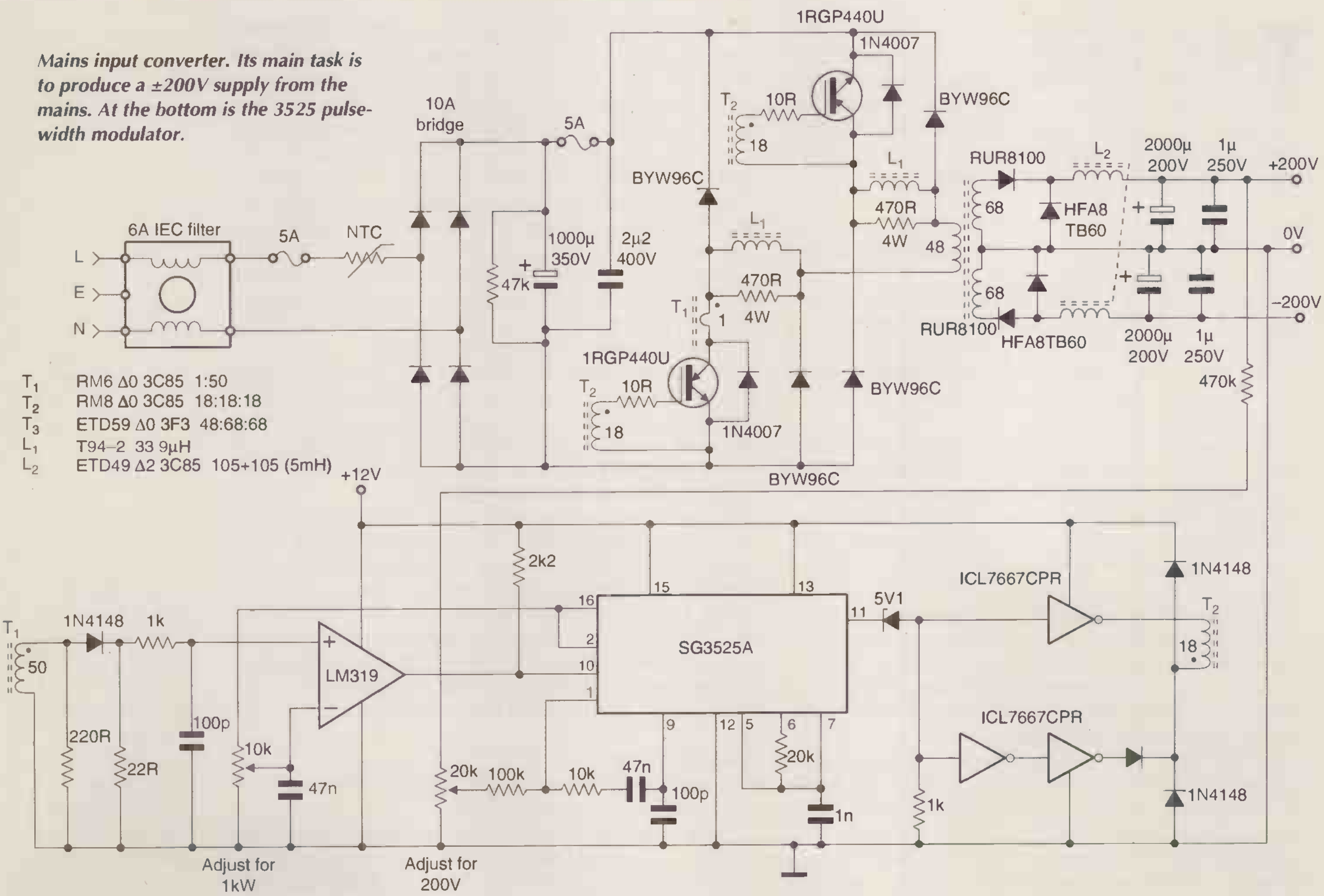
The algorithm used, in floating-point decimal, is:

```
A=INT(128*(1+SIN(2*PI*(X+0.5)/4096)))-0.5)
B=INT(128*(1+SIN(2*PI*(X+1365.83)/4096)))-0.5)
C=INT(128*(1+SIN(2*PI*(X+2731.17)/4096)))-0.5)
```

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.

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



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.

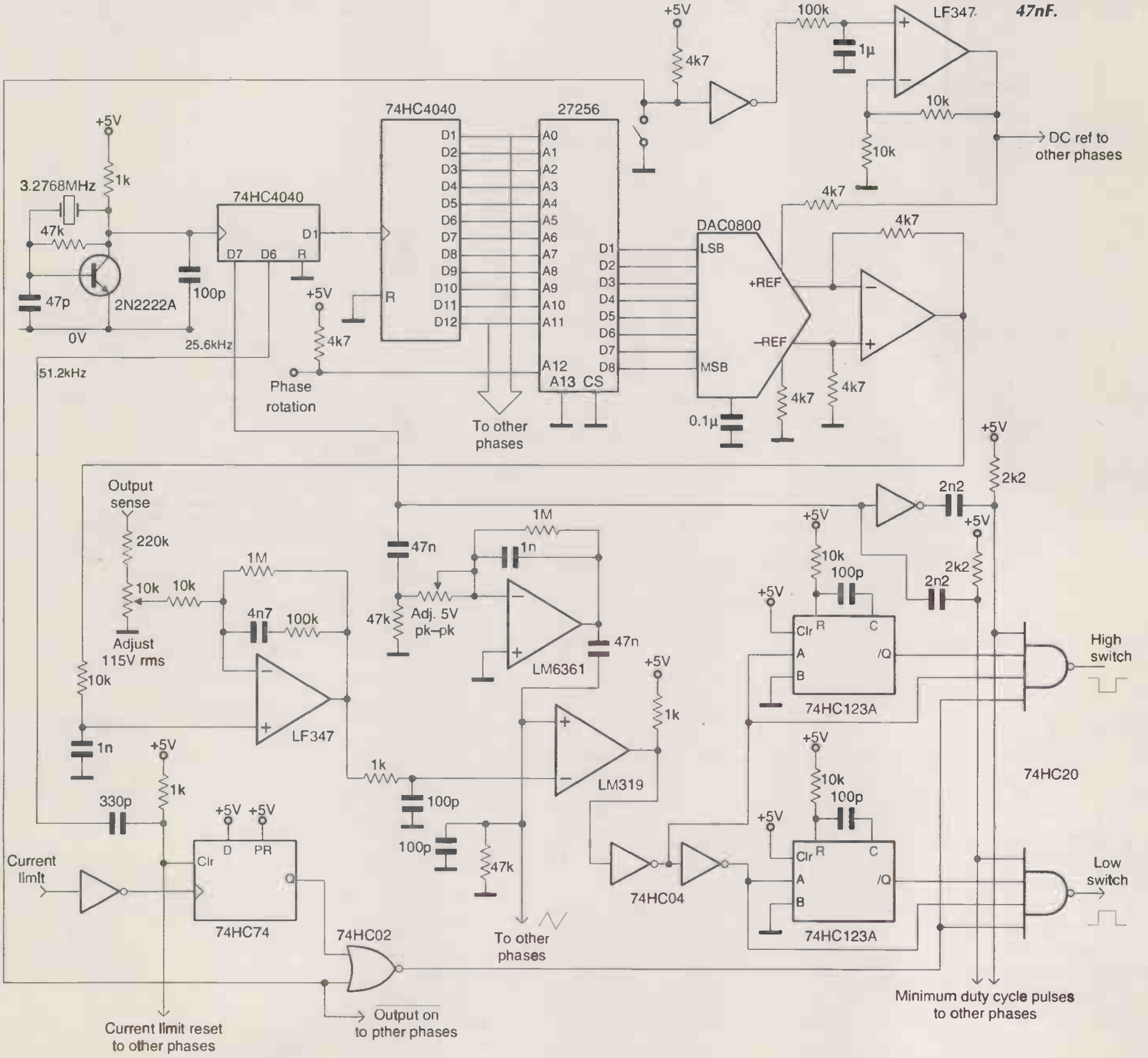
A single potentiometer sets the current-limit comparator references. This determines the overall kVA rating of the inverter and is set to approximately 5A for 3A rms output.

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

One phase of the intermediate driver circuitry. Sine-waves are constructed by a d-to-a converter from information in eprom. A crystal-controlled clock feeds the 4040 counter that addresses the eprom sequentially. Analogue ICs powered from ±12V, power pins decoupled with 47nF.



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^3/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.

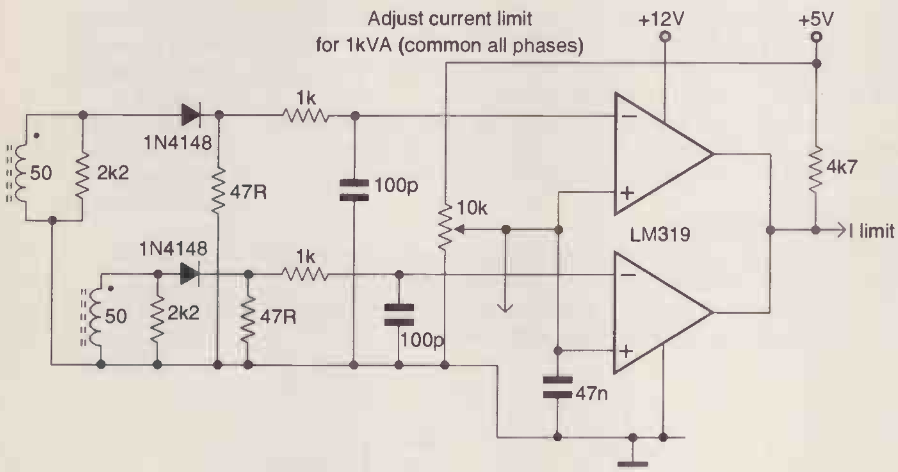
It is surprising how many commercial power switching designs have inadequate fusing. Without it, all manner of expensive blow-outs can occur.

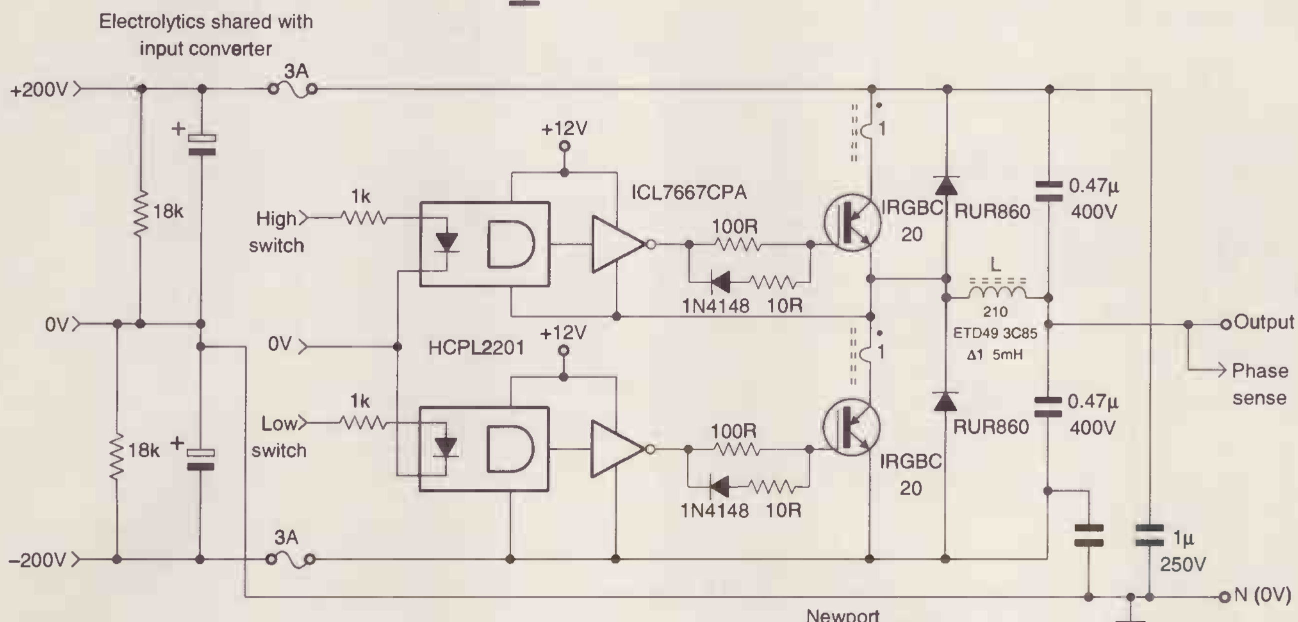
Five neons indicate, mains present, intermediate dc voltage present and output phases on. The output was tested using various 400Hz loads, small fans and blowers, an artificial horizon and array of 115V 100W lamps.

