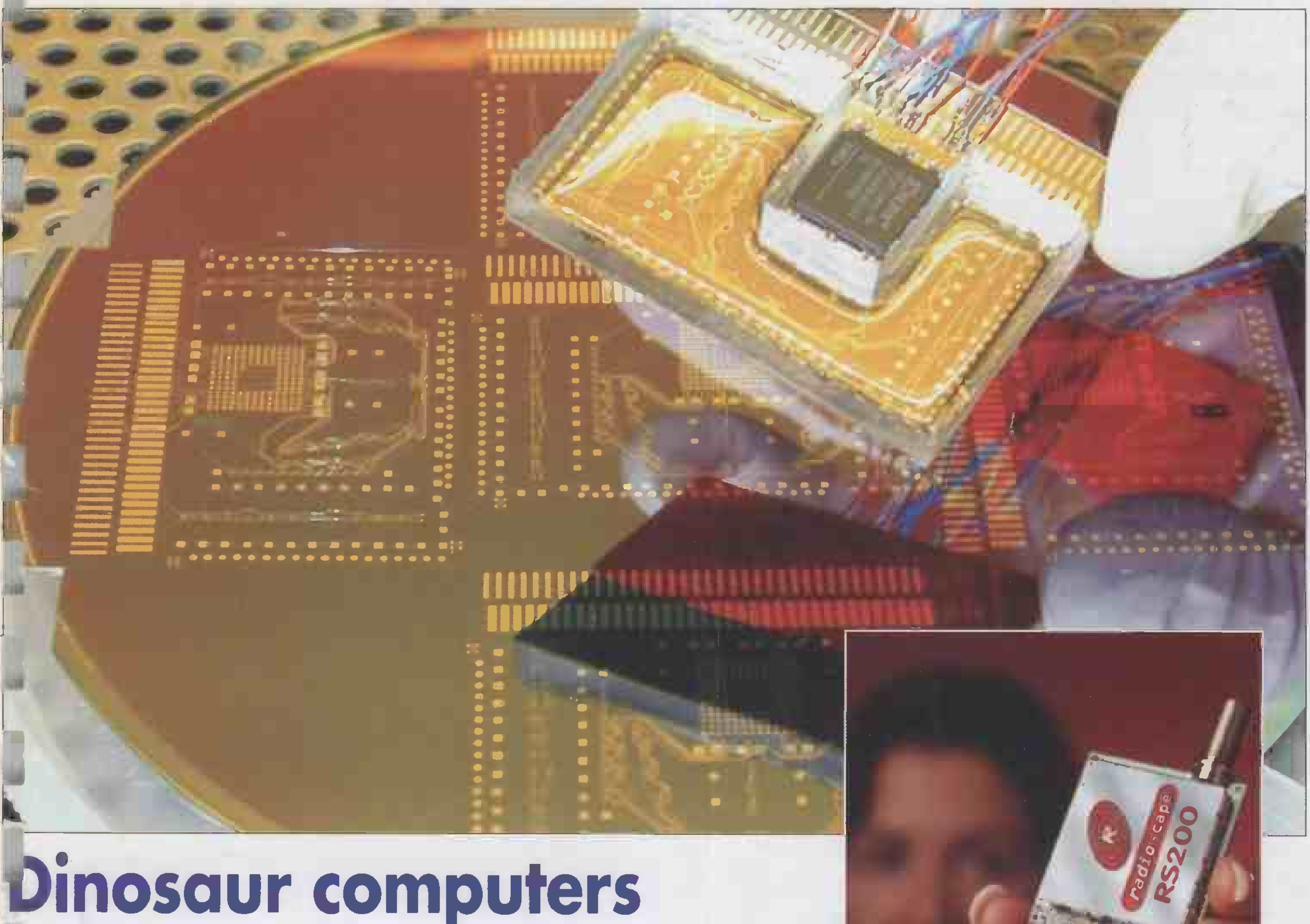
Electronics World's renowned news section starts on page 5

ELECTRONICS WORLD

JUNE 2003 £3.25

DRM reception on a PC



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Hewlett Packard 54600A - 100MHz – 2 channel	£675
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Meguro - MSA 4901 - 30MHz - Spec Anaylser	£600
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Tek 496 (9KHz-1.8GHz)	£2500

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Hewlett Packard 8922M + 83220E	£2000
Marconi 2955	£1250
Marconi 2955A	£1750
Marconi 2955B/60B	£3500
Marconi 2955R	£1995
Motorola R2600B	£2500
Racal 6111 (GSM)	£1250
Racal 6115 (GSM)	£1750
Racal 6103 (opts1, 2)	£5000
Rohde & Schwarz SMFP2	£1500
Rohde & Schwarz CMT 90 (2GHz) DECT	£3995
Rohde & Schwarz CMTA 94 (GSM)	£4500
Schlumberger Stabilock 4015	£3250
Schlumberger Stabilock 4031	£2750
Schlumberger Stabilock 4040	£1300
Wavetek 4103 (GSM 900) Mobile phone tester	£1500

MISCELLANEOUS

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Panasonic VP 8175A Sig. Gen. (100KHz-140MHz) AM/FM/CW	as new £650
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Wavetek 178 Function generator (50MHz)	£750
Wayne Kerr 3245 - Precision Inductance Analyser	£1850
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Failure rewarded

As response was favourable on his last article – you'll find another tome from the controversial Mr. Catt on page 47. Over half of you thought his EMC article interesting – a fact borne out by some of the letters this month. I will try and publish the rest next month.

Part of his article suggests that some parts of British industry have a different agenda to that of a 'normal' company that is inventing, manufacturing and selling innovative and cutting edge products. One of the companies he singles out for criticism is Marconi. I'd also like to add some of my own experiences with this company – who I contracted for a few years ago. I too was amazed that some of the engineering department I was in seemed more hell bent on wasting time than actually making the product work. In fact, my immediate boss had his workstation so arranged as not to be seen by any passing management and in fact him neither. I've never actually met anyone before who would sleep during the day and what little he did do was to make the whole engineering process as slow as possible by throwing huge spanners into the works at every opportunity. I would also point out that this was a civilian project. So it was no surprise to me when Lord Simpson departed after having frittered away Lord Weinstock's war chest in a very short space of time. In fact he turned the cash mountain into a £3bn debt. And then, he and his cohort - John Mayo -reportedly walked away with about £4m between them. Which just goes to show that failure is handsomely rewarded in the UK.

As a trial this month (and to try and move a large backlog) we've dropped the type size in the 'letters' section which enables us to get more in. I'll keep it like this unless lots of you complain. I also know some good shops that do magnifying glasses.

A number of readers (Tony Calligari for one) have suggested a free ads section. Well, we've decided to do it – so if you let me have your 'small ads' as soon as I've got enough for half a page – I'll publish it. I'm envisaging the ads will be for information requests, swaps and magazine back numbers etc. Obviously, I will not take any commercial advertising. To maximise space I would like to limit the contact details to phone numbers and email addresses.

I'm also pleased to announce the winner of the Modular Technology DAB card is Kevin Hudson from Barking, Essex, UK. We will be sending the prize to you very shortly. Thanks to all who entered and to Modular Technology who sponsored the prize.

Phil Reed

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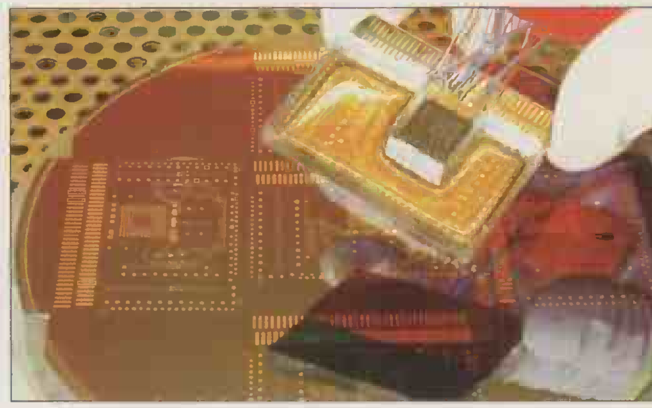


A team of scientists from Germany has produced a chip that collects and transports biomolecules and mixes them with reagents.

Developed by the Fraunhofer Institute, digital inputs to the chip control the movement of the molecules through the device. Such a chip could be used to experiment with DNA.

"We utilise polymer particles whose diameter can be less than one micrometer. DNA sections or other biomolecules adhere to their surface," said Dr. Patrick Wagler from the Institute.

The device uses a technique called microfluidics. Channels are formed in a plastic layer on top of a silicon chip. Low voltage signals are used to transport molecules and reagents under the chip's surface.

"Current applications for dynamic, programmable biomodules lie primarily in the fields of molecular diagnostics and evolutionary biotechnology," said Professor John McCaskill, head of the Fraunhofer Research Unit for Biomolecular Information Processing.

The Institute added: "It's now possible to couple the location of the molecule with switching and controlling mechanisms. Under the microscope, researchers can visually track the path of the biomolecules, marked with a fluorescent dye, and influence their flow with the push of a button."

Broadband rates to double

Broadband Internet subscribers are being given a boost by recent announcements from rivals BT and Telewest, both of which are set to double their top data rates.

BT is planning to offer a 1Mbit/s ADSL service, while Telewest is also doubling its cable rate to reach 2Mbit/s.

"Not every Internet user will want a 2Mbit connection, but we're now well on the way to offering a menu of broadband services to suit different requirements," said Gavin Patterson, MD of Telewest Broadband.

Telewest reckons that ten per cent of its 300,000 customers now subscribe to its top rate 1Mbit/s service. the firm has started a 1,500 user trial, while a nationwide rollout is expected by the year's end.

BT, meanwhile, has a similar timescale for its 1Mbit/s ADSL offering, with an autumn trial and wider rollout before Christmas.

In addition BT hopes to widen the area served by ADSL. The current 512kbit/s rate is set by the distance of the subscriber from the exchange due to attenuation over the copper wires.

The acceptable loss over the wires is 55dB, giving a maximum distance of 5.5km. By increasing the loss to 60dB the distance is raised to 6km, which BT said should bring a further 600,000 households into ADSL's reach.

ADSL is by far the most popular way to access the Internet at broadband rates, with some 750,000 subscribers. BT is in the process of upgrading another 206 exchanges and 102 more sites are being considered.

In the meantime, BT is expanding its trial of SDDL, or symmetric digital subscriber line, from 22 to 100 exchanges. Aimed at business users this can give 2Mbit/s data rates or more in both directions.

Service provider Easynet is already offering SDSL following the unbundling of BT exchanges. A 2Mbit/s bi-directional service costs under £6,000 a year, far cheaper than a leased line.

Duracell makes cell to back-up NiMH prismatics

Duracell is to introduce a prismatic 1.5V alkaline cell for portable audio devices.

Called LP1, it is 67x17x6mm and will run a typical solid state audio player (90mW) for over 20 hours, said the company.

It is a similar size to the rectangular NiMH cell found frequently in audio players. "Currently, over 200 digital audio devices can be powered by LP1 batteries," said Duracell, which expects equipment makers to start designing devices particularly for its new cell.

The cells will be available in the UK later in 2003.

Duracell LP1 cell.

Nominal Voltage:	1.5V
Voltage Range:	0.8 - 1.5V
Nominal Impedance:	0.12Ω @ 1kHz
Average Weight:	25g
Volume:	6.8cm^3
Typical Capacity:	1.5Ah @ 100mA to 0.8V
Operating Temp. Range:	−20 to 54ºC
ANSI name:	Not yet decided
IEC name:	LP1867

More information at www.duracell.com/prismatics/techLP1.htm

Lords push for national centre

A House of Lord's debate on the future of the UK's chip industry has once again called for a national centre of excellence in IC design.

"The UK should support a single national research institute similar to IMEC in Flanders," said Liberal Democrat Lord Methuen.

Conservative peer Lord Freeman said: "There is clear evidence in the report that in the field of information technology we are not doing enough in this country to exploit innovative ideas."

In March, *EW* reported on Chips for Everything, the House of Lords report that concluded the country needs a national centre of excellence to maintain our world standing.

"The research we are developing could be of vast advantage," said Lord Wade of Chorlton, chairman of the sub-committee that wrote the report. "There is an opportunity for the UK to take a more important role in the future."