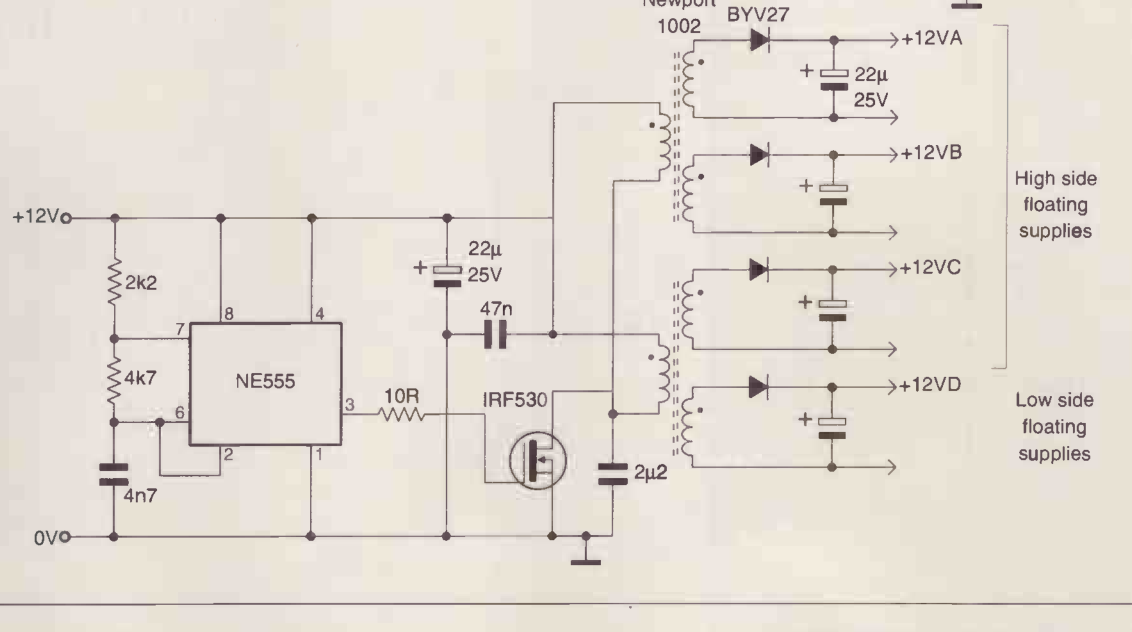
Simplifications and enhancements

Various simplifications and enhancements appear possible. Numerous possibilities exist for the sine wave references, with perhaps reduced precision. One techniques 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 in eprom with a simple *RC* filter to decode the pwm back to a sinewave. A 1.6384MHz clock would allow 64







Output bridge. At the top is the final conditioning circuit for current limiting. In the middle is one power driver. Below is power supply circuitry for producing the isolated low voltage needed for the high-side driver.

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[2] 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 at120° may be tricky or anologue 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[3] 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 *HCPL3120* and *HCPL3150* igbt opto-coupled gate drivers from Hewlett Packard[4] 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
4. Hewlett Packard Ltd, Amen Corner, Cain Road, Bracknell, Berkshire, RG12 1HN, tel. 01344 360000. Distributed in the UK by Farnell Electronic Components, tel. 0113 263 6311.

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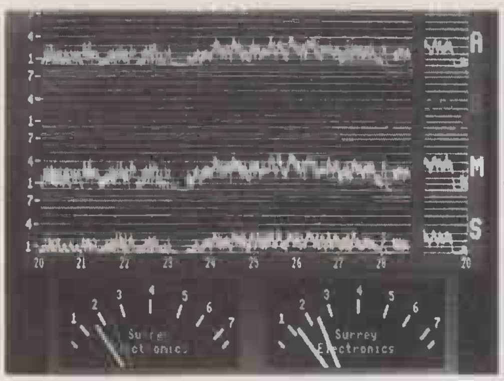

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Marconi RCL Bridge type TF2700 - £150.
Marconi/Saunders Signal Sources type - 605B-6070A-6055A-6059A-6057A-
6056- £250-£350. 400Mc/s to 18GHz.
Marconi Microwave 6600A 1 sweep osc., mainframe with 6650PI - 18-26.5 GHz or 6651 PI - 26.5-40GHz-£750 or PI only £600. MF only £250.
Tektronix Plug-ins 7A13-7A14-7A18-7A24-7A26-7A11-7M11-7S11-7D10-7S12-S1-S2-S6-S52-PG506-SC504-SG502-SG503-SG504-DC503-DC508-DD501-WR501-DM501A-FG501A-TG501-PG502-DC505A-FG504-7B80 + 85 - 7B92A.
Gould J3B test oscillator + manual - £150.
Tektronix Mainframes - 7603-7623A-7613-7704A-7844-7904-TM501-TM503-TM506-7904A-7834-7623-7633-7844-7854-7104.
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TEKTRONIX - 7S14-7T11-7S11-7S12-S1-S2-S39-S47-S51-S52-S53-7M11.
Marconi mod meters type TF2304 - £250.
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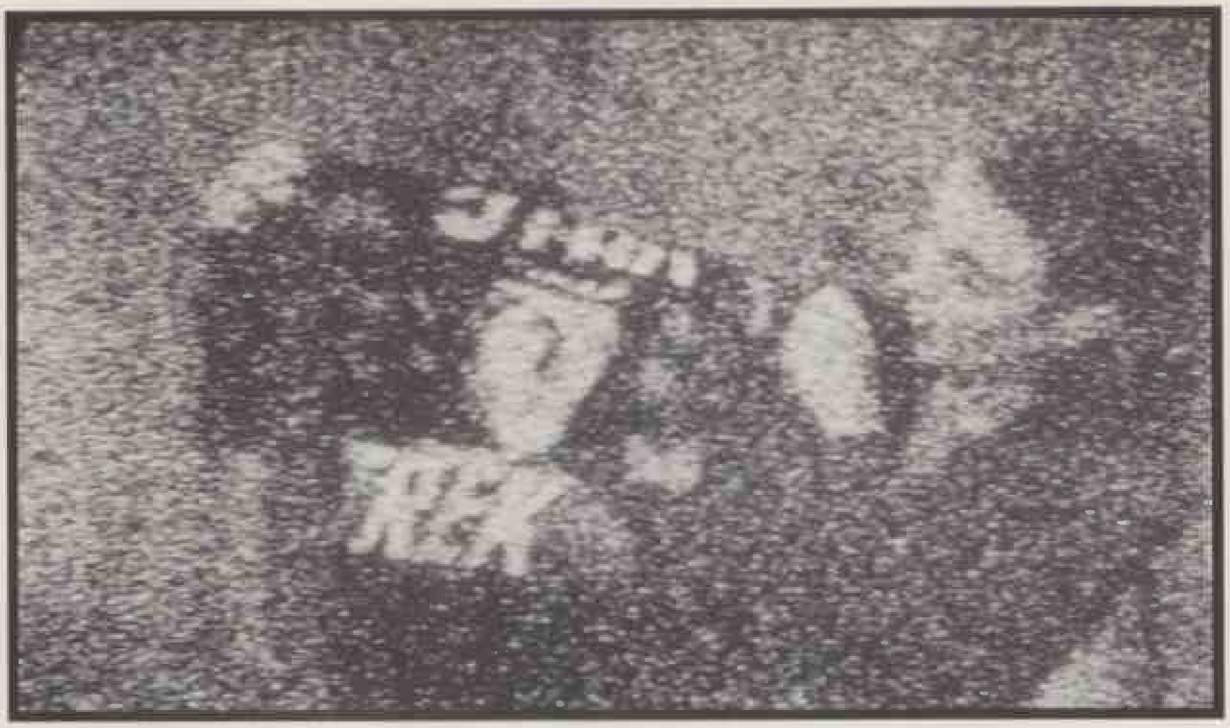

Know noise

Joe Carr looks at noise from the receiver designer's perspective and explains which elements of the receiving system are the biggest contributors to it.

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

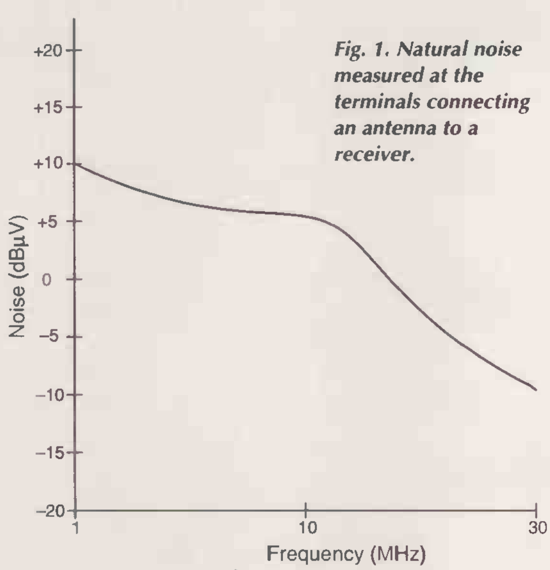

Fig. 1. Natural noise measured at the terminals connecting an antenna to a receiver.

Joseph J. Carr, MSEE

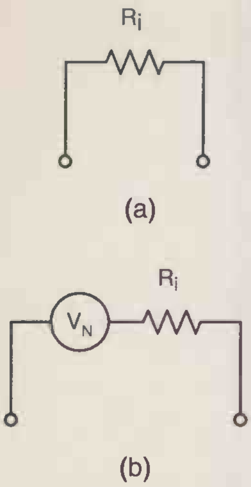

Fig. 2. Model of an ideal resistor, a) and a real resistor – i.e. pure resistance plus a noise source, b).

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_i.

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,

$$V_N = \sqrt{4KTBR} \qquad (1)$$

Where Vn is the noise potential in volts, K is Boltzmann's constant (1.38×10–23 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.

Table 1 and **Fig. 3** show noise values for a 50Ω resistor at various bandwidths out to 10kHz. Because different bandwidths are used for different reception modes, it is common practice to delete the bandwidth factor in equation 1 and write it as,

$$V_N = \sqrt{4KTR}\,\frac{V}{\sqrt{Hz}} \qquad (2)$$

With this equation, you can find the noise voltage for any particular bandwidth by taking its square root and multiplying it by the equation. It is essentially the solution of the previous equation normalised for a 1Hz bandwidth.

Signal-to-noise ratio

Receivers are evaluated for quality on the basis of signal-to-noise ratio, also known as S/N or SNR and sometimes denoted Sn. 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

The noise performance of a receiver or amplifier can be defined in three different, but related, ways: noise factor, or F_N, noise figure, or NF, and equivalent noise temperature, Te; 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_{no}, to input noise power, P_{ni}:

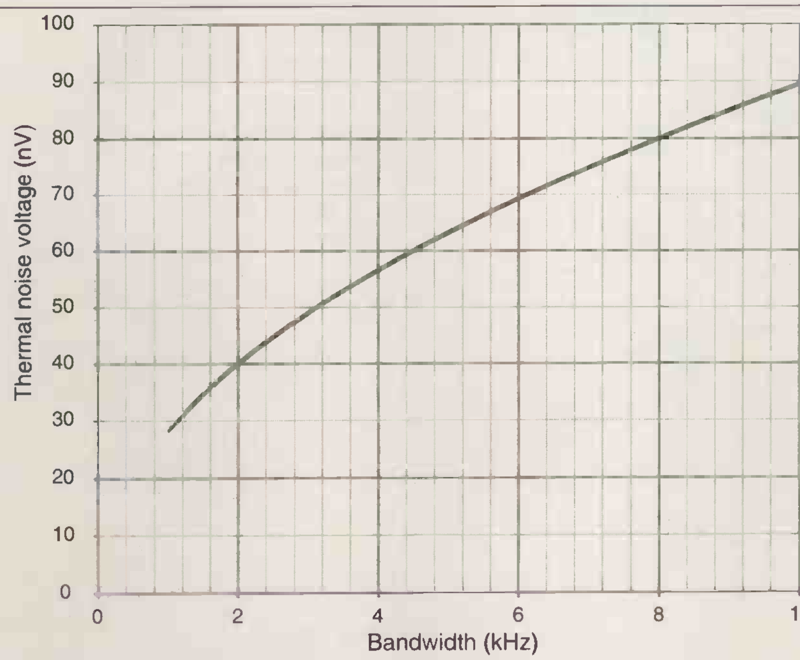

Fig. 3. Noise voltage for bandwidths to 10kHz for a 50Ω resistor.

Table 1. Noise voltage for bandwidths to 10kHz.

Bandwidth (kHz)	Noise×10^{-8} (V)
1	2.83
1.5	3.46
2	4.00
2.5	4.47
3	4.9
3.5	5.29
4	5.66
4.5	6.00
5	6.33
5.5	6.63
6	6.93
6.5	7.21
7	7.49
7.5	7.75
8	8.00
8.5	8.25
9	8.49
9.5	8.72
10	8.95

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

In order to make comparisons easier, the noise factor is usually measured at the standard temperature T_o 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:

$$F_N = \frac{S_{NI}}{S_{NO}} \qquad (4)$$

where S_{NI} is the input signal-to-noise ratio, S_{NO} is the output signal-to-noise ratio.

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,

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

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 (0K).

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:

$$T_e = (F_N - 1) T_o \qquad (6)$$

and to noise figure by

$$T_e = 290\left(10^{NF/10} - 1\right) \qquad (7)$$

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,

$$F_N = F_1 + \frac{F_2 - 1}{G_1} + \frac{F_3 - 1}{G_1 G_2} ... + \frac{F_N - 1}{G_1 G_2 ... G_{N-1}} \qquad (8)$$

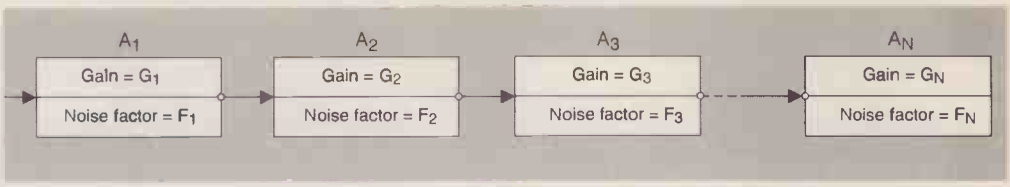

Fig. 4. In a cascaded amplifier chain like this one, each stage not only adds its own noise, but amplifies noise from the preceding stage.

where F_N is the overall noise factor of *N* stages in cascade, F_1 is the noise factor of stage 1, F_2 is the noise factor of stage 2, F_N 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 –130dBm, 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

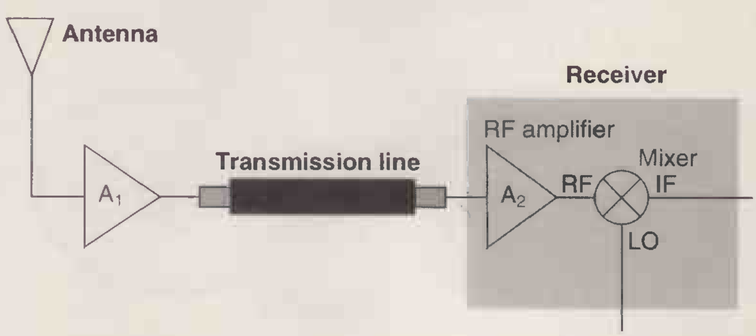

Fig. 5. Typical receiver system front-end. Low-noise amplifier A_1 is put before the transmission line. If it came after, it would have to deal with a signal subjected to more loss.

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

Stage	Gain/loss (dB)	Gain/loss (lin.)	Noise figure	Noise factor	Noise Temp.
Preamplifier	15	31.62	2.2	1.66	191
Transmission line	–2	0.63	2.00	1.58	170
RF amplifier	10	10.00	3	2.00	289
Mixer	–6	0.25	4.5	2.82	527
Overall	17	50.12	2.398	1.737	214

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 A_2. 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:

$$T_{e(line)}=T_L(L-1) \qquad (9)$$

where $T_{e(line)}$ 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,

Stage	Gain (dB)	Noise figure (dB)
Preamp	15	2.2
Trans. line	–2	2.0
RF amp	10	3.0
Mixer	–6	4.5

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:

Stage	New *NF* (dB)	Change
Low-noise amplifier	3.20	+0.8 dB
Transmission line	2.47	+0.072dB
RF amplifier	2.46	+0.062dB
Mixer	2.41	+0.012dB

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

1. Carr, J., RadioScience Observing, Vol. 1.

† All else remaining unchanged.

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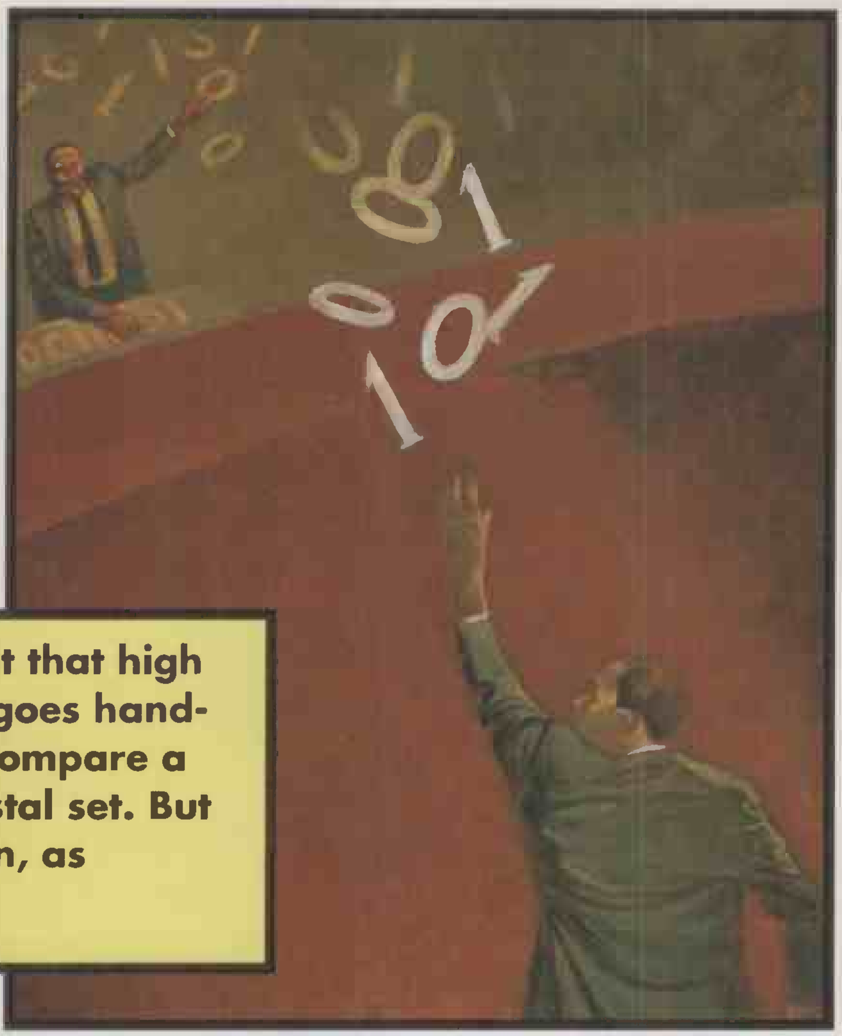

Conventional wisdom has it that high performance in a receiver goes hand-in-hand with complexity. Compare a comms receiver with a crystal set. But there is a notable exception, as Ian Hickman explains.

Super-regen or super-replacement?

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 rf amplifier with feedback is gradually reduced, 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 class-C 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.

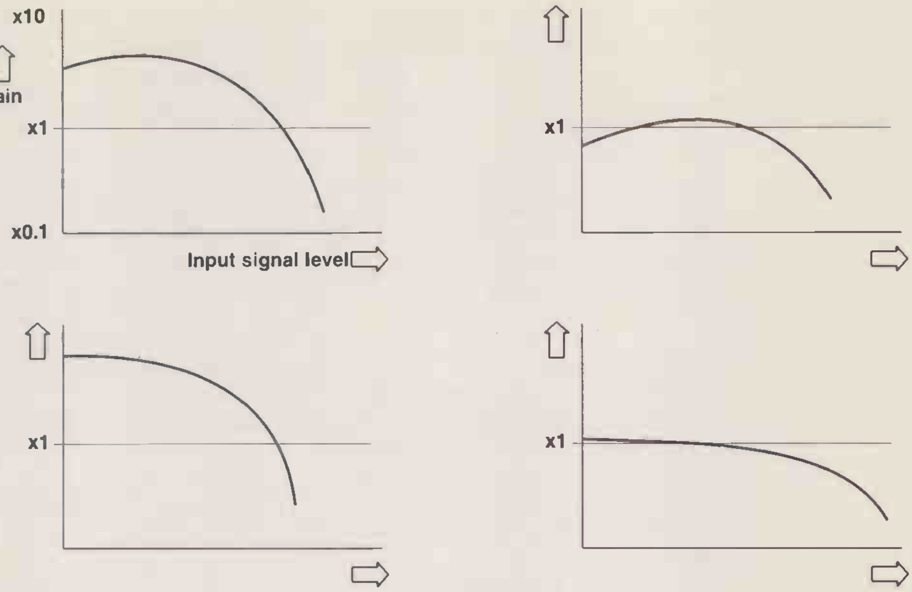

Fig. 1. Showing various ways the open-loop gain of an oscillator can vary with signal level.

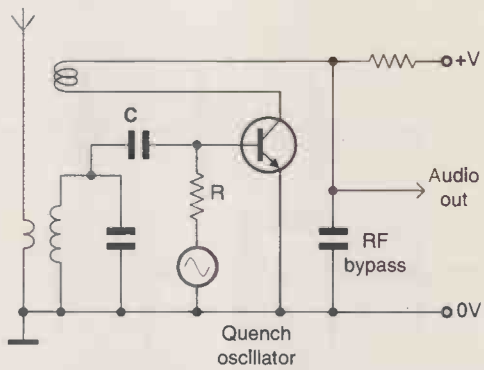

Fig. 2. Simplified circuit diagram of a basic super-regenerative receiver.

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-regenenerative 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.

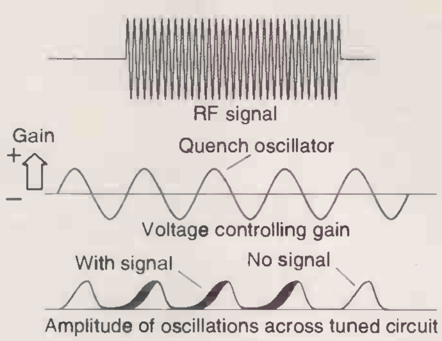

Fig. 3. Illustrating the circuit action of a basic super-regen receiver.

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

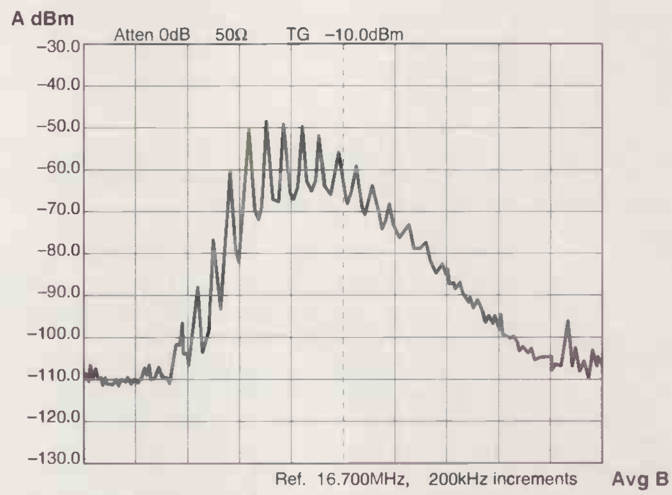

Fig. 5. Typical spectrum of the stray radiation from a super-regen receiver, actually from that shown in Fig. 4. The broad band of interference makes the super-regen a social outcast among receiver architectures.

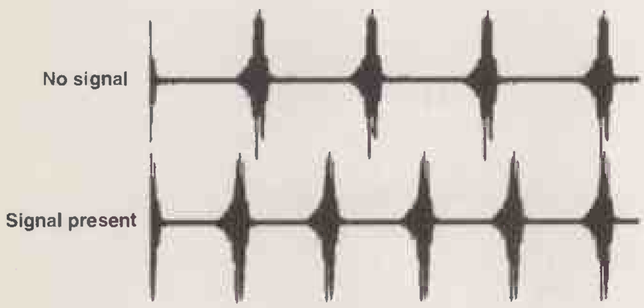

Fig. 4. Bursts of rf in a self quenching super-regen receiver. The no-signal quench frequency – upper trace – is about 80kHz. The increased pulse rate – with a consequent increase in supply current drawn – is seen in the lower trace. The ragged appearance of the rf pulses is due to sub-sampling of the waveform by the digital storage oscilloscope used.

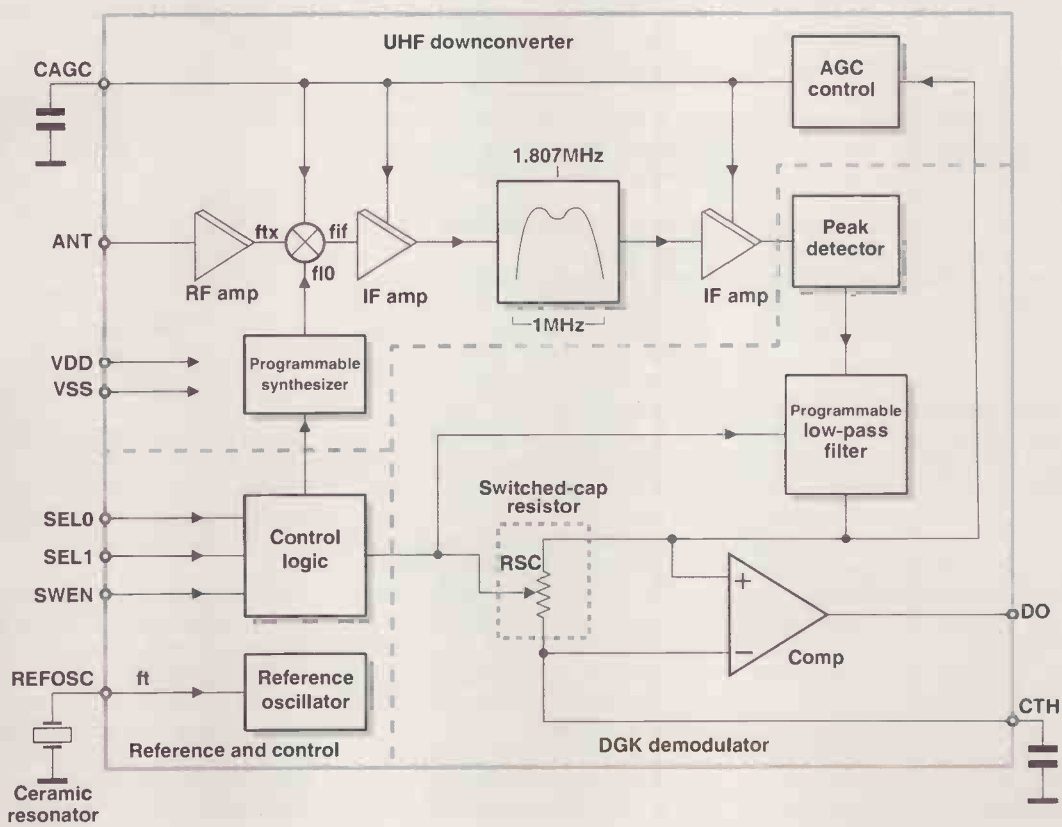

Fig. 6. Block diagram showing the internals of the MICRF001 uhf superhet receiver.

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 quench-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 teabreak 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 QwikRadio*[3] 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 on-off 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.

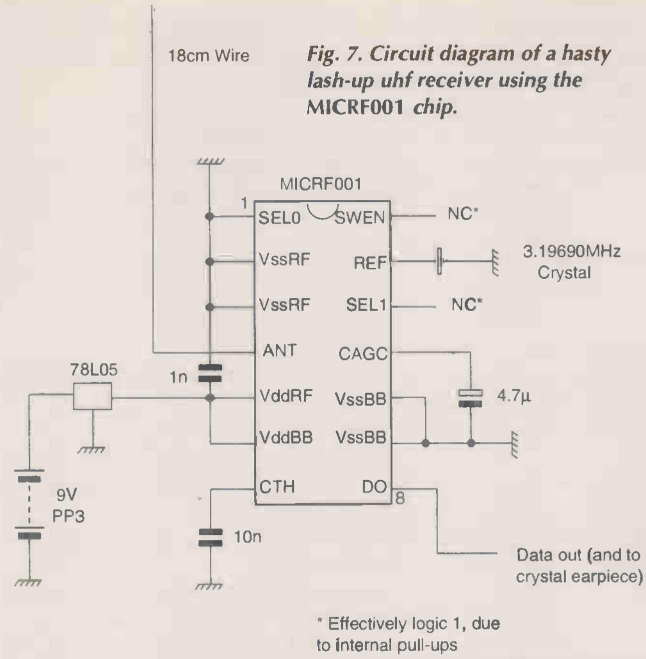

Fig. 7. Circuit diagram of a hasty lash-up uhf receiver using the MICRF001 chip.