In his response Lord Sainsbury, minister for science, said: "It is clear that if the UK is to remain at the forefront of research in innovative systems, it will need a significant and sustained investment in order to maintain a critical mass of activity."

Scotland's Alba Centre, located in Livingston, and its Institute for System Level Integration could form the cornerstone of Government plans to expand the UK's electronics industry.

The ISLI, noted Lord Methuen, "goes some way to meeting the criteria for a national institute".

Lord Sainsbury described the ISLI as "a great success", adding: "In preparing the Government's response to the report we shall take into account the Institute for System Level Integration experience and build that into our plans."

His comments were welcomed by Scottish Enterprise, which oversees the Alba Centre.

The Government will now consider its plans, and Lord Sainsbury is to decide whether any future institute should be "a virtual or a single centre or a major programme and what exactly it should cover".

The Chips for Everything report also called for UK research in CMOS technology to be refocused towards processor and architecture design.

Lord Wade argued chip manufacturing is too expensive and risky, especially considering a fab plant can cost upwards of £1bn.

"Current research funding is the wrong way around," he said. Lots of funding goes into CMOS, but that doesn't bring back revenue into the UK, as we have almost no CMOS manufacturing."

However, Lord Sainsbury said basic silicon research is still valid. "At the moment there is considerable commercial exploitation of microtechnology in silicon, not as integrated circuits but as microscale or nanoscale sensors and instruments."

The Government is still expected to issue a formal document in reponse to the select committee report.

Semelab's transistors are tougher

In response to requests from customers, UK transistor maker Semelab has introduced a new lead option on TO257 and TO220 high-reliability metal can packages.

"Not only do the new leads enable customers to pre-form and cut them with ease, but because they are pure copper they also reduce AC losses," said Damien Connolly, aerospace product support engineer for Semelab.

Prior to this, its high current hermetic packages used copper cored leads that enter the package through a glass seal.

The leads are substantial - 1mm diameter for TO220M - and very stiff. This means that stresses in forming and bending the leads are transmitted to the glass seal, which if incorrectly handled, can be weakened.

Shocks and vibration experienced by the device in service are likewise transmitted to the seal.

The new leads use a two-part construction: a standard rigid lead passes through the glass seal, and this is welded to a softer copper just outside the seal.

www.semelab.com

Osram enters the high-power LED market

Osram Opto Semiconductors has announced a range of 1W LEDs in miniature packages.

Proposed applications for Golden Dragon, as the range is called, include reverse lamps for vehicles, traffic signal lighting and display backlighting for LCDs.

The packages are surface mount and fit in a 1.8x6x7mm volume - four times more space-efficient than Osram's Power TOPLEDs offerings.

Operating temperatures is –40 to +100°C, and Osram claims frequent temperature changes "up to 1,000 times" and tropical climates can be withstood.

Optical efficiency is 20 lm/W and "lifetime can exceed 20,000 hours, depending on operating and ambient conditions".

Initial red and yellow Golden Dragon prototypes are available now, and volume production will begin mid-2003. White versions are currently in development and will be available as prototypes within the next two quarters.

www.osram-os.com

Italian vehicle designer Pininfarina presented this at the Geneva Car Show. Behind the low-profile headlights are high-brightness LEDs from Osram.

DAB firm launches module

Digital audio broadcasting firm RadioScape has developed a module for DAB reception that could cut receiver development time.
The RS200 module needs only a power supply, case, speakers, antenna, display and buttons to complete a DAB receiver.

"The DAB industry, particularly in the UK, is poised to take off," said John Hall, RadioScape's chief executive. "The broadcasting infrastructure is in place. Interesting and different content is being broadcast that people want to hear. The last piece is the availability of reasonably priced receivers in large volumes."

At the core of the module is Texas Instruments DRE200 chip which conforms to the Eureka147 standard. This software programmed system means the module can also receive FM broadcasts, without the need for extra components.

The module has a supply voltage of 5V and measures 110 x 44 x 15mm, making it suitable for handheld, battery powered systems as well as mains powered units. Prices start at around £25 depending on volume. "RadioScape is in a pivotal position to drive the DAB industry by enabling high volumes of DAB receivers to reach the market at low consumer prices starting from under £100," said Hall.

Options for the software include radio data stream (RDS), integral MP3 player software, infra red remote control, electronic programme guide display with record capability, and I^2C for external control of a CD transport.

"Our Software defined radio approach gives us great flexibility to adapt and customise very quickly because we can easily load new features and standards onto the DRE200 in the form of software that runs on the DSP," said Hall.

There are more than 250 DAB stations currently transmitting in the UK. Potential sales of DAB receivers still outstrip supply in the UK.

Silicon gets hard

Researchers in the US have found that nanospheres made from silicon are some of the hardest materials yet discovered.

Spheres from 100 nanometres down to 40 nanometres in diameter have hardnesses in between sapphire and diamond, around four times harder than conventional silicon.

The spheres can withstand pressures of 20 to 50 gigapascals and could be used to toughen up micro-electromechanical systems (MEMS).

By way of example, stainless steel has a hardness of 1 gigapascal, while diamond is 90 gigapascals.

The work was carried out at the University of Minnesota. Next up to test is silicon carbide, which should approach diamond for hardness.

The small size of the spheres, with perhaps 40 million atoms, allows the tests to be simulated on computer. The simulated results agreed well with experimental tests.

"Better designs for these sorts of nanocomposites will be based on a better understanding of what goes into them," said William Gerberich, professor of chemical engineering and materials science. "These measurements make it possible to pursue a bottom-up approach to materials design from a mechanical perspective."

LCDs go large

Samsung Electronics demonstrated a 54-inch liquid crystal display recently. The display has 6.2 million pixels and can display images at 60 frames/s.

Viewing angle is claimed to be 170 degrees, while contrast ratio is 800:1, said the firm.

Last year Samsung was the biggest supplier of large area LCDs (panels bigger than 10 inches), closely followed by LG.Philips LCD.

Both firms shipped over $3bn worth of displays with the market in total worth over $17bn. Some 18 million large area panels were shipped during 2002.

The top manufacturers are now producing LCDs from glass panels measuring 1,250 x 1,100mm, so called fifth generation production lines.

Oxfordshire display firm gets more cash and additional management.

Harwell-based Printable Field Emitters (PFE) has raised another round of venture capital funding.

"Existing investors 3i, Quester and NIF have continued their support for PFE by investing a further UK £2.5m," said company CEO Tom Holzel.

Along with the funding comes two new faces.

"3i have also enabled us to strengthen our team by introducing former Philips displays chief Bill Freer to the board as non-executive chairman and Ivor Thomas as chief operating officer," said Holzel.

PFE has now raised UK £10m from the venture capital community and has also had awards from the DTI's SMART scheme and EU's Fifth Framework IST programme.

The company is working on a field-emission display technology, which it aims to licence to big screen TV makers as a wide-viewing-angle alternative to LCD and long-life competitor to plasma panels.

Freer is already a displays industry insider, having recently managed Philips Mobile Display Systems in Hong Kong for five years. "PFE has probably the only cathode technology which has the stability and long life for use in flat, thin consumer TVs, at a cost approaching that of conventional CRT type TVs," he said.

Thomas is the first full-time financial officer for PFE; needed as the company's intellectual property licensing activities start to take off.

http://www.pfe-ltd.com

Noise turns up the heat

Yale University scientists are developing a thermometer based around thermal shot noise through a Josephson junction.

The device will be as accurate as existing primary standards and able to cover from millikelvin to the room temperature range. This is significant as currently multiple standards are needed to cover the temperature scale from close to absolute zero to hundreds of kelvin.

The technique relies on the change in forward and reverse tunnelling through a junction. As temperature increases the shot noise with zero potential across the junction also rises. The system can be calibrated to measure temperature.

Weather database hits 1Pbyte

The US National Center for Atmospheric Research database has reached 1Pbyte (petabyte=10^{15}, making it one of the largest databases ever assembled.

Information in the archive comes from various sources, including satellite and archaeology, and covers the atmosphere, ocean, and land from prehistoric times to now, as well as holding predictions to 2100 and beyond.

The database crossed the terabyte boundary in 1986, taking 16 years to reach its current size. Now accelerating data acquisition and production will swell it to 11Pbyte in 2005.

Data is stored using a StorageTek automated tape system which includes robot arms to swap tapes in and out of tape drives.

www.storagetek.com

Bluetooth gets shot in arm

Bluetooth, the short range wireless comms standard, has been given a boost by the unveiling of a single chip system from US firm Silicon Wave.

The SiW3000 device combines baseband and radio functions, which until now have been implemented in separate chips - the radio sometimes using discretes.

The radio portion of the circuit is a 2.4GHz direct conversion transceiver while the baseband side uses an ARM7TDMI processor.

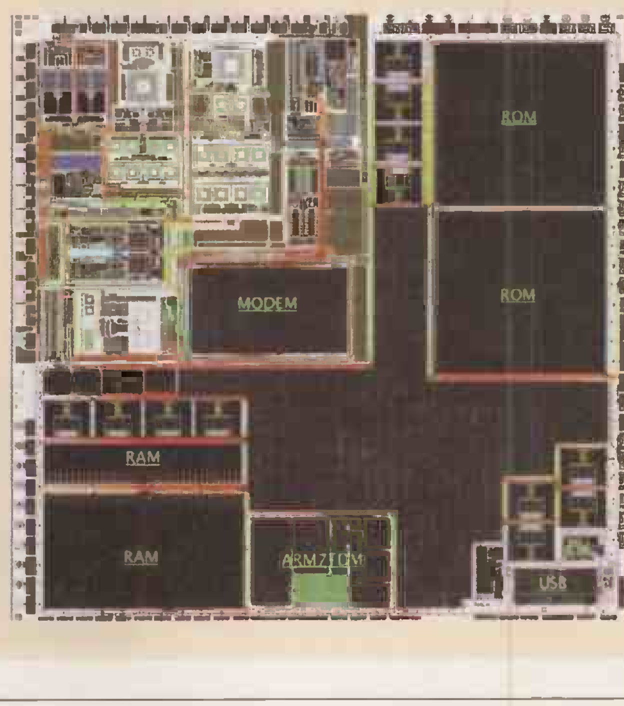
Protocol software runs in ROM to reduce cost, although an external flash memory chip could be used for custom software versions.

Jarvis Tou, head of product development at the firm, said the chip was the first to build a direct conversion radio using 0.18µm process technology.

Using a single chip keeps the cost low enough for mobile phone applications. Without the antenna, said Tou, "this is targeting a sub-$4 bill-of-materials".

Cost is further reduced by cutting out the balun filter or switch between the radio and antenna, he said.

Silicon Wave is partly owned by Intel and Intersil, the wireless-LAN specialist.




WELDEX 2003
WELDCOME. 11-14 November 2003
National Exhibition Centre Birmingham, UK
11-14/NOVEMBER/03

Waveguide halves optical cost

Defence research firm Qinetiq has developed an all-optical network technology using a hollow waveguide (HWG) structure. The format could halve the cost of optical circuits.

Rather than using a conventional 'rib' or 'ridge' structure, Qinetiq's technique uses a 'hollow' guide. The HWG is etched from a flat substrate, while performance can be improved by coating the walls. A lid is attached to complete the guide.

This layout simplifies placing components on a substrate, said Malvern-based Qinetiq. Rib structures take light from the component through air and into the waveguide. As the HWG is air, one of the interfaces is removed.

In addition, devices such as MEMS and multi-mode interference devices could be created at the same time as the waveguide.

Methanol fuel cell generates 12W for five hours

Toshiba has announced what it claims is the world's first prototype of a small size direct methanol fuel cell (DMFC) for portable PCs.

The cell currently produces an average output of 12W and maximum output of 20W - and can give approximately five hours of operation with a single cartridge of fuel.

Methanol delivers power most efficiently in a fuel cell at 3 to 6 per cent concentration in water - needing a large tank.

Performance:
12W average power, 20W maximum.
11V
275 x 75 x 40mm (825cc)
900g
5hr operation on 50cc of methanol, 10 hours with 100cc.
Cartridge:
50cc: 72g 33 x 65 x 35mm
100cc: 120g 50 x 65 x 35m

Toshiba has cut size using concentrated methanol diluted by water produced as a by-product of the power generation process. With this, the tank can be 90 per cent smaller - hence five hours operation on 50cc of fuel.