Technical support

MICRF001 – Micrel Semiconductor (UK) Ltd., 21 Old Newtown Road, Newbury, RG14 7DP. Tel: 01635 524455, fax: 10635 524466, 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.

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 low 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 quantitive 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.

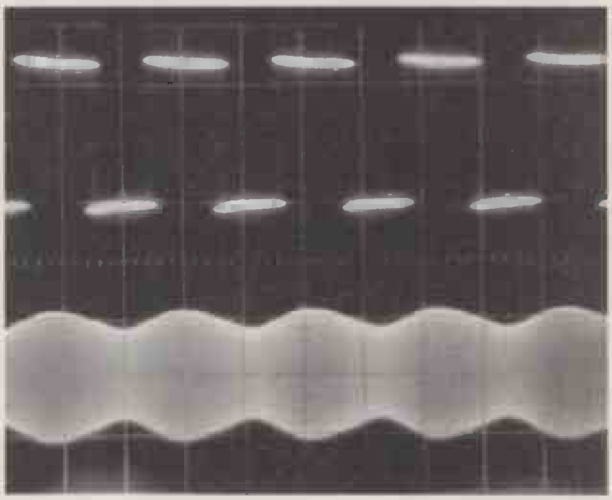

Fig. 8. Upper trace – a 010101 data stream at 2kbit/s, recovered from the fifth harmonic of the 83.6MHz output of a signal generator. 2V/div. vertical, 500µs/div horizontal. In the lower trace is the signal generator output, showing just 20% amplitude modulation depth. 50mV/div vertical, 500µs/div horizontal.

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, and predicts a range of just under 100m in a clear site.

Clearly, under more cluttered conditions, the useful range would be less, but then the circuit of Fig. 7 really does not take full advantage of the IC's potential. The pin 4 antenna input impedance at uhf is about 6kΩ in parallel with 2pF, whereas the impedance of a quarter wave whip working against a ground plane is 37Ω – a horrendous mismatch.

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

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.

To achieve the same broad bandwidth, the *MICRF001* uses a low IF, so that signals can be received with the local oscillator either high or low. Furthermore, two modes of working are available, in one of which, namely the sweep mode, the effective bandwidth is further increased as described later.

The equation relating the the intermediate frequency F_{if} and the synthesiser reference frequency F_{ref} is,

$$F_{if} = \left(\frac{F_{ref} \times (M+\alpha)}{390}\right) \times 2.25 \qquad (1)$$

where all frequencies are in megahertz, M=128 and α=1 for Sweep mode or α=2 for Fixed mode.

Fixed mode. This mode is used with transmitters having a good frequency stability. These would have, for example, a SAW or crystal frequency reference. In this mode the transmitter, receiver IF and local oscillator frequencies are related by,

$$F_{if} = F_{tx} - F_{lo} \qquad (2)$$

and the synthesiser reference frequency becomes,

$$F_{ref} = \frac{F_{lo}}{(M+2)} \qquad (3)$$

This assumes low-side mixing. From these three equations,

$$F_{lo} = F_{tx} \times \left(1 + \frac{2.25}{390}\right)^{-1} \qquad (4)$$

So, for a given transmitter frequency, F_{lo} is determined from equation 4, where F_{ref} is given by equation 3.

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,

$$F_{lo(min)} = F_{ref} \times M$$
$$F_{lo(max)} = F_{ref} \times (M+2) \qquad (5)$$

thus the sweep range ΔF_{sw}=2×F_{ref}. The resultant coverage is ΔF_{sw}+(2×F_{if})+F_{bp}. In Sweep mode, F_{ref} is simply given by,

$$F_{ref} = \frac{F_{tx}}{(M+1)} \qquad (6)$$

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

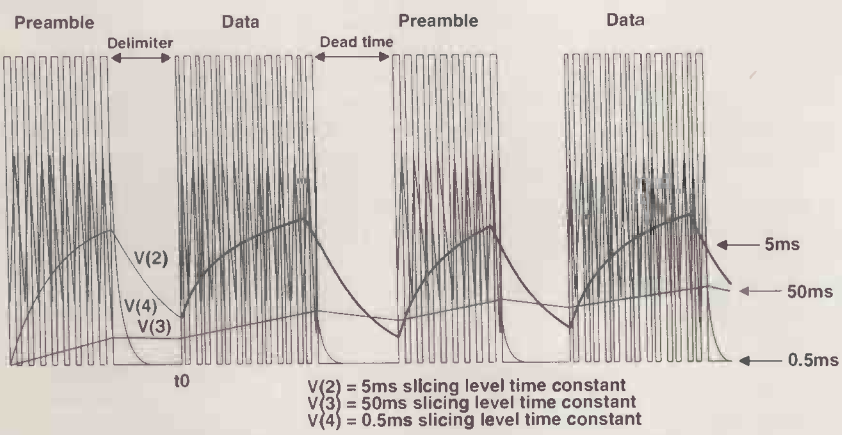

Fig. 10. Comparator action with various reference level filter time constants.

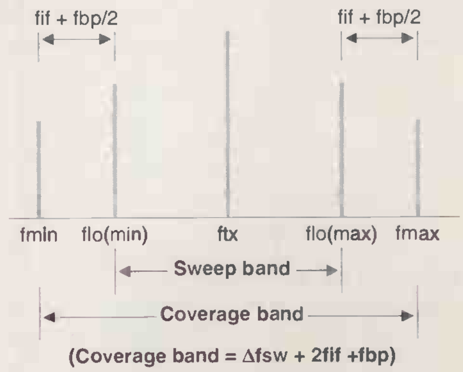

Fig. 11. Showing how in Sweep mode, the effective bandwidth is increased by sweeping the local oscillator.

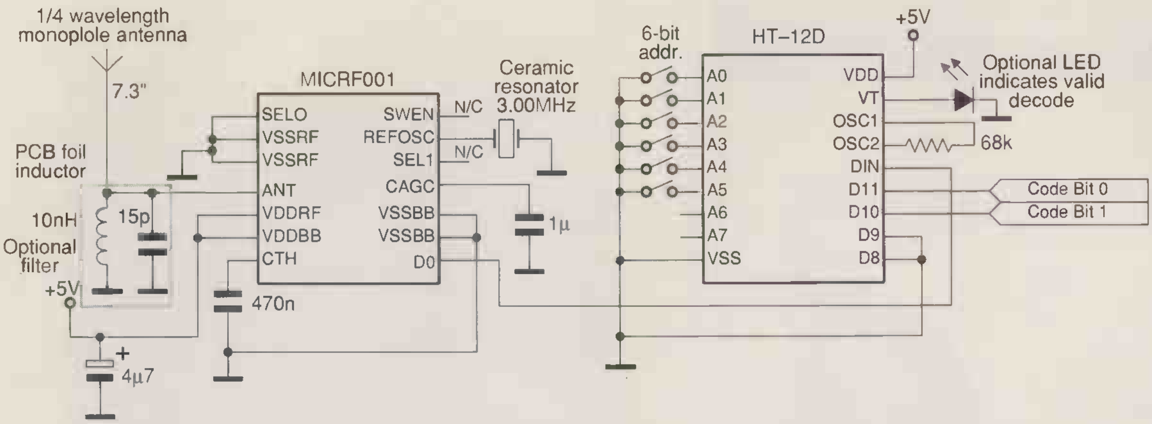

Fig. 9. A typical application circuit for the MICRF001 for North American use.

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 D_{11} and D_{12}. 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 srd 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

1. The Manual of Modern Radio, J. Scott-Taggart, The Amalgamated Press Ltd., London 1933
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.

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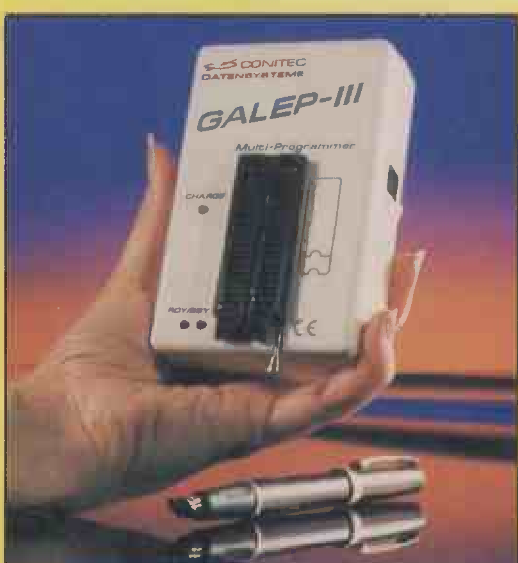

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Discrete active devices

H-v p-n-ps. New p-n-p transistors are able to handle a maximum collector/emitter voltage of 500V. Two types are available: the *FZT560* in SOT223 and the *FMMT560* in the smaller SOT23 package. Both provide the same high-voltage performance, the power dissipations being 2W and 0.5W. Current handling for both is 500mA peak pulse and 150mA continuously. At 50mA, typical gain is 80 at 500V.
Zetex plc. Tel., 0161 622 4422; fax, 0161 622 4420; web, www.zetex.com.
Enq no 504

Displays

12.1in svga tft. A 30000h life, high brightness tft liquid-crystal display panel from Toshiba, the *LTM12C289*, is meant for industrial applications and not necessarily for those involving personal computers. It provides wide viewing angles and brightness levels in excess of 250cd/m^2 with a typical contrast ratio of 200:1. Since the lighting ccfls are both at the top of the screen, size has been kept to 278 by 209 by 14mm to provide an active display of 245 by 184mm to an 800by 600 pixel resolution. Voltage needed is 3.3V and the unit can be supplied with an inverter designed to optimise backlight life.
Toshiba Electronics UK Ltd. Tel., 01276 694730; fax, 01276 694800.
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SXGA lcd controller. Digital View's *AC-1280* analogue lcd interface controller resolves to SXGA (1280 by 1024) at 75Hz, comes in single-board form and will drive 3.3V and 5V panels from all major makers. It provides full-screen image expansion for VGA, SVGA and XGA modes of operation, using 24-bit working to give millions of colours. There is auto-detection for sync-on-green inputs and the board takes interlaced and non-interlaced signal. Various accessories are offered and there are different housings available for desk-top, industrial use and panel mounting.
Digital View Ltd. Tel., 0181 2361112; fax, 0181 2361116; web, www.digitalview.com.
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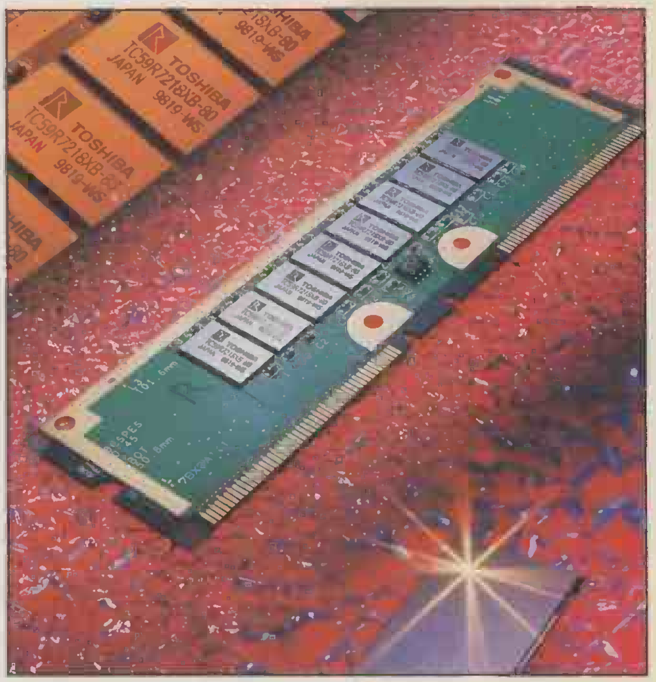

19in monitor. Panasonic's *SL90 ZenTan* crt monitor uses a 100° deflection tube, with the result that it takes up no more back-to-front space than a 15in type. Image quality is not compromised by the design, since the shorter gun-to-screen distance and the use of the company's specialised signal processor is claimed to actually improve performance. Use of a Crystal Pigment phosphor reduces ambient light reflection for better contrast, as does the screen coating. The monitor supports a number of power-saving standards, including Energy Star.
Panasonic UK Ltd. Tel., 0500 404041; web, www.panasonic.co.uk.
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Filters

Emc filters for machines. Steatite's *Sentinel* filters are designed to reduce conducted noise from electrical machinery and motors, in compliance with UL 1283 and EN133200 emc standards. Operating current is 6-180A and voltage ratings up to 520V. For currents to 25A, single-stage filtration is used; for currents between 36A and 180A, there are two-stage filters. All have versatile mounting flanges on the aluminium enclosures and the filters themselves are relatively small. As a result, they will often fit inside equipment control panels. Transient protection is available as an option.
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Direct Ram-bus dram. Toshiba offers working samples of the new generation of 64M and 72M rdrams, which provide a data transfer speed of 800MHz or 1.6Gb/s. Organisation is 4Mword by 18 bits with a 1kbyte page size. Refresh cycle is 8kcycle/32ms, voltage supply is 2.5V, power 2.2mW, or 260mW in standby and 10mW asleep.
Toshiba Electronics UK Ltd. Tel., 01276 694730; fax, 01276 694800.
Enq no 512

Hardware

Spot cooling fan. Micronel'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 straighter than is usual. Speed is 13000rev/min and operating voltage 12V or 24V.
Radiatron Components Ltd. Tel., 01784 439393; fax, 01784 477333.
Enq no 509

Please quote *"Electronics World"* when seeking further information

Small fan. Designed to cool small components such as individual semiconductors, the *Model 2008* by Shicoh 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 0.015m^3 per minute. It is designed to work from 70mA at 12V dc, but starts working at 7V and still turns at 2.5V. 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 0.05-0.1Ω/square in a 15μm thickness; and *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

Thin-film terminators. PCS terminators are capable of stable working at up to 10GHz and offer a vswr between 1.1 and 1.3. Stray inductance and capacitance are negligible and stability with temperature and time is down to 0.2%±0.5Ω following the cycling and load life tests. Power ratings in the series cover 125mW to 80W in 50Ω or 75Ω versions.
Rhopoint Components Ltd. Tel., 01883 717988; fax, 01883 712938; e-mail, components@rhopoint.co.uk
Enq no 520

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 *RISController* micros for communications systems. Available in speeds of 180, 200 and 250MHz, they are 3.3V devices tolerating 5V i/o, a jtag interface and an enhanced write mode to simplify support of synchronous dram. They are also compatible with Windows CE and other op. systems and deliver a 330-Dhrystone performance at 250MHz. Two-way set-associative caches have cache locking and the *RC64474* has a 33-bit interface bus to provide 64-bit processing and low-cost 32-bit memory. The *RC64475* uses 64 bits throughout to give over 1Gb/s bus bandwidth and 4Gb/s system bandwidth.
IDT Europe. Tel., 01372 363339; fax, 01372 378851.
Enq no 514

Photosensor. *UZE* is a new photoelectric sensor by Matsushita that operates from 12-240V dc or 24-240V ac. It offers sensing ranges of 30m for through-beam applications, 7m in the retro-reflective mode and 0.7m with diffused beam. The sensor is only 18 by 62 by 35mm in size; retro-reflective and diffuse versions have automatic cross-talk protection and may be mounted next to each other. Its case is IP66 sealed. There is also the option of dark-on or light-on switching. To ease alignment, some models have a red led light source.
Matsushita Automation Controls Ltd. Tel., 01908 231555; fax, 01908 231599; e-mail, info@macuk.co.uk; web, www.mac-europe.com.
Enq no 527

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 1Mb/s and 156Mb/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 FO7 PN type. The unit is contained in a standard 1-by-9 sip 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. *OCO1000* oscillators are stable to within 0.03ppm 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/year; both types provide Hcmos output. Frequencies lie in the range 10-26MHz, with specific frequencies at 10, 13, 16.384 and 26MHz. 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 0603, 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 0603, the range is 0.047μH-27μH at 50/2mA. All are shielded and are compatible with vapour-phase and ir reflow soldering.
BI Technologies Ltd. Tel., 0116 2781133; fax, 0116 2781199.
Enq no 517

Chip attenuators. Kamaya *RAC16* chip attenuators replace three resistors with the one chip, which measures 1.6mm 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

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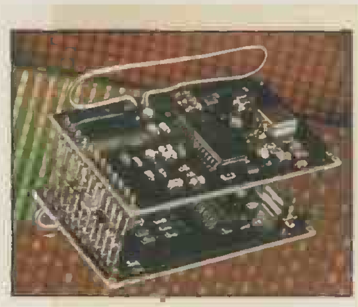
coefficients down to 40ppm/°C. Power ratings are 0.6W-6.8W in straight strips or preformed in 5mm to 25mm steps. Resistance values are 5% or 3%.
VTM (UK) Ltd. Tel., 01494 738600; fax, 01494 738610.
Enq no 519

Power semiconductors

Low R_{on} p-channel power mosfet. This SO-8 power mosfet by International Rectifier has the lowest on resistance of any available in this outline. The *IRF7210* is a 12V type with an on resistance of 7mΩ at a gate/source voltage of 4.5V, which is about the same as that quoted for n-channel devices and around half that previously achieved in SO-8.
International Rectifier. Tel., 01883 732020; fax, 01883 733410.
Enq no 521

Protection devices

Surge protection for Ericsson slics. *TISPPBL* programmable telecomms surge protectors by Power Innovations are for use with Ericsson's *PBL3xxx* 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 the 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



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 is also available as a complete system in a case.
RF Solutions Ltd. Tel., 01273 488880; fax, 01273 480661; e-mail icepic@pavilion.co.uk; web, www.rfsolutions.co.uk.
Enq no 538

Switches and relays

Rubber keypads. Keypads in rubber by Radiatron give a proper response to touch, choices of keystroke and travel 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 439393; 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 for the single changeover type, the twin and H-bridge types double the width. Switching capability is 20A/14V dc per contact. Three package styles are available. There is a single changeover with spdt operation, a dual changeover with a twin-coil relay with two spdt 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; web, www.mac-europe.com.
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 types in 8-pin packages and single-throw types in 4-pin or 6-pin packs, all in through-hole or surface-mounted versions. Also in the range are single-in-line types and i/o relays for use between logic and load.
ICE Electronics. Tel., 01480 496466; fax, 01480 498335.
Enq no 525

Sealed push-buttons. *ITW 49-59* series of momentary-action push-button switches are sealed to IP67. They are available with or without led status lighting and can be panel mounted with a series 16 microswitch or with flying leads. Maximum current is 10A and the action is spdt, double break to provide reliable dc switching. They come in round or square bezels in six colours and are made in PBT thermoplastic.
Townsend Coates Ltd. Tel., 0116 274 4488.
Enq no 526

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 6mm 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 small, mains-powered rotary tool turning at speeds variable from 8000 to 21000rev/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 makers. 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 rapid charge to 80%, followed by absorption for the other 20% and float to maintain the charge. High currents can be supplied to allow the battery to power a heavy load without going flat. The chargers will cope with badly regulated mains. When batteries are left on charge for a long period, the Hitec analyses battery state and gives whichever charge is needed. Various protection alarms are provided.
Merlin Equipment. Tel., 01491 824333; fax, 01491 824466.
Enq no 532

Universal bench supplies. From Kenwood comes the *PDS* range of

Microwave bulb. Primarc UV Technology offers the *Primarc* electrodeless bulb for ultraviolet curing in optical-fibre coating, cd manufacture, etc. It is excited by magnetron, ignition being by means of a low-pressure mercury lamp in the bulb, which irradiates the gas and ionises it. Warm-up takes a few seconds. Standard gas fill is mercury/gas, but halides may be added to modify the output.
Primarc UV Technology. tel., 01753 528678; fax, 01753 811678; e-mail, uv@primarc.com.
Enq no 529

Data/telemetry transceiver. A synthesised transceiver for use in portable and hand-held equipment to provide two-way radio communication, the Wood & Douglas *SX500* is approved to ETS 300 220. The unit mounts on a board and measures 60 by 40 by 17mm, works in the 400-500MHz band and provides up to 100mW output power from a 5.5V-15V supply. It has 128 frequencies, selected via the serial interface and programmed over 5MHz switching bandwidth without being realigned. Modulation may be digital or analogue. Other versions will soon be available to work in the 130-185MHz and 860-880MHz bands. A development kit is available.
Wood and Douglas Ltd. Tel., 0118 981 1444; fax, 0118 981 1567 email,info@woodanddouglas.co.uk; web,www.woodanddouglas.co.uk.
Enq no 539

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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 as that of large, fully linear 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 an internal GPIB, RS232 or analogue interface.
Kenwood UK Ltd. Tel., 01923 655291; fax, 01923 655297.
Enq no 533

Low drop-out regulators. Toko's *TK112xxB* 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 100nA. 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 *BXB* family of dc-to-dc converters is 150W series meant for use in communications and distributed power applications. These come in the industry-standard half-brick package and have the same footprint as *BXB50/75/100* 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

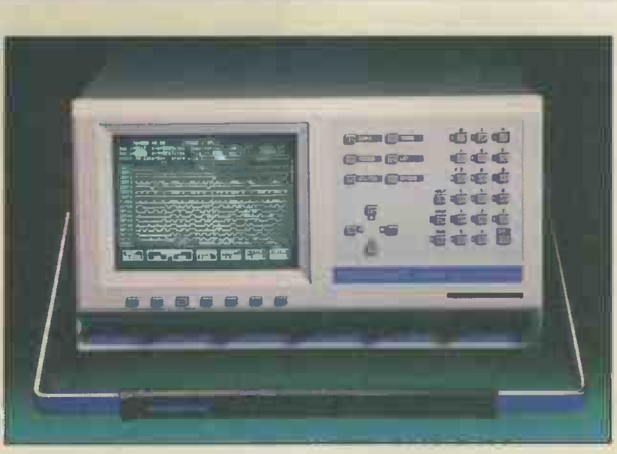
Multiple-supply controller. Cherry's *CS-51313* synchronous buck controller allows the generation of a number of different supply voltages to power computer motherboard core logic with just the one switching regulator. A 1% internal bandgap reference is taken to an output pin, where it may be used with 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, 001 503 615-8900; web, www.triquint.com.
Enq no 537

Test and measurement

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



80-channel logic analyser. Thurlby Thandar's *TA4000* logic analyser series is capable of asynchronous data capture at 400MHz with a memory depth of 8Kword. 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 Not-ed, the latter triggering on the absence of a word. All this goes at 50MHz without restriction or at 100MHz if a 20ns delay between steps can be tolerated. The instrument works as a timing analyser with a resolution of 2.5ns and the screen displays any 16 channels and a marker. Up to 512Kbyte of data card storage is available and there are RS232 and GPIB interfaces, with a Centronics for printing.
Thurlby Thandar Instruments Ltd. Tel., 01480 412451; fax, 01480 450409; e-mail, sales@ttinst.co.uk.
Enq no 540

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

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includes digital oscilloscopes, digital multimeters, arbitrary waveform generators, Fast Fourier analysers and serial data analysers. Advantages of virtual instruments in, for example, an oscilloscope, include faster set-up, fast sampling, deep memory buffering, multiple acquisition records, advanced triggering and small size.
National Instruments UK. Tel., 01635 572400; fax, 01635 524395; web, www.natinst.com/uk.
Enq no 540

COMPUTER AND DATA HANDLING

Computers

233MHz Pentium sbc. ICP's *NOVA-600* is a 233MHz single-board computer that complies with the Ampro/Motorola EBX specification, which is a non-backplane form for embedded boards. The processor supports MMX and PC/104-Plus (PCI-enhanced PC/104). It offers up to 128Mb of dram, 72Mb solid-state flash, four serial ports, an EPP/ECP parallel port, an Ultra DMA/33 enhanced PCI IDE interface, 10/100Mb/s Ethernet controller, floppy disk interface and muse and keyboard interfaces. There is also an lcd/crt display controller to handle a 36-bit lcd and 2Mbyte of video memory.
Wordsworth Technology. Tel., 01732 861000; fax, 01732 863747; e-mail, sales@wordsworth.co.uk; web, www.wordsworth.co.uk
Enq no 541

Data communications

Modem/audio card. Smart has announced its internal *Data/Fax Modem and Audio PCI Combo card*, which is said to be the first for oems and which meets V.90 and K56flex standards for 56K transmission speed. It is Soundblaster Pro-compatible. The card runs under Windows 98/95/NT and has power management for wake-up-on-ring and caller identification.
Smart Modular Technologies. Tel., 01908 234030; fax, 01908 234191; e-mail, infouk@smartm.com.
Enq no 541

Development and evaluation

MBX 860/821 development. Two development platforms for use with MBX compact *PowerPC 821/860* embedded computer boards are available from Crellon. One of them, *CMS-MBX-SDC*, is for software development and the other, the *CMS-MBX-HDC*, is for hardware. The *SDC* unit is based on a 5.25in half-height disk-drive chassis, its panel having leds to show power in Ethernet activity, while the rear has connectors for one serial port and a 10BaseT Ethernet port, further expansion being possible from the front panel. Hardware development is the province of the *HDC*, which has a 150W supply and space for a 3.5in drive and two 5.25in peripherals. The *MBX* is on top of the chassis to provide access to the links and connectors and allow a backplane to be fitted.
Crellon Microsystems. Tel., 01734 776161; fax, 01734 776095.
Enq no 542

Interfaces

Data security. *Compblock* by Adital is designed to prevent unauthorised access to computer data and, indeed, the computer itself. The unit connects between keyboard, screen and pc with many security screws, disarming the keyboard, mouse and screen when armed. An electronic key using a secure code allows access, up to eight keys for each *Compblock* being allowed. The keys may not be scanned to obtain the code and they need no batteries, although they can be cancelled and new ones issued. The unit automatically arms at switch-on and again when the user leaves the pc, so that no passwords or rebooting are needed.
Adital Ltd. Tel., 01803 844455; fax, 01803 846032.
Enq no 543

Mass storage

USB floppy drive. TEAC has a stand-alone 3.5in floppy disk drive that connects directly to the USB port of notebook or palmtop computers, avoiding the situation where small computers are sometimes without a drive or where the drive must be removed to allow the insertion of a cd-rom. Capacities supported are 720KB, 1.25MB and 1.44MB, transferring data at 250kb/s and

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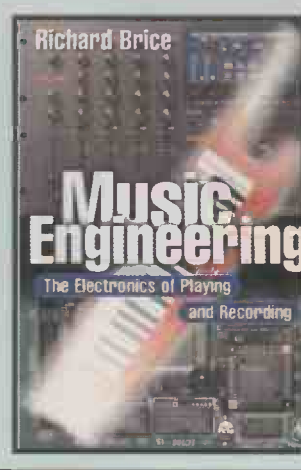

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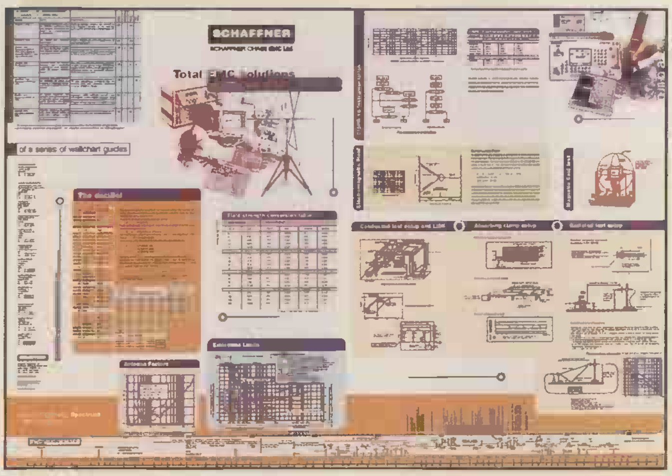