The company has produced miniature ancillary components to go with its cell. The envelope includes interface and electric circuits for power delivery; sensors for methanol concentration, liquid level and remaining methanol; a low-power liquid pump; air pumps; and a DC-DC converter for the pumps.

Bio fuel cell drinks vodka

Scientists at Saint Louis University have developed a long-lasting bio fuel cell that can be recharged with drinking alcohol.

Bio fuel cells use enzymes rather than metal catalysts to extract electricity from chemicals and have been studied for nearly half a century without practical cells emerging.

"The only items consumed in a bio fuel cell are the fuel and oxygen from the air," said Dr Shelley Minteer, assistant professor of chemistry at Saint Louis. "Given the proper environment, an enzyme should last for long periods of time. It is creating this environment in a fuel cell that researchers have struggled with for years."

Enzymes are extremely sensitive to changes in pH and temperature, and even slight departures from ideal conditions can lead to inactivation.

The typical approach to keeping enzymes operating has been to immobilise them by attaching them to the electrodes, but they still tend to decay too quickly to be useful.

Minteer and her colleagues coated the electrodes with a polymer that has specially tailored pores for enzymes to live in. "The enzyme has everything it needs to function for a very long period of time, instead of denaturing like it normally would," said Minteer. "Other bio fuel cell studies have had lifetimes of a few days; our technique allows for enzyme activity over several weeks with no significant power decay. With proper optimisation, these bio fuel cells could last up to a month without recharging."

Minteer's 5cm square cells run on ethanol. She has tested between 30 and 50 of them - and successfully run cells on vodka, gin, white wine and flat beer. "The fuel cell didn't like carbonation," said Minteer.

Watch or phone?

Japan's leading telecoms firm, NTT DoCoMo, is to start selling a wristwatch mobile phone.
Dubbed Wristomo, the watch is waterproof and includes an email service, transferring data at up to 64kbit/s, and can access basic websites.
When unfolded, the watch measures 172 x 40 x 19mm and weighs 113grams. NTT claims two hours talk time. Unfortunately the phone only works on Japan's PHS networks.

An Electronic BALUN

A lot of domestic or 'semi-pro' audio equipment has only unbalanced outputs. This can cause problems when interfacing to a balanced system. This is especially true for 'cost effective' radio microphones and Ian Hickman analyses the problem, provides some practical answers and explains the complexities of balanced circuits in simple terms, into the bargain.

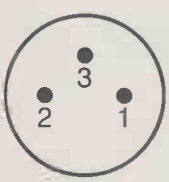


Fig. 1. View on the pins of an XLR balanced circuit plug. Pin 1 is ground; pins 2 and 3, balanced signal.

In many halls, lecture theatres and anywhere 'broadcast', the interface to the sound reinforcement system is a balanced input, typically via an XLR socket or PO jack. While a microphone or microphones may be provided at the lectern or rostrum, many speakers seem to like to go walkabout whilst delivering their talk or lecture - perhaps to point out something on a screen where slides are being shown. In the process, some speakers even commit the heinous sin of actually turning their back on the audience! The result is that, all too often, those seated at the rear of the auditorium cannot hear some, or even a large part, of the proceedings. The solution is to 'wire the speaker for sound' with the aid of a radio mike. But radio microphones typically provide an unbalanced output from the receiver unit. They frequently come with an unbalanced to balanced adaptor, consisting of a mono ¼" jack socket wired to a three pin XLR plug. This arrangement may prove unsatisfactory, due to introducing hum problems. This is because the output is still asymmetrical, or unbalanced – and just wired to 'look' like a balanced signal.

The interface

Figure 1 shows a view on the pins of an XLR plug, as commonly used with balanced circuits. Pin 1 is ground and may or may not be connected to the body of the plug, depending on the particular make. Pins 2 and 3 are the balanced signal input pins. In an unbalanced to balanced BSA (between series adaptor), pins 1 and 3 are connected together, the input thus being applied to the remaining balanced signal line. Using a balanced input in this way may prove unsatisfactory for a number of reasons, the most pressing being, often, the introduction of an unacceptable level of mains hum. The circuit described below is designed to circumvent this problem.

'Balun' is the term used to describe a balanced to unbalanced transformer. These are commonly used to interface between equipment and a telephone line, and are also widely used in RF (radio frequency) circuits, as described in Ref.1. Being passive devices, they may be used either way round, to transfer a balanced input signal to an unbalanced output, or vice versa, providing galvanic isolation in the process. Using techniques such as a symmetrical balanced winding and an interwinding screen, they can provide a large CMRR (common mode rejection ratio, a concept explained below). However, a suitable

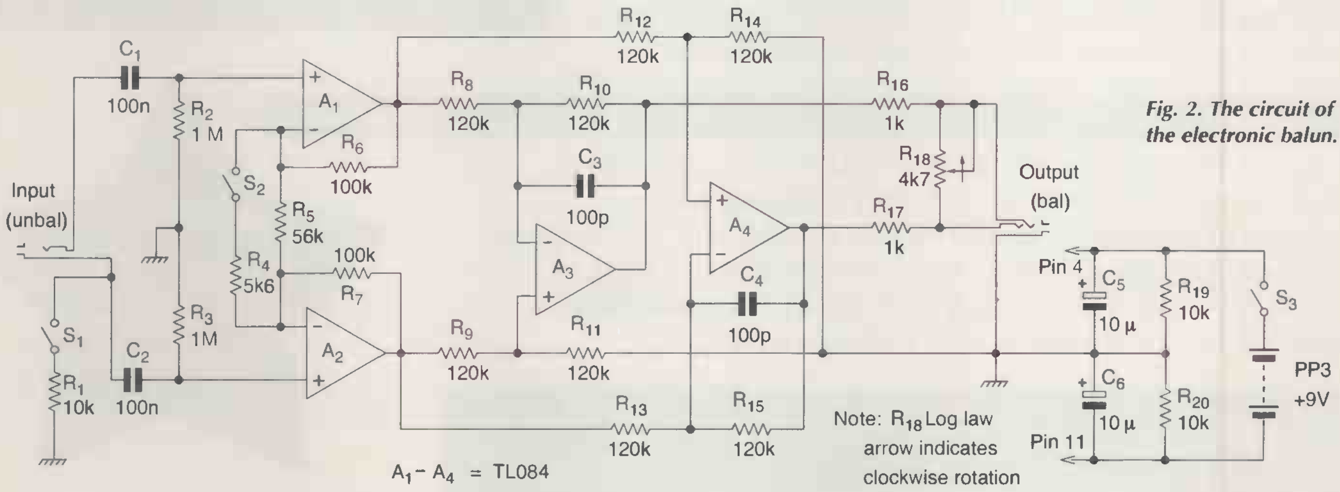


Fig. 2. The circuit of the electronic balun.

design to cover the whole audio band can result in an expensive component and hum pickup from stray mains magnetic fields linking the transformer core may still result in hum in the output. So the circuit described here is an electronic (active) balun, designed to accept an unbalanced signal and provide a balanced output. As such, of course, it is unidirectional and cannot be used in reverse, to interface an unbalanced input to a balanced output. In addition to translating from an unbalanced circuit to a balanced one, it is designed to reject any unwanted common mode signal, such as mains hum. It also provides a comprehensive level adjustment facility, ranging from attenuation to a gain of up to 37dB.

The circuit

Figure 2 shows the circuit of the electronic balun, as it finished up after several modifications as the result of experience in its use. The gain of A_1 and A_2, set by R_5 - R_7, is approximately +14dB, or about +34dB if switch S2 is closed. As A_3 and A_4 operate at unity gain, these are also the overall nominal gain figures to each of the balanced output lines for the completed unit. Thus the nominal maximum gain, unbalanced input to balanced output, is +20 or +40dB. Other values may be arranged, by appropriate modification of R_4 and R_5.

Since the output of any radio mike which may be connected to the circuit cannot be relied upon to be d.c. free, blocking capacitors C_1 and C_2 are included. This necessitates the inclusion of d.c. return resistors R_2 and R_3, to bias A_1 and A_2 in the middle of their common mode input range. A_1, A_2 and A_3 are clearly just an instrumentation amplifier identical to **Fig. B**, its ground referenced output being applied to R_{15}.

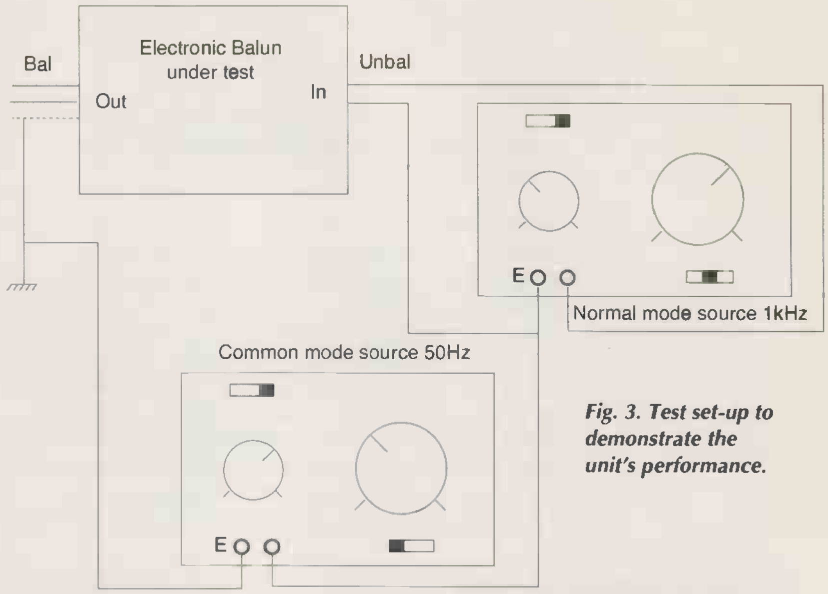


Fig. 3. Test set-up to demonstrate the unit's performance.

A_1, A_2 and A_4 also form an instrumentation amplifier, the output of which is applied to R_{17}. The signals applied to R_{16} and R_{17} are in antiphase and thus represent a ground-centred balanced output. Potentiometer R_{18} provides a continuously variable gain control, from zero output up to a maximum of 3dB below the nominal gain.

Signals "bal" and "unbal"

In a two-wire circuit, if the voltage at every instant on one line is equal in magnitude but opposite in sign to that on the other line, both being measured with respect to ground, the circuit is carrying a perfectly balanced signal. **Fig. A.** shows, on the left, a vector diagram of a slightly unbalanced signal, say a 1kHz 200mV (nominal) peak sinewave. Assume the voltage on one line is 101mV, and on the other 99mV; the difference has been exaggerated for clarity. On the right is shown how this can be alternatively represented as the sum of a 200mV perfectly balanced (normal mode) signal and a 1mV completely unbalanced (common mode) signal, i.e. one where the voltage on the two lines is identical. The 'degree of balance' is then said to be 46dB, that being the relative magnitude of the signals.

In this example, the unbalanced component is in phase with the signal on one of the lines, but in other cases it might not be. If it were in quadrature, the amplitude of the two signals would be equal, but one would be advanced in phase and the other retarded, by $\tan^{-1}$ (1/200) or 0.005 radians. Thus the signals on the two lines would not be in antiphase, but separated instead by (π - 0.01) radians. In the more general case, the unbalanced component could be at any phase angle relative to the balanced.

In the most general case of all, it could be at a completely different frequency, for example the mains distribution frequency of 50 or 60Hz, a common problem. A circuit which provides 60dB less gain to a common mode signal than to a normal mode signal is said to have a CMRR (common mode rejection ratio) of 60dB. Various nomenclatures are used to describe balanced and unbalanced voltages; for example the audio designer of valve output transformers would talk of 'push-pull' and 'push-push' components. The op-amp designer talks of 'normal mode' and 'common mode', while telephone engineers talk of 'transverse' and 'longitudinal' components (UK) or 'metallic' and 'to ground' voltages (USA).