Posters

Free EMC 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

500kb/s. The drive complies with USB specification Rev.1.0 and may be used with Win 95, 98 and NT 5.0 up. Power is 500mA from 5V.
TEAC UK Ltd. Tel., 01923 225235; fax, 01923 236290.
Enq no 544

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

PUBLICATIONS

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@dial.pipex.com. ■
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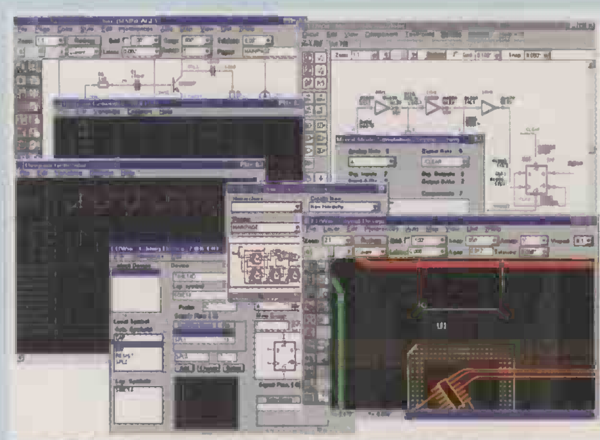

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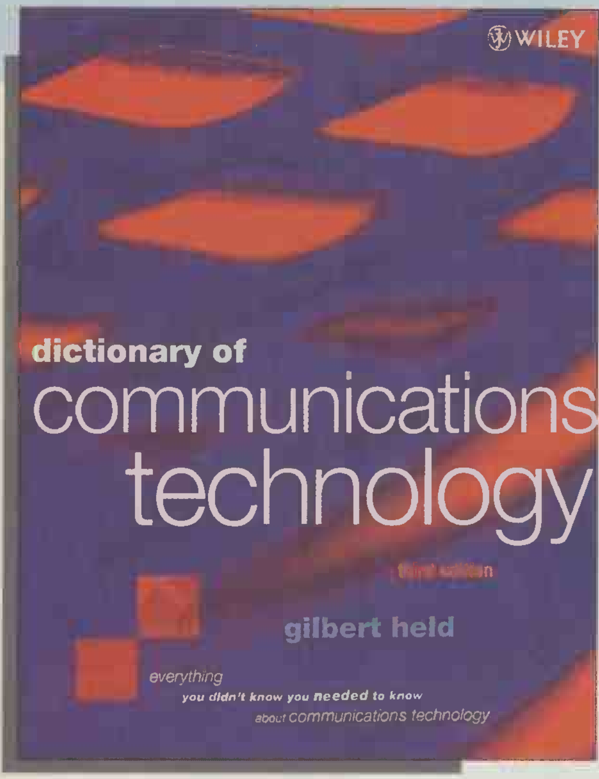

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concatenation 1. The linking of transmission channels or subnetworks end to end. 2. The linking of blocks of user data or protocol transmissions. 3. In fiber optic technology, the interconnection of two or more fibers into one continuous length

concentration Collection of data at an intermediate point from several low- and medium-speed lines for transmission across one high-speed line

concentrator A device used to divide a data channel into two or more channels of average lower speed. dynamically allocating space according to the demand in order to maximize data throughput at all times.

conditioned circuit A circuit that has been electrically altered to obtain the desired characteristics for voice and data transmission The reader is referred to the entries C-1 through C-8 and D-1 and D-2 for specific information on C-level and D-level conditioning.

conditioned loop A loop that has conditioning equipment, usually equalizers. attached to obtain a desired line characteristic, to facilitate voice or data transmission.

conditioning The "tuning" or addition of equipment to improve the transmission characteristics or quality of a leased voice grade line so that it meets specifications for data transmission. (See figure below.)

modem, multiport A device that combines a multiplexer and a modem allowing two or more DTEs to be connected to the same line Also split stream modem.

modem, quick turnaround A modem with minimal turnaround time when the line is used in a half-duplex mode. Also Quick Poll (QP), Fast Poll (FP).

modem, short haul Description of both line drivers and limited distance modems.

modem, wideband A modem designed to operate at speeds greater than those used with high-speed modems, such as 19.2 or 56 Kbps. Wideband modems will not operate over voice-grade circuits but require a wideband circuit.

Modem-7 Communications software program supporting the public-domain, X-modem, error-correcting file transfer protocol. This version of the X-modem has multifile transfer capability.

modem connect The name used in DNA for that class of communications links governed by industry standards for modem connection.

modem eliminator A device used to connect a local terminal and a computer port in lieu of the pair of modems that they would expect to connect to: allows DTE-to-DTE data and control signal connections otherwise not easily achieved by standard cables or connectors. Modified cables (crossover cables) or connectors (adapters) can also perform this function

modem operation characteristics See page 270.

modem pooling A feature of a PABX and other communications products that permits subscribers to be automatically or manually connected to a group of shared or "pooled" modems.

modem sharing unit A device that splits a signal among a cluster of terminals and allows them to share one modem.

modem substitution switch An external option that allows you to reroute your data through a "hot" spare (a modem that is already powered up) in the event the original modem fails.

moderator A participant who is in charge of a conference. A moderator is responsible for keeping the discussion on track, for alleviating fights, and for similar functions.

MODES Discrete optical waves that can propagate in optical waveguides. Whereas, in a single-mode fiber, only one mode, the fundamental mode, can propagate There are several hundred modes in a multimode fiber which differ in field pattern and propagation velocity (multimode dispersion). The upper limit to the number of modes is determined by the core diameter and numerical aperture of the waveguide.

Modified Chemical Vapor Deposition An AT&T Bell Laboratories-patented process that uses high temperatures to speed the manufacture of large quantities of fiber lightguide. The glass is made by allowing hot vapors to form a coating inside a tube of heated silica, which is later drawn into fiber Temperatures reach 4000 degrees F. (The melting point of steel is 2800 degrees F.)

Modified Final Judgment (MFJ) The 1982 Federal Court ruling that determined the rules governing the divestiture of the Bell Operating Companies from AT&T and other antitrust and deregulation issues. Presided over by Judge Harold Greene, as was the AT&T Antitrust settlement which the MFJ modified. Judge Greene continues his involvement in enforcing and interpreting the provisions of this settlement.

modular distribution accessories A term used to reference splitters, modular adapters and modular

SPEAKERS' CORNER

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.

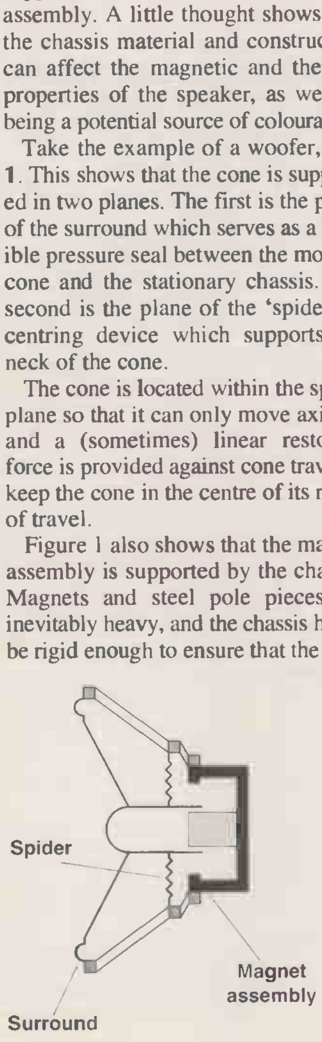

Fig. 1. Chassis locates surround, spider and magnet. It also protects against operational loads and transit shocks.

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 dissipates 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.

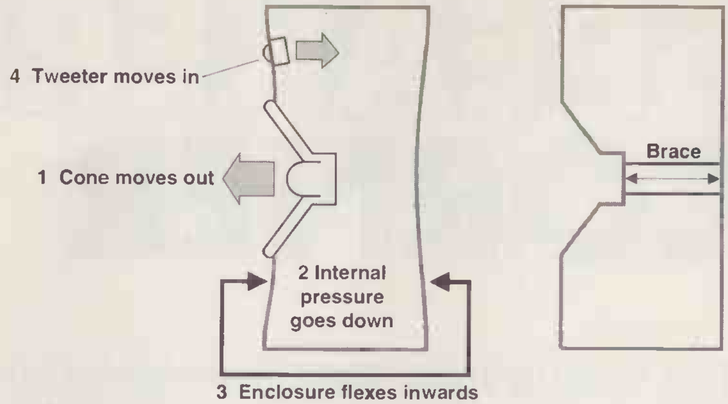

Fig. 2. An easy way of preventing 'woofer reaction' is to brace the back of the speaker against the back of the cabinet, as in b).

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 which are well within the scope of the home builder. Sand casting is, however, labour intensive and becomes uneconomic as quantity rises.

Casting may advantageously be taken further than just the chassis. 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 practicably 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. ■

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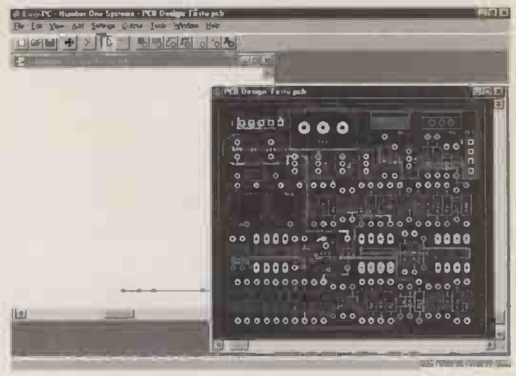

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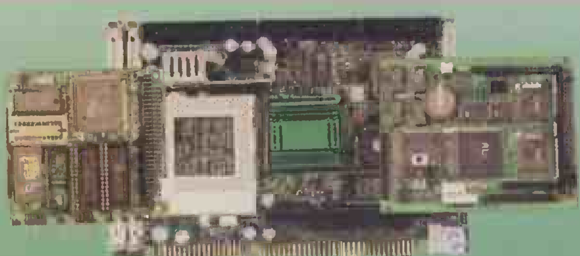

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Image portrayal

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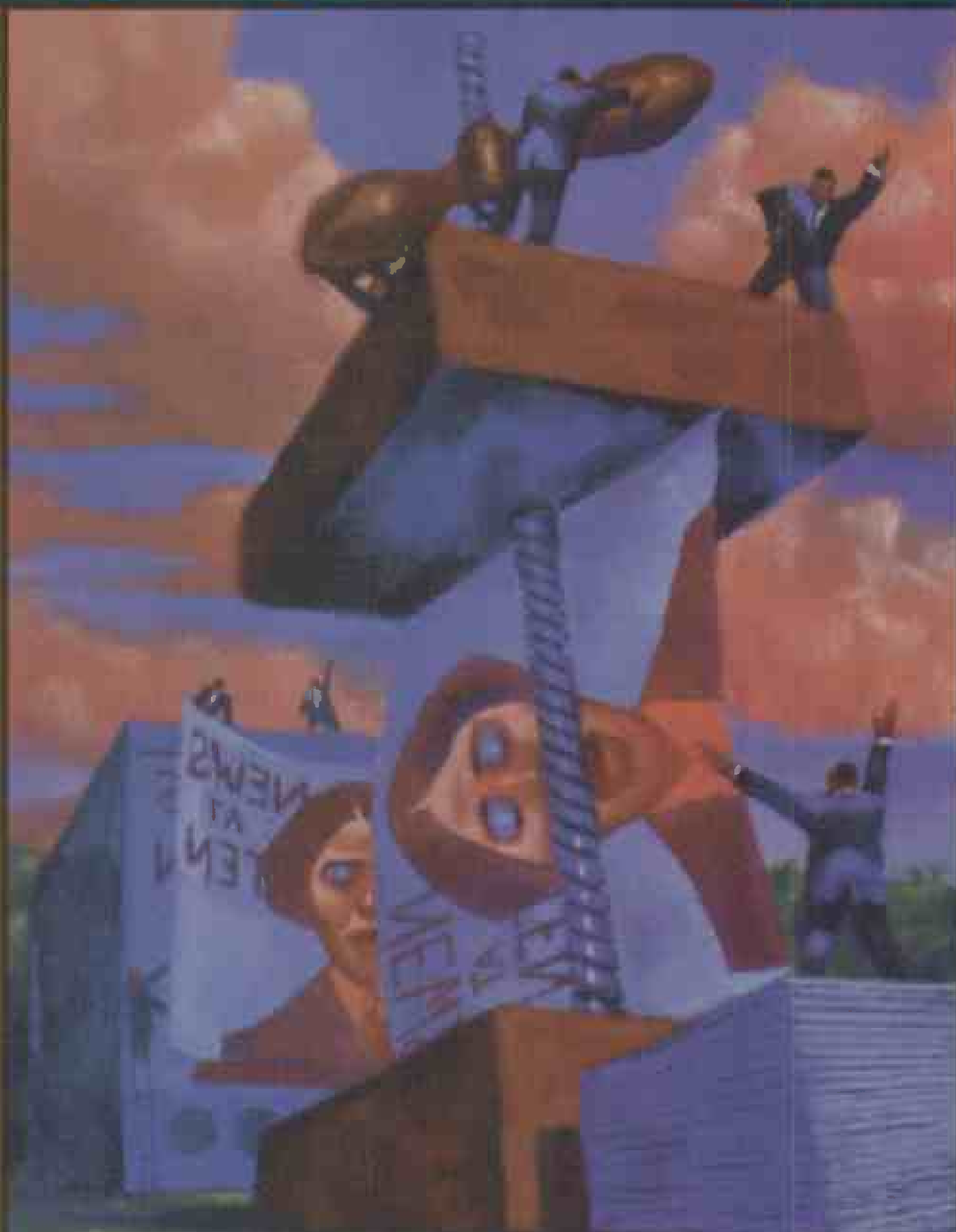
Technologies for image portrayal in computer graphics, film and television were once very different, but digital electronics is causing them to converge. Some features of the old technologies will remain useful. Others – among them interlacing – will be a hindrance, as John Watkinson explains in this second article.



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

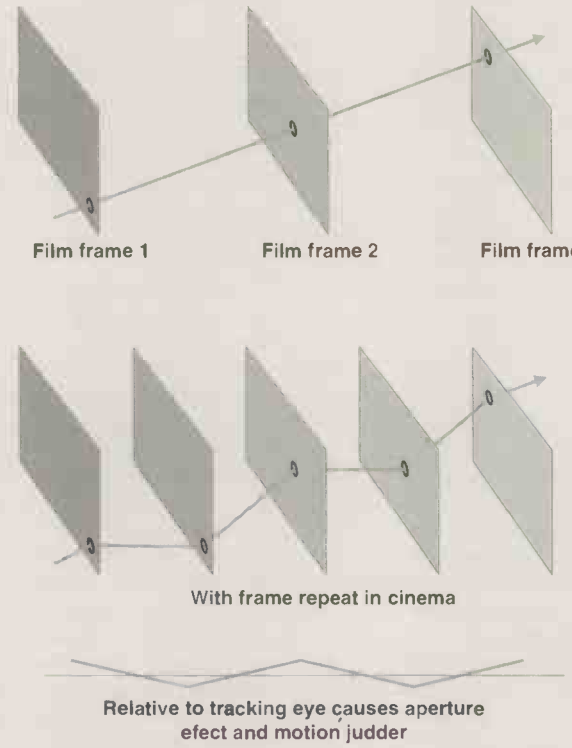


Fig. 1. Frame repeat damages optic flow axis.

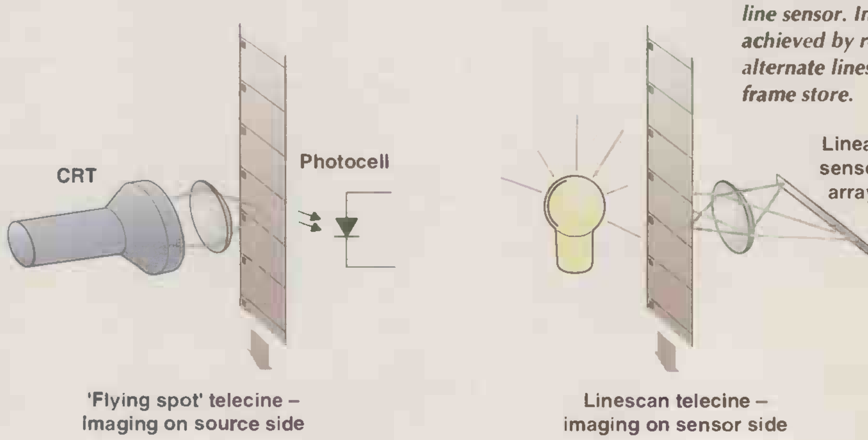


Fig. 2. Telecine basics. The 'flying-spot' telecine, a), uses a crt to develop a two-dimensionally scanned spot which is focussed onto the film. The vertical scan of the crt allows interlaced fields to be created in real time from steadily-moving film. In the more modern line-scan telecine, b), vertical 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.

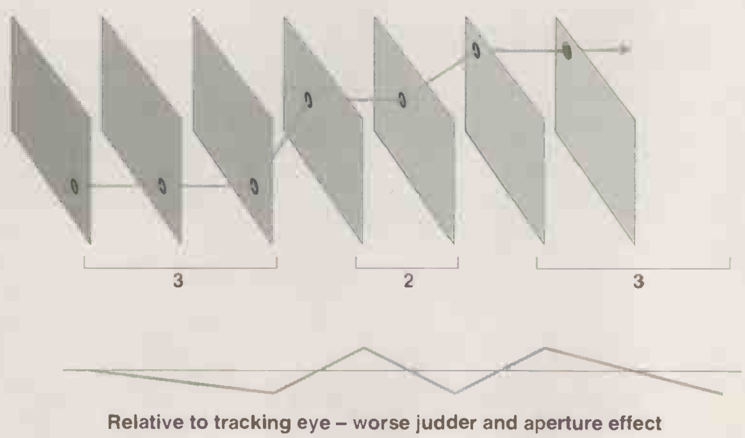


Fig. 3. To obtain 60Hz video from 24Hz film, a process called 3:2 pull-down is used. Resultant demolition of the optic flow axis causes judder.

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 interlace aliasing. Consequently a motion artifact of film has the result of concealing an interlace 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 convertor. 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 interlace 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 wide-screen 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 axisymmetrical. 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-axisymmetrical 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

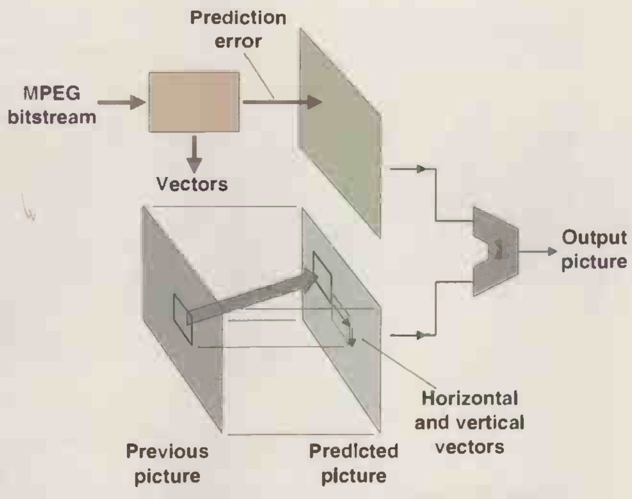


Fig. 4. MPEG achieves much of its compression by sending vectors to shift a previous picture so that it more closely resembles the current picture. A prediction error is sent to cancel the remaining small differences.

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 interlace. 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.

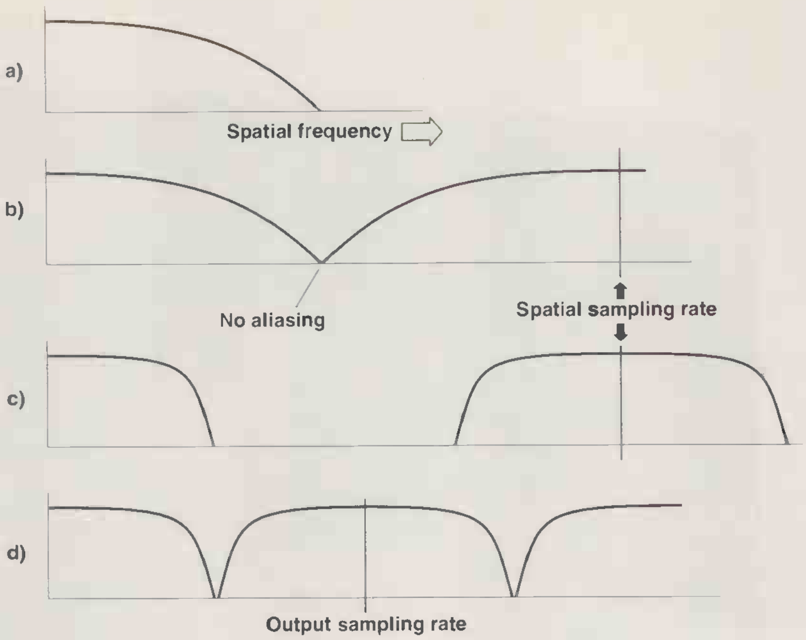


Fig. 5. Spatial oversampling. Modulation transfer function, or mtf, of camera plus sensor has gradual roll-off, a). In b), sampling at high spatial frequency avoids aliasing. In the digital domain, c), a low-pass filter restricts the spectrum. In b), the output sampling rate has dropped and the output has no aliasing or aperture effect.

Although oversampling has totally dominated digital audio because of its obvious merits, it is harder to use it in conventional television because of interlace. Interlace puts half the picture data at another time and reduces the performance of spatial resamplers. Once interlace 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 convertor 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 convertor is necessary, which increases the input picture rate by interpolation. Such an oversampling convertor 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. ■

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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'.

This engineering process started over twenty years ago and will continue for many years yet. Fully digital television, and digital scanning standards, will emerge when the flat-screen tv replaces the cathode-ray tube in our television sets. Then, analogue tv and all its trappings, such as PAL (or NTSC) coding, sync pulses, colour bursts and interlace, will be history.

That digital future, with our current analogue tv obsolete, will give us a new view of television's engineering history. The early years of mechanically-scanned television – viewed for decades with disdain – will then, I believe, sit alongside electronic analogue tv as an equally valid engineering solution to 'television'.

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Mechanically-scorned tv

Today though, most of us have accepted a view originating from the BBC back in the late thirties. We think of John Logie Baird's low-definition television system of the twenties and early thirties as somehow 'wrong', and of electronic television as being 'right'.

Part of this comes from 'technology arrogance'. In the sixties, the BBC[1] seriously questioned Baird's achievements because no part of his technology was in sixties' television systems. But, today, nothing directly of sixties' technology is in a nineties' consumer digital video camcorder – with its chip sensor, image stabilisation, digital autofocus, lcd, digital data recorder and computer interface.

We should neither revere nor ridicule historic technologies – they are merely the best solutions available at the time, **Fig. 1**.

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[2] 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

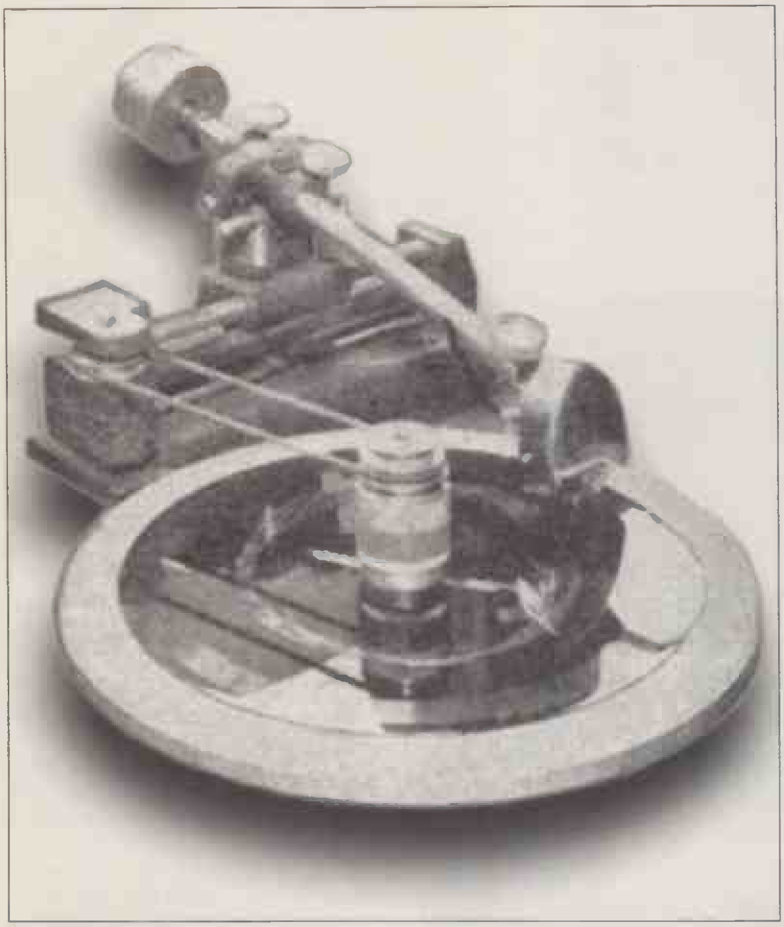

Fig. 2. One of the many consumer devices that recorded audio onto aluminium discs. On more than one occasion, machines such as this were used by viewers to record the video signal of the BBC's 30-line broadcasts.

Fig. 1. Mechanically-scanned television is in use today by the military. In airborne reconnaissance, the high-resolution television cameras on RAF Tornado GR1A aircraft use mirror-drum scanning. Coincidentally the aspect ratio is similar to that of Baird's 30-line standard. (from Crown Copyright original)

Fig. 3. With no clue as to date or authenticity, one of the discs has a hand-written message "Woman. Large Head". This unflattering message describes the main disc of Betty Bolton's BBC tv performance in the thirties.

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[3] and were encouraged by articles describing how to do it.[4]

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.** [5]

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.

Fig. 4. The mirror-drum camera of the thirties scanned the scene using a projected flying spot. The Nipkow camera disc of Baird's video recording experiments of the twenties used more traditional – but less efficient – lens-based imaging.

Fig. 5. Betty Bolton. The photo on the left and its simulated 30-line equivalent show Betty in 1929. The two pictures on the right have been restored off-disc. One shows the glint off Betty's hair and the other, her distinctive profile with kiss-curl and hair clasp.

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[6] and relative to a genuine 30-line re-make of a 1930 play[7], 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,[8] 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',[9] 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.

Fig. 6. An unknown male operatic singer. Details of his collar, tie and jacket show up well considering that the computer-restored sequence originated from a dictaphone quality audio recording.

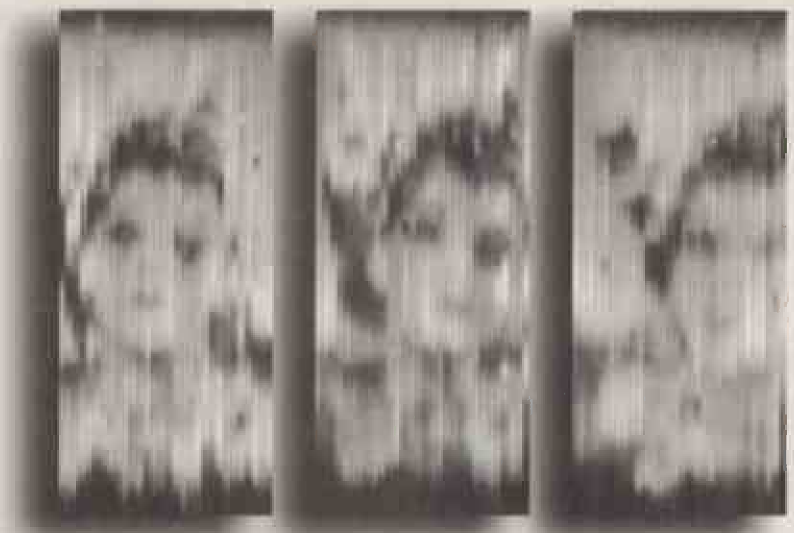

Fig. 7. An unknown female singer performs in silence through a rain of high disc-surface noise. On the right she is caught part-way through blowing a kiss at us.