Balanced circuits are traditionally used for telephony. The last dozen yards from a telegraph pole to a house was often a line with two spaced wires with a nominal characteristic impedance of 600Ω, though often now replaced by a twin core cable. Other impedances encountered in balanced circuits are 135Ω, 140Ω, 200Ω, 900Ω and, in a few countries, 1200Ω. The source supplying a balanced signal may be 'floating' or centre-tapped to ground. In the former case, e.g. the isolated output winding of a balun, the degree of balance of the signal will be determined by strays, mainly the capacitive ones, both in the source itself and in the circuit to which it is connected. In the centre-tapped case, the balance will be virtually perfect, unless the circuit to which the signal is connected is far from ideal. Similarly, the circuit to which a balanced signal is delivered may also be either floating or centre-tapped to ground. In addition, it may be 'terminating', i.e. presenting a load equal to the signal's characteristic impedance such as 600Ω, or 'bridging' (high impedance), as in a measuring instrument such as a psophometer, designed to tap across a circuit in use, without affecting it. Such a balanced transmission system, in addition to conveying the intended balanced signal, may present the receive end with an unwanted longitudinal or common mode signal. Equipments are designed to accept the former, and reject the latter.

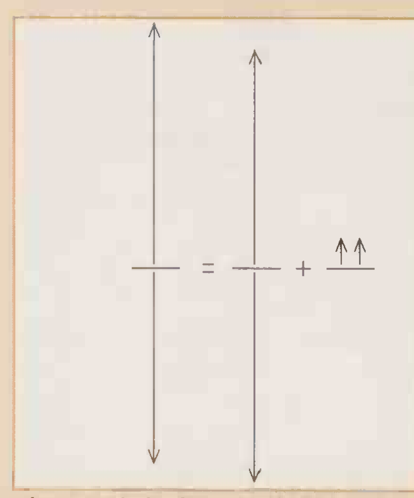


Fig. A. Analysis of an imperfectly balanced signal.

The circuit is powered by a 9V PP3 battery, a decoupled centre voltage being supplied by resistors R_{19}, R_{20} and capacitors C_5, C_6.

In operation

A test set-up was arranged, as in **Fig. 3.** To avoid complications with possible earth loops, the two audio frequency generators were battery operated types. They produced a small wanted 1kHz triangular wave riding on a large 50Hz sinewave as shown in **Fig. 4a.** Also shown is one of the balanced output lines from the unit, with R_{18} set for maximum output. It can be seen that the signal has been amplified whilst the rejection of the common mode component is virtually complete. In **Fig. 5.** the common mode source has been removed and the negative line (supply plug outer) of a plug-top power supply connected to the E terminal of the signal source instead. The plug top power supply was part of an Audio-Technica radio microphone, model ATW. The large common mode component is still almost, although not entirely, rejected. The coupling mechanism between the plug-top's mains input and its output is not entirely clear, but appears to be due to internal capacitive coupling. It is common on plug-top supplies to find a plastic 'earth pin' on the standard BS1363 ring main plug arrangement, but the Audio-Technica unit has a proper brass earth pin.

The unit has also been successfully used with a Ross radio microphone, model RWM101. This unit can be powered either by a 6V plug-top power supply, or internal batteries. Its signal output is via an RCA phono socket and hence, of course, like the Audio-Technica unit, is unbalanced.

With other equipments, the common mode supply

The ins and outs of CMRR

Figure B shows a typical instrumentation amplifier schematic. It responds to the normal mode input, while, ideally, completely rejecting any accompanying common mode signal. It may be realised with three separate op-amps, three sections of a quad op-amp, or as a dedicated 'instrumentation amplifier'. The latter often comes with the option of selectable gain, by strapping various pins. A long established example is the Analog Devices AD524, which offers pin programmable gains of 1, 10, 100, and 1000, a CMRR of 120dB (at gain G = 1000), low noise, low non-linearity, low offset and drift voltages and a gain bandwidth product of 25MHz.

When designing a balanced input to unbalanced output amplifier with three op-amps, there are some interesting points to observe in order to achieve the optimum performance. Consider first, the right-hand op-amp A_3. This will convert a balanced input to a single-ended or unbalanced output, with unity gain if R_3 - R_6 are all equal. Thus –1V at the output of A_1 and +1V at the output of A_2 will result in +2V at the output of A_3. But zero output will result from a common mode input signal - assuming that the CMRR of the op-amp is infinite. Whilst infinite is a little much to hope for, most op-amps provide a CMRR of at least 60dB. For example, the long established and deservedly popular TL08xC series of commercial grade op-amps typically provide a CMRR of 86dB, with a minimum of 70dB, or 75dB minimum for the premium grades. This means that in practice, the CMRR actually achieved will be set by the tolerance of the resistors R_3 - R_6.

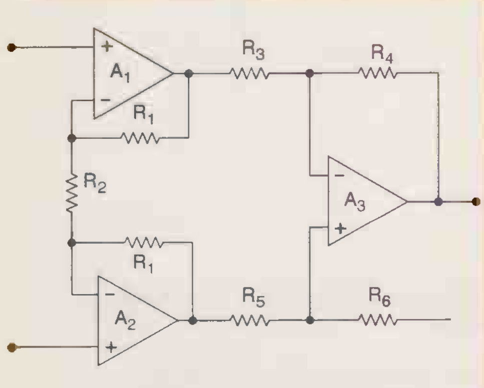


Fig. B. Basic instrumentation amplifier.

I long ago settled on 1% tolerance for my stock resistors, at a time when the price differential between 1% and 5% types had become really quite small. The worst case gain error to balanced inputs, and CMRR to common mode inputs will result when all four resistors are on their 1% limit, in various arrangements. However, such an eventuality is exceedingly unlikely. A reasonable guide to the sort of errors which may be encountered in practice can be arrived at by assuming three of the resistors to have 0% tolerance, and the fourth to be on the 1% limit. On this basis, the errors are given in **Table 1**, for various gains.

The CMRR is defined as the excess of normal mode gain over common mode gain. It can be seen that at low gains, reducing the gain by 6dB reduces the CMRR by only 3dB, whilst at higher and higher gains, for the one resistor on 1% tolerance case considered, the CMRR becomes asymptotic to (40 + G)dB, where G is the nominal gain. The real worst case is when all four resistors R_3 - R_6 are at the 1% tolerance limit. There are two cases to consider. In the first, R_3 and R_5 are both +1% and R_4 and R_6 both –1%, or vice versa. As the bridge formed by the four resistors is still balanced, common mode signals are completely rejected. However, the gain error is ±0.174dB. If however R_3 and R_6 are both +1% and R_4 and R_5 both –1%, or vice versa, the gain error is halved to ±0.087 dB, and the CMRR is 33.9dB.

Now consider the input stage, A_1 and A_2. For a balanced input, the gain of each, with respect to ground, is $(R_1 + R_2/2)/(R_2/2)$, so the gain, balanced input to balanced output, is $(2R_1 + R_2)/R_2$ or $2R_1/R_2 + 1$. By making R_1 large compared to R_2, the gain to balanced inputs, i.e. the normal mode gain G, will be also be large. But however large G, the gain to common mode signals is always just unity, as both amplifiers then operate as simple buffer stages. Thus the CMRR of the input stage, defined as above, is simply G.

The consequence of this is that, for a given required overall gain from the balanced input to the unbalanced output at A_3, it pays to raise as much of the gain as possible in the input stage. For, as Table 1 shows, reducing the gain of A_3 from x2 to x1 will reduce its CMRR by some 3dB, while increasing the gain of the input stage by a factor of two, will increase its CMRR by 6dB, a net overall CMRR gain of 3dB. In principle, it could be advantageous to operate A_3 at less than unity gain, but the bandwidth of the system may then be inadequate, due to the finite gain-bandwidth product of A_1 and A_2, and the maximum available peak to peak output from A_3 will also be reduced.

Table 1

Nominol goin	x0.5	x1	x2	x5	x10
In decibels	–6	0	6	14	20
Goin error dB	0.049	0.022	0.014	0.007	0.004
Common mode goin	–49.5	–46	–43.5	–41.6	–40.8dB
CMRR	43.5	46	49.5	55.6	60.8dB

component could conceivably be even larger, exceeding the common mode supply range of the op-amp. In the case of the TL084c, this extends typically from 3V above V–, up to V+, or worst case to within 4V of either supply rail. Whilst a second PP3 battery could easily be accommodated in the case used, clearly, a more modern quad op-amp type, with rail to rail input common mode range, would be a better choice for this application.

However, another option exists and this is the purpose of R_1 and S_1. Closing S_1 provides a 'static drain path' for any hum voltage on the earthy line of a radio mike's power supply. Such a voltage will obviously come from a high impedance and there is clearly something wrong if it doesn't! On the other hand, R_1 reduces the common mode voltage to small proportions, while avoiding any possible hum loop due to a direct connection to the output earth of the electronic balun and thence to the input of the sound reinforcement system.

Construction

The unit was constructed in a small aluminium box, the finished unit being shown in **Fig. 6.** The balanced output was not via a stereo jack socket as shown in the circuit diagram, but via twin screened leads, terminated in a stereo ¼" jack plug and a stereo ¼" jack socket to XLR plug BSA. The metal outer of the stereo ¼" jack socket was connected to the earthy jack sleeve contact, and to pin 1 of the XLR plug end of the BSA. Strangely, there was no true connection between the metal outer of the stereo ¼" jack socket and the immediately adjacent metal outer of the XLR plug end of the adaptor. Both were finished in some kind of plating, resulting in a variable contact of about 5Ω between the two metal outers of the BSA.

For a one-off unit of simple design, 0.1" pitch copper strip board forms a quick and convenient alternative to a PCB and was used on this project, as is apparent from the internal view, **Fig. 7.** The strip board carrying the circuit was mounted on stick-on stand-offs, stuck to one side of the box. A 'Terry' clip was used to retain the PP3 battery, whilst connectors and controls were mounted on the ends of the box. ■

References

1. Practical RF Handbook, Ian Hickman, 3rd Ed. 2002, Newnes Butterworth-Heinemann, ISBN 0 7506 5369 8.

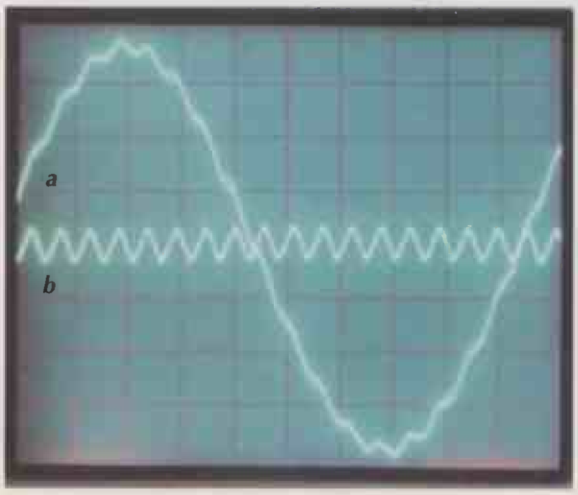


Fig. 4. a) Input, 1kHz triangular wave riding on a 50Hz sinewave. b) Output, one balanced lead viewed relative to ground. Both traces 100mV/div. vertical, 2ms/div. horizontal.

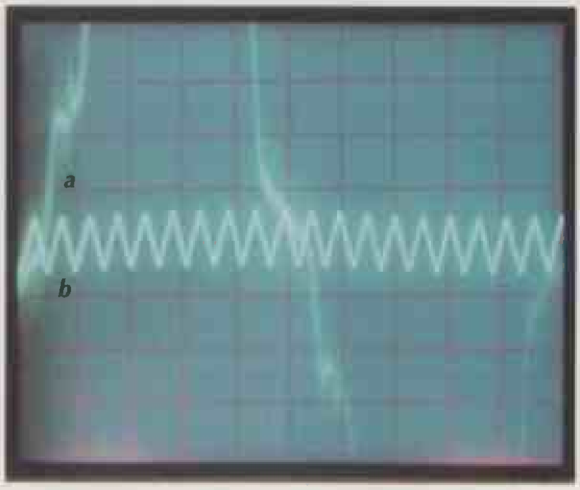


Fig. 5. Showing the common mode component on the output of the power supply of a commercial radio microphone.

Figure 6: A view of the completed unit.

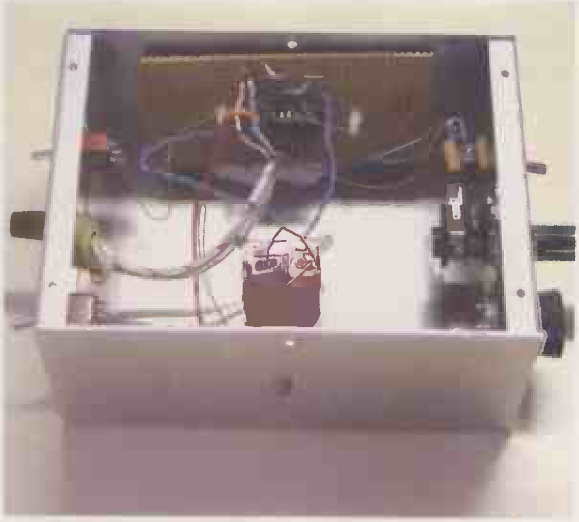


Figure 7: An internal view of the unit.

Humidity sensor with PC interface

Emil Vladkov presents a system for relative humidity and temperature measurement using a calibrated and highly-integrated sensor with digital output. This is a stand-alone meter but it also has a serial interface that can be connected to a PC for data logging and other monitoring applications.

Integrated sensors that are calibrated in precision chambers are now available with digital outputs . This makes designing a humidity and temperature measurement system a tempting task.

The humidity meter described here was designed as a stand-alone system with an intelligent display that shows the actual values of relative humidity and temperature approximately every second.

As the system incorporates a microcontroller it was an easy job to add a serial port to the device, which turns the system into a data logger for humidity and temperature. It simply sends its measurement results every second to the host computer, where these values can be stored for display and post-processing.

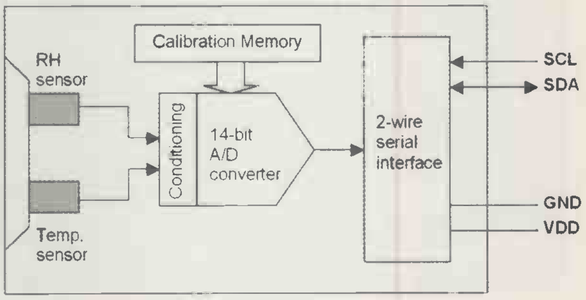


Fig. 1. The SHT11 single chip relative-humidity and temperature sensor.

SHT11 integrated sensor

The design of such a compact measurement device is only possible with a highly-integrated digital output sensor such as the SHT11 from the Sensirion company. The diagram of the internals of the SHT11 is presented on **Fig. 1**.

Included in the device are two precision-calibrated microsensors – one for relative humidity and one for temperature – that connect to a 14-bit analogue-to-digital converter through conditioning circuits.

A serial digital two-wire interface is integrated on the same chip, so superior results in terms of signal quality are obtainable.

Due to its highly integrated architecture, the device is practically immune to external EMC. The calibration coefficients for each individual sensor are programmed in on-board one-time-programmable memory.

The device's maker suggests applications of the sensor in the field of the automotive industry, instrumentation, medical equipment, air-conditioning systems and so on.

Basic specifications of the sensor are given in **Table 1**. Although the sensor is capable of operation at a full resolution 12 bit for humidity and 14 bits for temperature, the proposed design uses only 8 and 12-bit resolutions, as its main goal is to achieve compactness and not excessive bit numbers.

The microcontroller reading the measurement results from the integrated sensor has integrated 2k program memory – or 4k if 89C4051 is used. If full resolution is

Table 1. Specifications of the humidity measurement system.

	Parameter	Min.	Typ.	Max.	Units
Humidity					
	Resolution	0.5	0.03	0.03	%RH
		8	12	12	Bits
	Repeatability		±0.1		%RH
	Nonlinearity		±3		%RH
	Range	0		100	%RH
Temperature					
	Resolution	0.04	0.01	0.01	°C
		12	14	14	bits
	Repeatability		±0.1		°C
	Range	–40		123.8	°C

used, complicated non-linearity compensation techniques are needed. These employ floating-point maths, which would be difficult or maybe impossible to implement with the microcontroller used.

Nonlinearity Problems

The humidity sensor is a nonlinear device, so software compensation is needed. This can be accomplished by the implementation of a formula supplied by the device manufacturer, given by the equation,

$$RH_{Real} = c_1 + c_2 \cdot RH_{Meas} + c_3 \cdot RH^2_{Meas}$$

The 'c' coefficients have different values for 8 and 12 bit resolution as stated in **Table 2**. As you can see, complicated floating point maths would be needed for high-resolution linearisation so I decided to use a less computation intensive method. Unfortunately, this method is only available for 8-bit resolution.

The formula used is:

$$RH_{Real} = \left(a \cdot RH_{Meas} + b\right)/256, \%RH$$

Values for the a and b coefficients are given in **Table 3**.

This implementation involves 16-bit additions and divisions, which are easily implemented on the 89C2051 micro used. Coarse approximation involved in this compensation technique leads to nonsensical results at the margins of the measurement intervals, i.e. 0% RH and 100% RH. As a result, special checks are necessary at these limit values, so that no negative or greater than 100% values result from the linearisation algorithm. These check procedures are described by the conditional operations as given:

If ($RH_{Meas} \leq 107$ and $a \times RH_{Meas} < 512$) then $a \times RH_{Meas} = 512$
If ($RH_{Meas} > 107$
and ($a \times RH_{Meas} + b) > 25600$) then $a \times RH_{Meas} + b = 25600$.

The temperature sensor in the SHT11 is very linear, so compensation is not needed. Format conversion is needed though, so that the 12-bit binary value is translated into a valid temperature in the range from –40°C to 123.8°C. This simple conversion is done with the formula;

$$T_{Real} = -40 + \frac{T_{Meas}}{25}, °C$$

This is easily implemented in the integer maths functions of the 89C2051 micro. There is no special instruction for the 16-bit division, so this is done by a software procedure in the firmware.

SHT11 commands

The integrated sensor has a build-in two-wire serial interface, containing a serial data (SDA) and a serial clock (SCL) line. Unfortunately this interface is not a standard one – at least in my opinion – so the available I^2C routines for the 8051 cannot be used.

To accomplish the communication protocol between the microcontroller and the SHT11-sensor, dedicated procedures have to be written to control the SCL and the SDA-lines. Fortunately, the device manufacturer gives a software example (in C), part of which I have used in my assembler-routines.

Fig. 2. The 'Transmission Start' sequence precedes every transmission of a command from the microcontroller to the SHT11 integrated sensor.

Table 2. The 'c' coefficients have different values for 8 and 12 bit resolution.

Resolution	c_1	c_2	c_3
12-bit	–4	0.0405	-2.8×10^{-6}
8-bit	–4	0.648	-7.2×10^{-4}

Table 3. Values for the a and b sensor linearisation coefficients.

Measurement range	a	b
$0 \geq RH_{Meas} \geq 107$	143	–512
$108 \leq RH_{Meas} \leq 255$	111	2893

Table 4. Commands sent to the SHT11 sensor by the microcontroller.

Command	Code	Description
Reserved	0000x	Reserved
Measure Temperature	00011	Temperature measurement
Measure Humidity	00101	Humidity measurement
Status Register Read	00111	Read access to the status register
Status Register Write	00110	Write access to the status register
Reserved	0101x-1110x	Reserved
Soft reset	11110	Reset chip, set the status to defaults

Transmission-start sequence. The 'Transmission Start' sequence precedes every command sent to the SHT11 sensor. After this sequence, three address bits and a 5-bit command follow. Currently, only address '000' is supported. The commands are listed in **Table 4** and the transmission start sequence is presented in **Fig. 2**.

Connection-reset sequence. If communication with the SHT11 device is lost due to interference or some other problem, the sequence described in **Fig. 3** can be used to reset the serial interface. The serial clock line has to be toggled 9 or more times.

Measurement commands – temperature and humidity. To accomplish a measurement, the microcontroller issues a measurement command. These are '00000101' for relative humidity and '00000011' for temperature. The controller has to wait 11ms for the 8-bit measurement to complete and 55ms for the 12-bit one to complete, but the firmware program waits around 300ms to provide headroom for valid measurement results.

After the measurement is complete, the SHT11 pulls the SDA-line low to signal the controller. The microcontroller has to read three data bytes – two measurement result bytes and one checksum word.

After receipt of the first two bytes, the micro pulls the SDA-line low to acknowledge valid reception. The

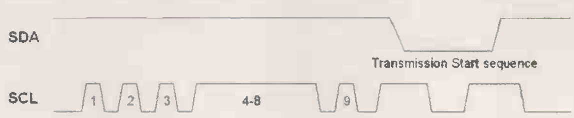


Fig. 3. If communication with the SHT11 device is lost a 'Connection Reset' sequence has to be issued from the microcontroller, which toggles the SCL line nine times or more.

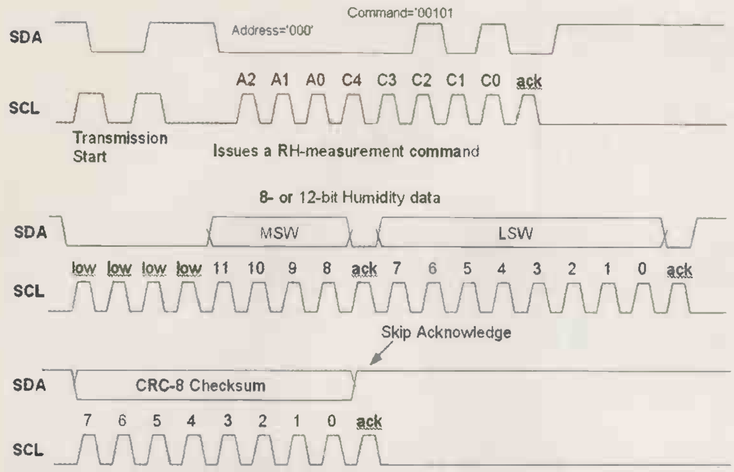


Fig. 4. A typical measurement session consists of a 'Measure Humidity' or 'Measure Temperature' command, sent from the microcontroller to the SHT11-sensor. The sensor responds with two measurement result data words and a checksum. The microcontroller has to acknowledge the reception of the MSW and LSW by pulling the SDA-line low. Reception of the checksum is not acknowledged and the SHT11 returns to sleep-mode automatically.

checksum word is not acknowledged by the microcontroller and so the communication session is terminated.

Data words involved are send MSW (most significant word) first, LSW (least significant word) last. The bits in the MSB are right justified, which means that for a 12-bit measurement, the MSW contains zeros in the first four transmitted bits, and for a 8-bit measurement the whole MSW is composed from zeros.

Timing diagrams for a typical measurement session are given in **Fig. 4**.

Device configuration commands

Device configuration commands are issued through writing to the status register.

Sensor availability

The SHT11 sensor can be ordered from Farnell using order code 3913065. Prices for low volumes are as follows:

1+	USD 15.00/EUR 16.50
10+	USD 13.25/EUR 14.55
25+	USD 12.50/EUR 13.75
50+	USD 11.85/EUR 13.00
100+	USD 11.45/EUR 12.60,

The device is not the cheapest one available, but don't forget that it's a precision industrial-grade product with all supporting circuitry for data conversion and transmission integrated.

Every bit in the status register has its own function in controlling the SHT11 operation and this is presented in **Table 5**. So to implement a 8/12-bit measurement in place of the 12/14-bit enabled by default, the microcontroller has to write to the status register 01_{16}.

Through the status register, an on-board heater can be also switched on. This function is not implemented in the proposed design, but it would be extremely useful if the device were to be operated in high humidity environments where condensation can occur.

Implementing the sensor

The circuit diagram of the complete humidity meter is shown in **Fig. 5**.

Pin assignments for the SHT11-sensor, IC_3, are those given in the manufacturer's data sheet. The device is provided with a power supply, V_{cc}, ground and two data lines for SDA and SCL.

As the main goal of this design was portability and simplicity, I decided to use the 89C2051 from Atmel for IC_1. It is a fully-featured 8051-based microcontroller with 2k on-board flash for the program.