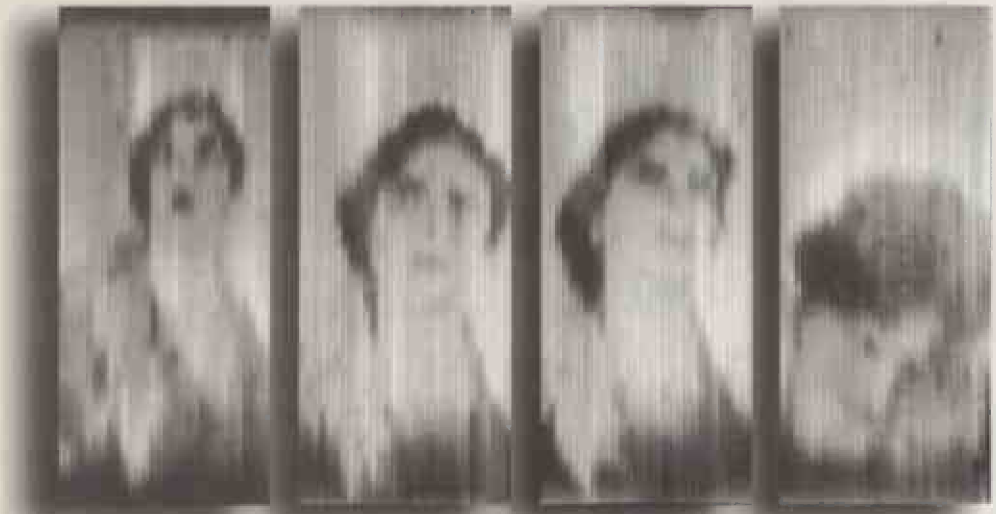

Fig. 8. Captured at 120rev/min, this female singer's performance is spread across three of the eleven separate recordings. They have been brought back together digitally as one long sequence.

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 –

Fig. 9. The 30-line video test disc manufactured and sold for seven shillings by the 'Major Radiovision Company' under F. Plew. The only recording of 30-line Television in the BBC's archives is 12PH 69197. Disappointingly, this turns out to be a poor copy of this 'Major Radiovision' disc.

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-drums.

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'.

Fig. 10. Animated binary images of the mid-twenties pre-dated Baird's successful demonstration in 1926. The Major Radiovision disc of 1934-5 has more in common with those early images than 'true' television.

Fig. 11. The time-base corrected image directly off-disc shown on the left suffers from 'ringing' at around 5kHz. On the right, signal processing has greatly reduced the distortion and the proper arc-scan pattern has been restored.

Fig. 12. A composite of most of the pictures from the 'Major Radiovision' test disc. The strange pattern at bottom right is a high frequency test pattern.

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[11], made in the same way as the 'Major Radiovision' disc but containing different subject matter. 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

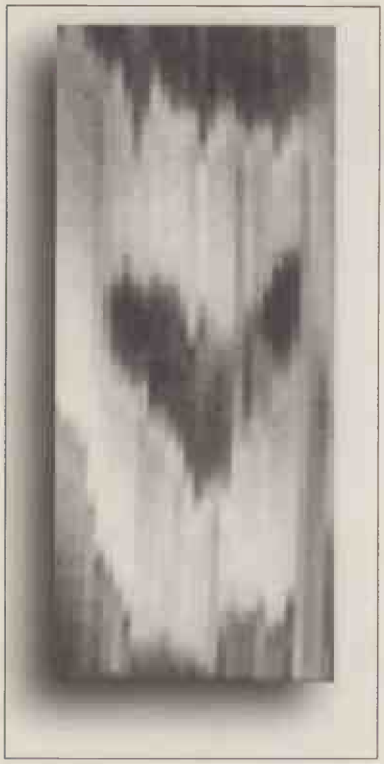

Fig. 13. Identical in every way but content to the 'Major Radiovision' 30-line test disc, a second disc contains test stills that are clear yet unrecognisable.

Fig. 14. John Logie Baird – Britain's foremost television pioneer, 1888-1946.

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[12] 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 and demonstrated the world's first practical solution to television.

Uniquely amongst the tv pioneers, Baird 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 – honourary Fellowship of the Royal Society of Edinburgh.[13] 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 Eliot 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. ■

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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."

DSP takes control

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."

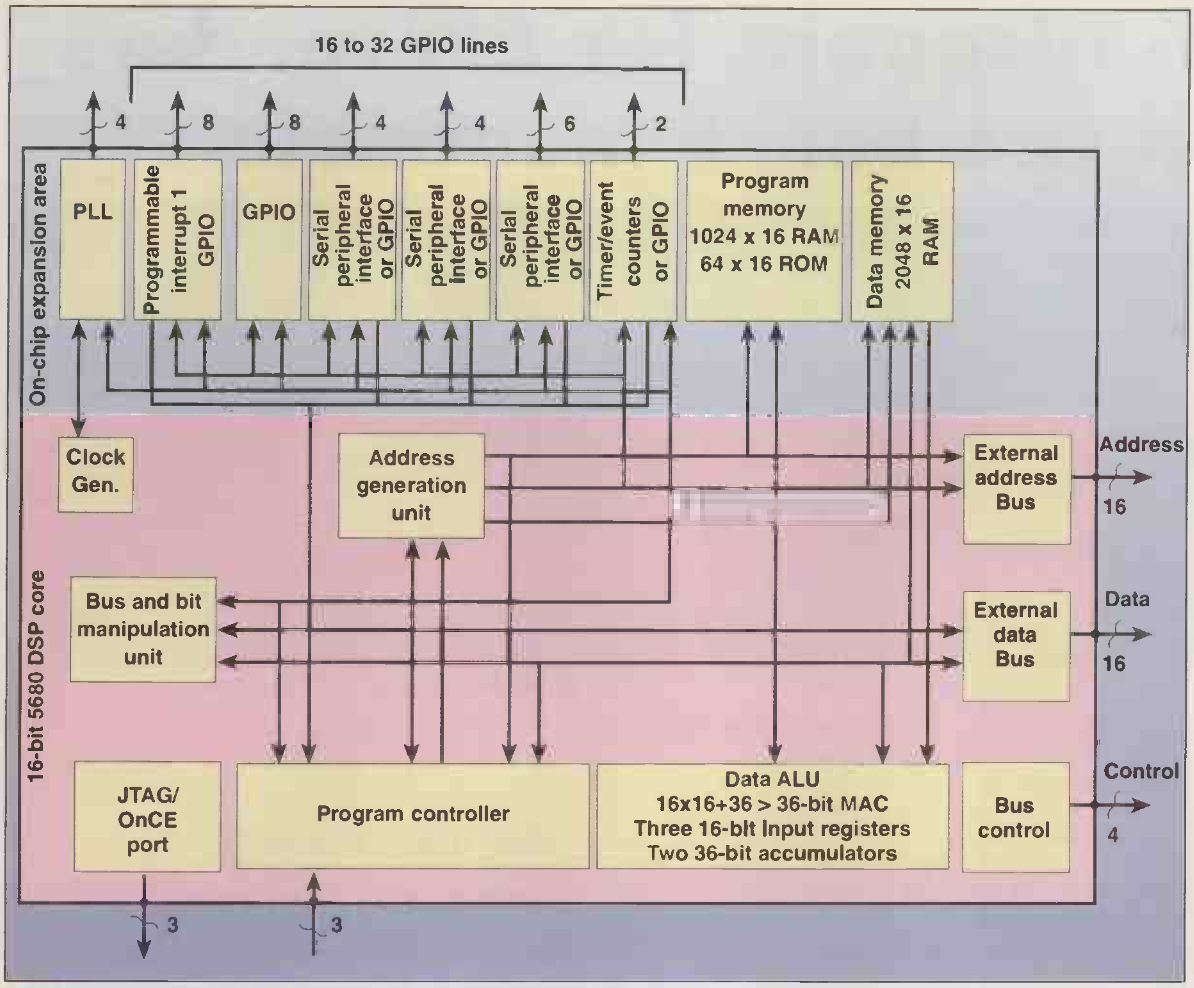
An example he cites is motor controllers, where TI, Analog Devices and Zilog already have dedicated dsp products. "This is a success. It was a pure microcontroller market which is now switching to medium performance dsps because the on-chip peripherals, pulse-width modulators and timers, focus the product 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



Peripherals are appearing on dsps, moving them on in the same way that they turned microprocessors into microcontrollers.

functions like battery management and operating the human interface, or you can use a single dsp part that does everything."

This 'everything' includes storing its own program code, as Zilog's range includes one-time programmable and mask-rom on-chip memory options, but not yet flash. "We will have flash memory in the second quarter of next year," said Provis.

He sees two other ways to make dsps more attractive.

One is to offer them in small packages. Zilog has one in a 44-pin PLCC; the other is to keep development tool costs low. Provis said, "Our lowest cost in-circuit emulator is $99. This is a full function emulator, the only thing that it hasn't got is a hardware trace."

Motorola's *56800* family, currently at 35Mips and mapped to 100Mips in 2000, is another with multiple microcontroller-like peripherals laying claim to a similar range to Zilog's.

Power consumption is also important, not only in portable equipment, but as a way of reduced fixed and recurring costs in mains-powered installations.

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. ■

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DC current	: 4mA,40,400,10A Accy 0.7%
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Resistance	: 400,4k,40,400,4M, 40M Accy 0.6%
Capacitance	: 4nF,40,400,4uF,40uF
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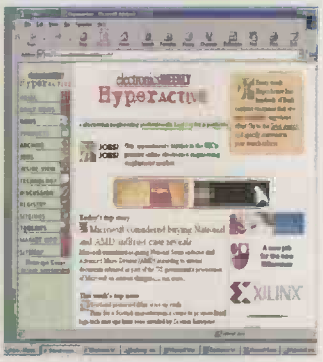

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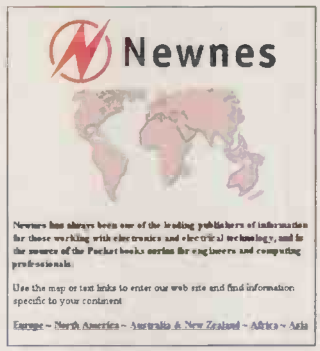

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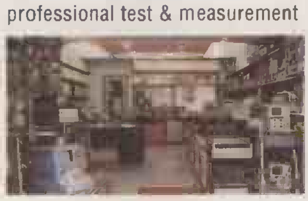

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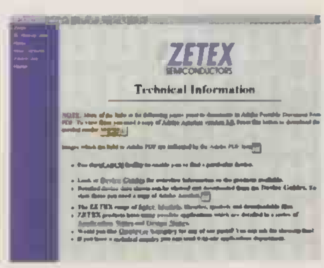

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Ref: AJ97EWd98

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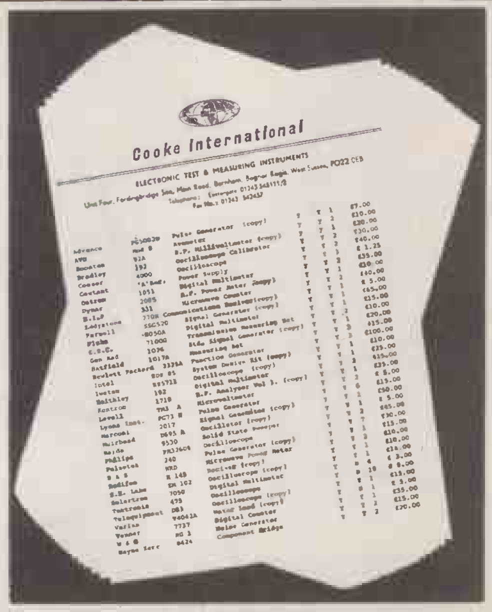

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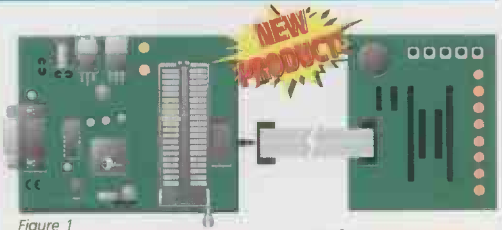

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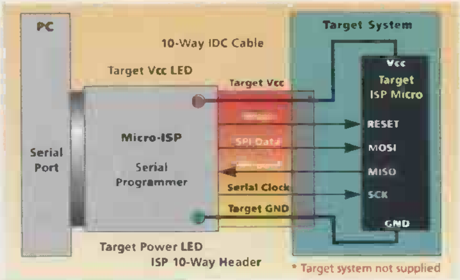

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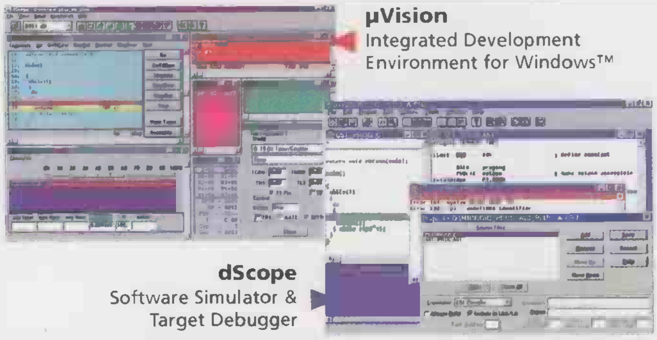

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