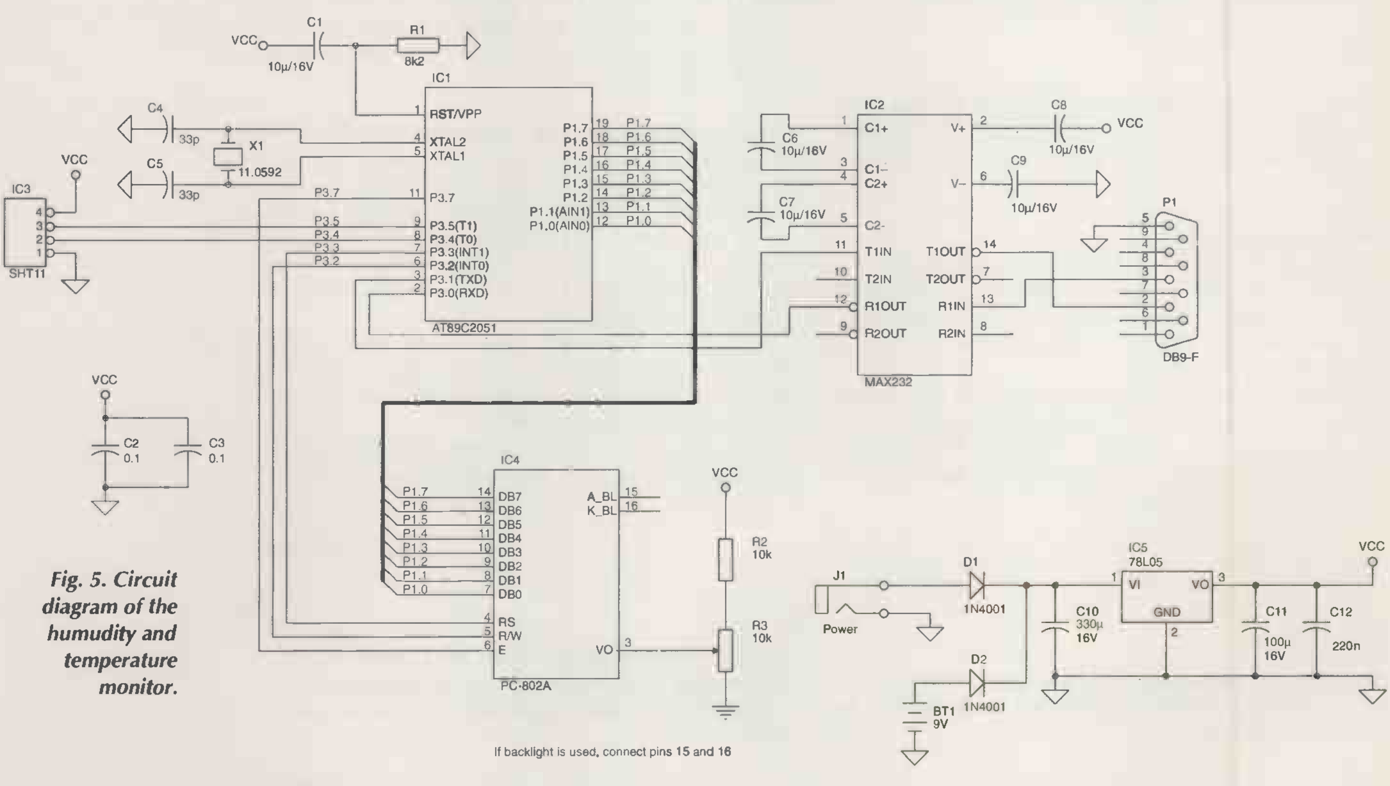


Fig. 5. Circuit diagram of the humudity and temperature monitor.

Two of the general-purpose lines of the micro are used to generate the serial communication signals with the SHT11 – these are P3.4 for SDA and P3.5 for SCL. The clock signal for the microcontroller is supplied by the crystal, X_1, and capacitors $C_{4,5}$. Reset is provided by components R_1 and C_1.

Results from measurements are displayed on a two-by-eight alphanumerical liquid-crystal display, IC_4. The device I used was a PC-802A, but as this is a standard device, you may well find an equivalent. Usually the pin-assignments of the display are standard, but check the device data sheet if you intend to use other display models.

Both command and display ASCII data are applied to the LCD by the Port 1 (P1.7 – P1.0) of the microcontroller.

Three additional control signals are needed to drive the display. These are 'Register Select', RS, 'Read/Write', RW, and 'Enable', E. They are generated in software by three of the general purpose lines of the microcontroller, namely P3.3, P3.2 and P3.7.

Components R_2 and R_3 are used to set the contrast of the LCD. The part that I used did not have a backlight so pins 15 and 16 of IC_4 are not used. You should connect a series resistor with an appropriate rating if you plan to use a device with backlight, but consider the power consumption if you power the device from a battery.

Although the system is intended to be used as a stand-alone device, it may sometimes be necessary to use it as a data logger for humidity and temperature. To meet this need, a serial port, P_1, is provided, which makes necessary the use of the level converter IC_2 with the associated components $C_{6\text{-}9}$. The serial port is built into the microcontroller (pins P3.0-RxD and P3.1-TxD).

Capacitors C_2 and C_3 provide power supply filtering. In my case, power is supplied to the device from an external wall-cube adaptor. It has a DC output but AC can also be used with the arrangement proposed). The raw input voltage between 9V and 15V is regulated with the three-terminal low-power (100mA) regulator IC_5, which is a 78L05 device.

Capacitors $C_{10\text{-}12}$ are power supply filtering components. Diode D_1 is provided as voltage reversal protection or rectifier diode if an AC-power source is used. Diode D_2 is used to decouple the optional battery (9V type) BT1 from the wall-cube power supply.

Device firmware and software algorithm

The firmware is the software residing in the 2k flash of the 89C2051 microcontroller. It controls the SHT11 sensor, the display and the serial port communications.

Object code for the software is given in **Listing 1**. It can be obtained via e-mail from the editorial offices of *EW*. The algorithm driving this software and making it work is presented in **Fig. 6**.

Figure **6a)** shows the main body of the code. It consists of an endless loop, which is started after the initial set up of the serial port communication and the liquid-crystal display.

Every measurement session is executed exactly as in the timing diagrams in Fig. 4. Each consists of a command sent from the microcontroller and three result words for measurement data and checksum.

Results from relative humidity measurements are stored in register R5 ready for the linearisation algorithm. Temperature is stored in registers R6/R7 for use by the degree-celsius conversion algorithm.

The two conversion algorithms return integer/fractional results for humidity/temperature in the register pairs R4/R5 and R6/R7 respectively. As the results are in hexadecimal form they need to be converted to a decimal ASCII representation to be printed on the display directly.

Table 5. Every bit in the status register has its own function in controlling the SHT11 operation.

Bit	Type	Description	Default	
7		Reserved	0	
6	R	End of Life (Low Voltage Detection)	x	
5		Reserved	0	
4		Reserved	0	
3		For Testing only	0	
2	R/W	Heater	0	off
1	R/W	No reload from OTP	0	Reload
0	R/W	1 = 8/12-bit RH/temperature 0 = 12/14-bit RH/temperature	0	12/14-bit resolution

This is accomplished by an ASCII-conversion routine. It takes the input in TH0/TL0 registers and returns an ASCII-string representing the unsigned decimal number equivalent to the 16-bit input hex number.

The ASCII-string is stored in the 89C2051's RAM, starting at location 50_{16}. It ends with an EOT (end-of-table) marker. This procedure is run once for the integer part of every result and once for the fractional part, which is also stored as unsigned 16-bit number. The comma is printed on the display between the two decimal ASCII results and the final measurement result is presented on the LCD.

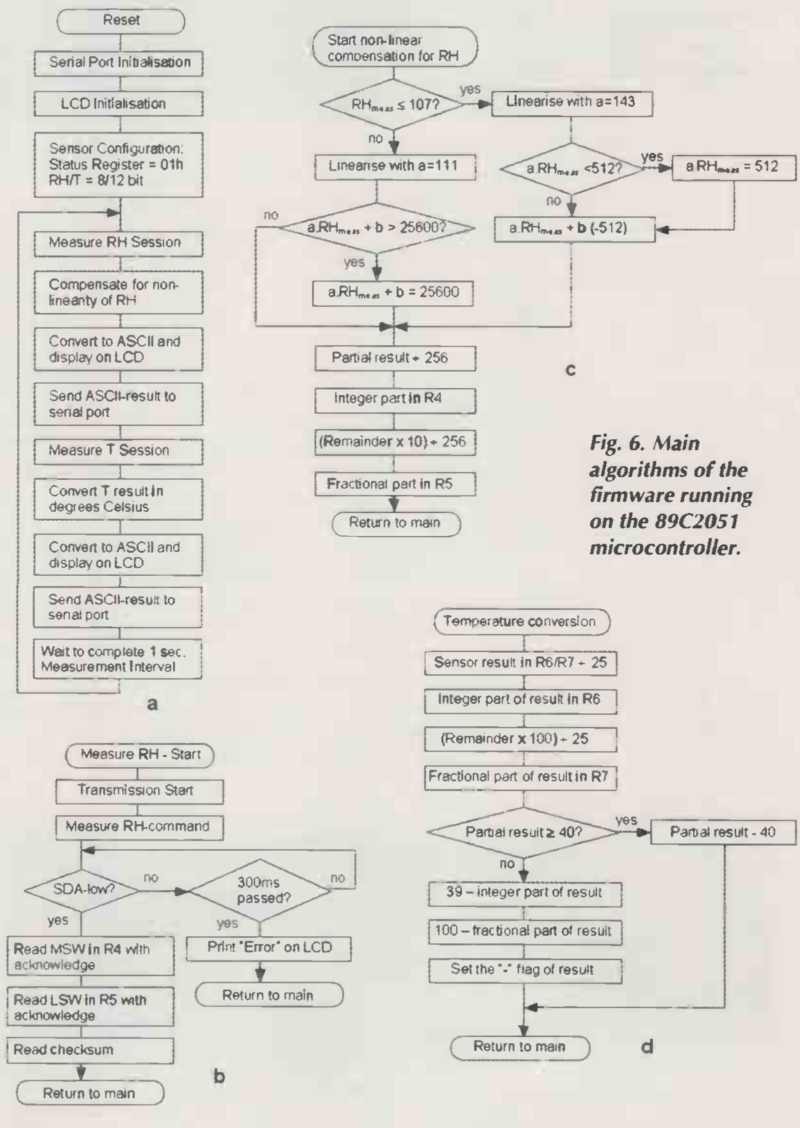


Fig. 6. Main algorithms of the firmware running on the 89C2051 microcontroller.

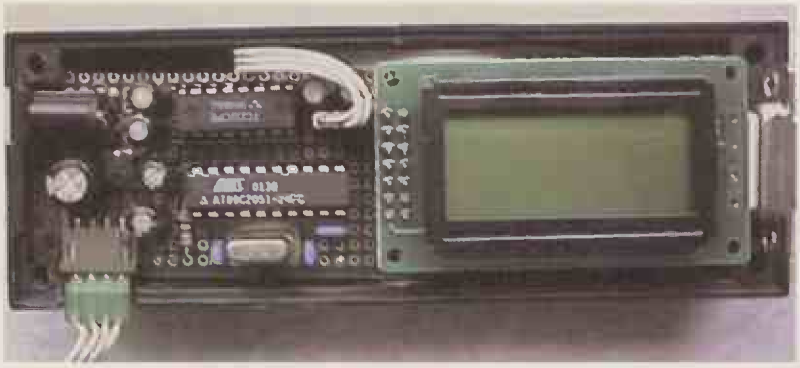


Fig. 7. Internals of the RHTS-11L device with the display mounted in a piggyback-style and the 89C2051 microcontroller in the middle.

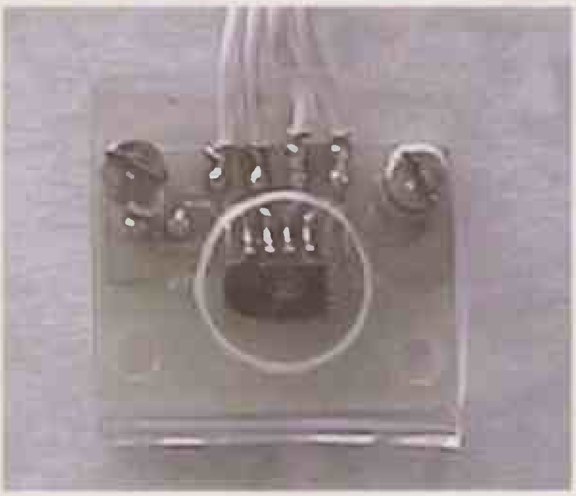


Fig. 8. SHT11 integrated sensor mounted on a dedicated SMT-board with a protective cover.

After every partial result, the corresponding ASCII-string is sent to the serial port for reception by the host computer. When a terminal program is started on the machine and the settings are configured to 9600,8,N,1 then the following data input should be observed:

```
H    58.9    T      20.96
H    58.9    T      21.00
```

and so on. Each line is terminated with a CR and LF and the fields are tab-delimited. This makes the results easy to manipulate and graphed by a spreadsheet on a PC. Using a spreadsheet, relative humidity and temperature trends over a number of hours can be easily observed.

Figure **6b)** shows the measurement sequence for relative humidity monitoring. The session starts with the microcontroller issuing the 'Measure RH' command. The algorithm waits for the SDA-line to be pulled low by SHT11. If this occurs then the MSW and the LSW are read in registers R4 and R5.

A read of the checksum follows for completeness, although the checksum is not used in the design proposed here. The algorithm provides a time-out feature: if the SDA-line is not pulled low in 300ms then an error-message is printed on LCD and communication is restarted.

The algorithm for measuring temperature differs only in the command issued by the microcontroller. In this case it is the 'Measure Temperature' command and the registers holding the result in this case are R6/R7.

Figure 6c. outlines the algorithm responsible for compensating for the nonlinearity of the relative humidity sensor. Depending on the value received by the SHT11, the software uses two different coefficient sets with the margin set at RH_{meas}=107.

As discussed earlier, the algorithm checks for intermediate values, which will result in values lower than 0% or greater than 100%. If such a case is detected, the system forces the intermediate result to the limit values.

A division by 256 routine is common to the two linearisation segments and is accomplished by a routine for 16-bit unsigned division. This routine returns integer result in R2/R3 registers and a remainder in R4/R5.

The integer result, which fits easily in R3 only, is stored in R4 and forms the integer part of the linearisation result. The remainder is multiplied by 10 and then divided by 256, so that the fractional part of the linearisation – the 'tenths' – is obtained. This fractional part is returned in R5.

The algorithm for the degrees celsius conversion according to the equation described in the section headed 'Nonlinearity problems' section is depicted in **Fig. 6d.** The value obtained from the SHT11 and residing in R6/R7 is divided by 25. The integer part is stored in R6 and the remainder is multiplied by 100 and again divided by 25, so that the fractional part of the result (the "hundreds") is obtained and stored in R7. A value of –40 needs to be added to this partial result.

If the partial result is greater than or equal to 40, the subtraction is straightforward. If it isn't, the integer part of the partial result is subtracted from 39 and the fractional part is subtracted from 100. The negative sign flag is set in this case.

All the above mentioned subroutines make extensive use of several common subroutines: 16-bit integer division, hexadecimal-to-unsigned decimal number conversion and several print-to-display and print-to-serial port utilities.

Fig. 9. RHTS-11L measurement system.

Further reading and data sheets

1. SHT1x Humidity & Temperature Sensmitter Data Sheet, Sensirion AG: http://www.sensirion.com/getfile.asp?pk=601.
2. SHT1x Humidity & Temperature Sensmitter Application Note: Soldering Procedure, Sensirion AG: http://www.sensirion.com/getfile.asp?pk=565.
3. SHTxx Humidity & Temperature Sensmitter Application Note: Compensation of RH non-Linearity, Sensirion AG, http://www.sensirion.com/getfile.asp?pk=576.
4. SHTxx Humidity & Temperature Sensmitter Application Note: Sample Code, Sensirion AG, http://www.sensirion.com/getfile.asp?pk=600.
5. SHTxx Humidity & Temperature Sensmitter Application Note: Status Register, Sensirion AG, http://www.sensirion.com/getfile.asp?pk=578.
6. AT89C2051 8-Bit Microcontroller with 2K Bytes Flash, Atmel, www.atmel.com.
7. PC 0802-A Series LC displays, PowerTip.

My prototype

I built the prototype RHTS-11L meter on a piece of perforated board with the display module attached to it in a piggy-back-style. This can be seen in **Fig. 7**.

The SHT11 is housed in a Plexiglas box to protect the tiny package. In the middle, just above the sensor, a hole is drilled to provide for air circulation as depicted in **Fig. 8**. **Figures 9** shows the complete system .

The device's manufacturer does not recommend connecting a serial cable to the sensor that's longer than 10cm because crosstalk and loss-of-communication problems could arise. I used a 20cm interconnecting cable without experiencing any problems, so I suppose the use of even longer cables (up to a 1m) may be possible.

If longer runs are needed – when, for example, the sensor is in an industrial environment that's remote from the meter – additional cable drivers will be needed. I encourage all readers who find the idea of the device worth implementing and who make improvements to the design proposed to share their experiences here. ■

Listing: Object code for the RHTS-11L measurement system running on the 89C2051 microcontroller.

```
:030000000200807B
:080003003232323232323265
:08000B003232323232323225D
:080013003232323232323255
:08001B0032323232323232324D
:0800230012066832323232325B
:1000800075A800D2B4D2B51206961201E574807537
:10009000F052120218748175F048120218748775B4
:1000A000F02512021874C075F05412021874C1754C
:1000B000F0DF1202181202BC7B011203091202438 4
:1000C00012031C12048A1201A6794F7720758C0046
:1000D0008C8A12054E75F08412043F12016B7485F0
:1000E00075F02E1202181 2017D758C008D8A120592
:1000F0004E75F08612042F12016B1201CC12034AC6
:1001000012050012 0193B9FF09794F772D1201886A
:100110008004794F7720758C008E8A12054E75F019
:10012000C412043F12016B74C575F02E120218122E
:1001300017D758C008F8A12054E7851B6800B18A0
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:100160002430200C00200C00200C07850B6800105
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:1001F0002111202507590011202111202507590F4
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:10027000B48002D2B4D2B5000000C2B5D0E023C031
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:1002A000C38001D333C2B5D8F220D104D2B48002C6
:1002B000C2B4D2B5000000C2B5D2B422D2B4C2B525
:1002C0000D2B500C2B400C2B5000000D2B500D261
:1002D000B400C2B522D2B4C2B57809D2B5C2B5D87D
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:1002F000221202BC7407120264120378D2D11202D5
:1003000096F9C2D1120296FA221202BC74061202A7
:1003100064120378EB120264120378221202BC7496
:10032000051202641203787803120243 30B408D82D
:10033000F8C2D112037822D2D1120296FCD2D11285
:100340000296FDC2D1120296FA221202BC74031266
:1003500002641203787803120243 30B408D8F8C25A
:10036000D112037822D2D1120296FED2D112029675
:10037000FFC2D1120296FA2230D10122748075F0A8
:1003800045120218748175F052120218748275F0C9
:1003900052120218748375F04F120218748475F0AB
:1003A00052120218748575F021120218748675F0C5
:1003B00020120218748775F02012021874C075F0AC
:1003C0002012021874C175F02012021874C275F060
:1003D0002012021874C375F02012021874C475F04C
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:1005500050C0D0C000C001C002C003C004C005C06C
:1005600006C007C0F0AE8CAF8A78277910C2D5AA32
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:1005C000F0C000A8F0F6D000C0F0D0F0D007D00600
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:1006200007EB9D5003C38008C3EB9DFBEA9CFAD304
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:10068000AC223098FDC298E599F608B84F02783050
:10069000B40DEF80E022E587C2E7F587758DFD7523
:1006A0008BFD758921D28E759850222253485431 82
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:00000001FF
```

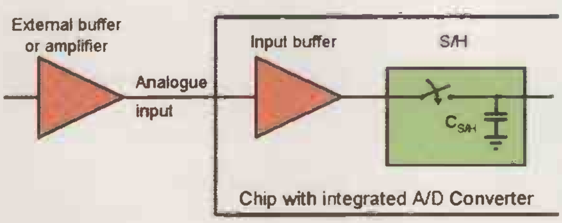
Understanding inputs of ADCs

Many embedded applications utilise an A/D converter. However many users unknowingly ruin the A/D measurements by connecting incorrect circuitry to the A/D converter input. Daniel Malik explains

Figure 1 shows a typical application circuit of an A/D converter with integrated sample & hold (S/H) circuit – an application so simple, that it almost cannot be incorrect. However it is incorrect and the reading delivered by the A/D converter will be lower than expected.

To understand what is wrong, we have to look at the S/H circuit. Modern S/H circuits are much more complicated than the one outlined here, however the basic principle is still the same. At sampling time the switch is closed and the sampling capacitor is charged. To protect the external circuitry from experiencing the shock of a capacitor being connected to its output an on-chip analogue buffer is used. We have created ideal buffers in theory and everyone uses them on paper, however there is nothing like an ideal buffer in the real world of electronics. The buffer will act as an impedance transformer and the change of capacitance on its output will be transformed to change of capacitance on its input.

Fig. 1. Typical application of A/D converter.



The sampling process is very fast, much faster than the bandwidth of the external amplifier we have connected to the A/D converter input. Therefore whatever happens at the A/D input will be unaffected by the external amplifier.

Figure 2 shows the equivalent circuit, which will enable us to tell what happens at the time of sampling. Before sampling takes place, the combined capacitances of the PCB track and chip pin ($C_T + C_P$) are charged to input voltage V_{IN}. At sampling time the discharged S/H capacitance transformed across the on-chip input buffer (C_X) is connected in parallel to these capacitances and the voltage on the input pin will drop. The only component capable of delivering more charge to the capacitors and lifting the input voltage is the external amplifier, but it will not react until it is too late. How much will the input voltage drop?

$$\frac{1}{2}(C_T + C_P)\cdot V_{IN}^{\;2} = \frac{1}{2}(C_T + C_P + C_X)\cdot V_{IN}'^{\;2}$$

$$V_{IN}' = V_{IN}\cdot\sqrt{\frac{C_T + C_P}{C_T + C_P + C_X}}$$

Let's assume some reasonable values, for example: (C_T

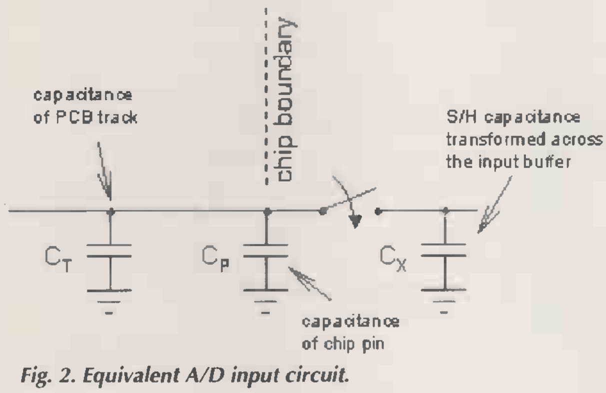


Fig. 2. Equivalent A/D input circuit.

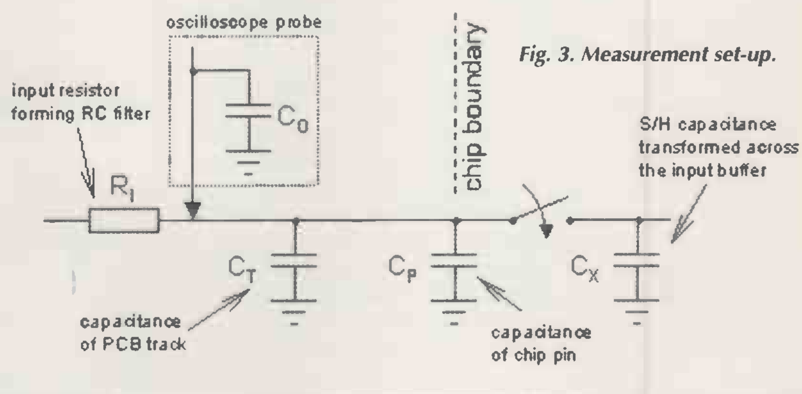


Fig. 3. Measurement set-up.

$+ C_P) = 5pF$, $C_X = 0.5pF$. The input voltage will then drop to 95%! It is clear that we can lower the drop by making the capacitance attached to the A/D converter input higher. Let's calculate the minimum capacitance needed to keep the voltage drop below $^1/_2$ LSB of the A/D converter.

$$V_{IN} - V'_{IN} \overset{!}{=} \tfrac{1}{2}LSB$$

$$\tfrac{1}{2}LSB = V_{IN} - V'_{IN} = V_{IN} - V_{IN} \cdot \sqrt{\frac{C}{C + C_X}}$$

$$\tfrac{1}{2}LSB = V_{IN} \cdot \left(1 - \sqrt{\frac{C}{C + C_X}}\right)$$

$$\frac{LSB}{2 \cdot V_{IN}} = 1 - \sqrt{\frac{C}{C + C_X}}$$

$$\frac{2 \cdot V_{IN} - LSB}{2 \cdot V_{IN}} = \sqrt{\frac{C}{C + C_X}}$$

The conditions will be the worst for maximum allowable input voltage. If we assume an A/D converter with resolution of N bits, then the maximum input voltage equals .

$$2^N \cdot LSB$$

$$\frac{2 \cdot 2^N \cdot LSB - LSB}{2 \cdot 2^N \cdot LSB} = \sqrt{\frac{C}{C + C_X}} \quad , V_{IN} \overset{!}{=} 2^N \cdot LSB$$

$$\frac{2^{N+1} - 1}{2^{N+1}} = \sqrt{\frac{C}{C + C_X}}$$

$$\frac{(2^{N+1} - 1)^2}{2^{2 \cdot (N+1)}} = \frac{C}{C + C_X}$$

$$\frac{2^{2(N+1)} - 2^{N+1} + 1}{2^{2 \cdot (N+1)}} = \frac{C}{C + C_X}$$

$$C_x \cdot (2^{2(N+1)} - 2^{N+1} + 1) = C \cdot (2^{2(N+1)} - 2^{2(N+1)} + 2^{N+1} - 1)$$

$$C_x \cdot (2^{2 \cdot (N+1)} - 2^{N+1} + 1) = C \cdot (2^{N+1} - 1)$$

$$C = C_x \cdot \frac{2^{2 \cdot (N+1)} - 2^{N+1} + 1}{2^{N+1} - 1}$$

$$C = C_x \cdot \frac{2^{N+1} \cdot (2^{N+1} - 1) + 1}{2^{N+1} - 1}$$

$$C \approx C_x \cdot \frac{2^{N+1} \cdot (2^{N+1} - 1)}{2^{N+1} - 1} \quad , 2^{N+1} \cdot (2^{N+1} - 1) \gg 1$$

$$C \approx 2^{N+1} \cdot C_X$$

Therefore, if we for example, intend to use a 12-bit A/D converter with input capacitance change of 0.5pF, the minimum capacitance connected to the A/D input must be larger than pF i.e. 4nF to keep the voltage drop below $^1/_2$ LSB.

It is a known truth that chip manufacturers often do not provide the data the designer needs. I have seen many A/D converter datasheets where the change of input capacitance at sampling time was not provided. However things are not lost yet, because we can measure this parameter very easily. The equipment needed for such

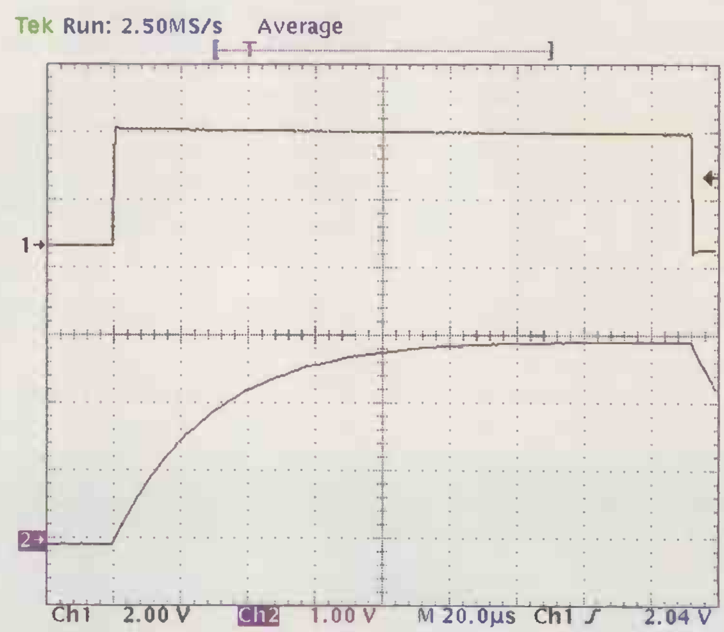


Fig. 4. Measuring input capacitance C.

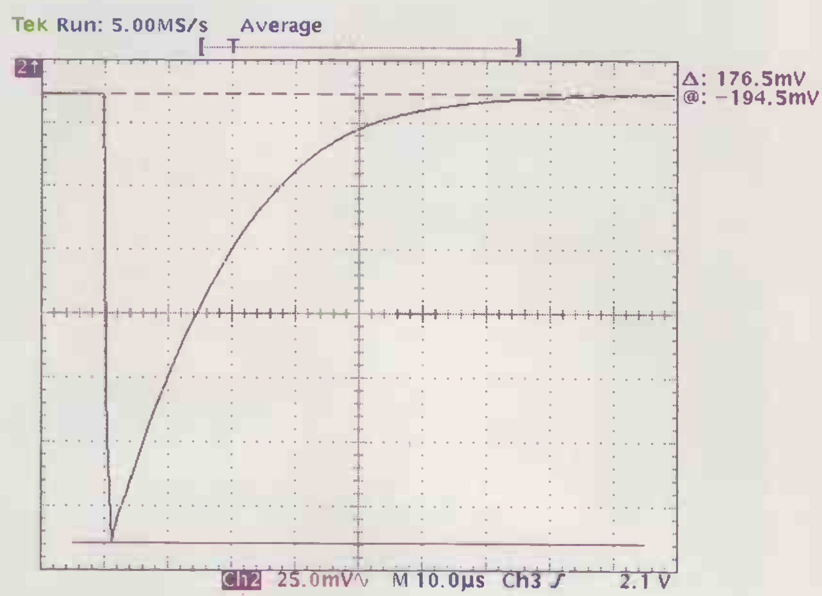


Fig. 5. Observing the voltage drop.

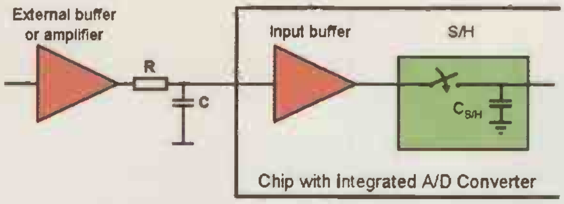


Fig. 6. Correct application of A/D converter.

measurement is an oscilloscope and a signal generator. This simple measurement is not precise, but will give at least rough estimate. We will turn the situation around and compute the change of capacitance from the voltage drop we will observe at the chip pin.

The measurement set-up will look like the one outlined in figure 3. The input resistor R_I should be quite large to make the time constant of the RC network long enough for comfortable measurement. I have used 1MΩ in my measurements.

First of all we have to measure the capacitance connected to the A/D input ($C = C_O + C_T + C_P$). We will do this by applying a square wave signal to the input resistor and observing time constant of the resulting waveform on the scope (see figure 4). The time constant can be guessed directly from the scope, but it is better to transfer the data into an Excel spreadsheet and calculate it more accurately. In the example shown in figure 4 the time constant comes out to be approximately 28.5µs.

$$\tau = 2\pi \cdot R \cdot C$$

$$C = \frac{\tau}{2\pi \cdot R}$$

In our example C ≈ 28.5µs / 6.2832 / 1MΩ ≈ 4.54pF.

We will now apply the highest allowable DC voltage to the input resistor and start the A/D conversion. The resulting voltage drop can be seen in figure 5 – The voltage drop is around 176mV at 3.3V. Once we have measured the voltage drop, we can calculate the change of A/D input capacitance

$$\frac{V'_{IN}}{V_{IN}} = \sqrt{\frac{C}{C + C_X}}$$

$$\frac{V_{IN} - V_{DROP}}{V_{IN}} = \sqrt{\frac{C}{C + C_X}}$$

$$\frac{(V_{IN} - V_{DROP})^2}{V_{IN}^2} = \frac{C}{C + C_X}$$

$$C_X = C\,\frac{V_{IN}^2 - (V_{IN} - V_{DROP})^2}{(V_{IN} - V_{DROP})^2}$$

$$C_X = C \cdot \left(\frac{V_{IN}^2}{(V_{IN} - V_{DROP})^2} - 1 \right)$$

Amplifiers usually do not like capacitive loads. Therefore an extra input resistor is added in figure 6. This RC network will also provide additional filtering against high frequency noise.

Input leakage current of A/D converter is usually below 1µA. If we choose hundreds of ohms for the input resistor, the voltage drop across it will be around 100µV and way below $^1/_2$ LSB. ■

NEW PRODUCTS

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Chip capacitors cope with stress

New chip capacitors that can handle up to 400 per cent more mechanical stress have been introduced by Syfer through Flint in the UK, in case sizes from 0603 to 3640. These greatly reduce the risk of

cracking during board assembly. The range is based on the X7R dielectric, and address the issue of stress damage to MLCC (multi-layer chip capacitor) devices caused by board flexing during the assembly process. The devices use a proprietary flexible epoxy polymer termination material, applied under the usual nickel barrier finish. Tests have shown that Flexicap capacitors can withstand between 75 and 400 per cent greater stress before mechanical cracking occurs, depending on the package size. The capacitors can be stored, handled and soldered using the same manufacturing process as conventional capacitors, and offer the same electrical characteristics and performance.

Flint
www.flint.co.uk
Tel: +44(0) 1530 510333

Micro-vias on high density boards

Teradyne is offering deep micro-via technology for customers using what it calls high performance printed circuits (HPC). As package density and technology drive the need for greater density on the printed circuit board, deep micro-via technology provides several benefits to printed circuit board designers, said Teradyne. Its capabilities include panel sizes up to 24x28in. and micro-vias 3 layers deep or 3 in diameter. The firm's high density interconnector capabilities also include fine lines, thin cores, buried vias and micro vias.

Teradyne
www.teradyne.com
Tel: +4 049 8941 861109

Embedded workbench for ARM

IAR Systems is offering a version of its IAR Embedded Workbench for ARM. This includes a plug-in to the CMX-RTX RTOS, support for the ARM Angel protocol as well as C++ templates. According to the supplier, support for the ARM Angel protocol and the Jeeni JTAG emulator from EPI means new debugging opportunities. The availability of C++ templates and STL should give possibilities to those developers who prefer object-oriented programming. This release also includes the IAR Embedded Workbench Professional, a toolkit that includes graphical tools for system design, test, and automatic system design documentation in addition to all the traditional features of the IAR Embedded Workbench.

IAR Systems
www.iar.com
Tel: +44(0) 20 7554 8585

Timer module plugs in relay socket

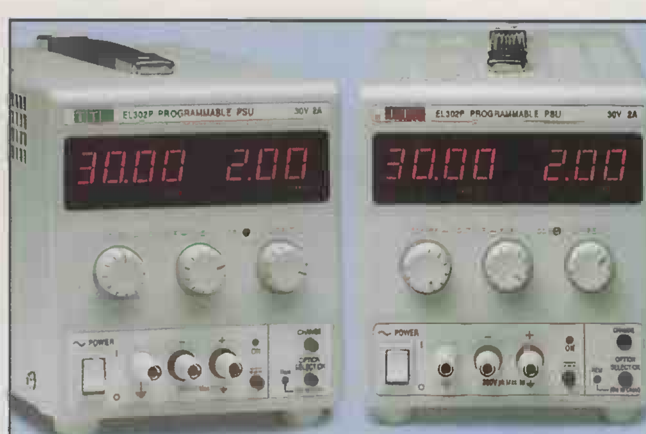
To increase flexibility and reduce inventory, a timer module from Finder is able to operate from any supply voltage. Plugging directly into the relay socket, it allows a standard relay to be used for a wide variety of timing functions. The 86 series timer module can be used with Finder 60 series two and three-pole 10A relays, and also the 62 series two and three-pole 16A power relays. A total of eight timing functions, both power and function initiated, together with seven time scales from one second to 100 hours are provided. The module is able to operate from AC or DC supplies from 12V to 240V. Function and time scale settings are accessible on the front of the module, yet are physically protected against accidental changes. The module is easily retrofitted without any disturbance to installation wiring.

Finder
www.findernet.com
Tel: +44(0) 1785 818100

Supply gets digital control

TTi (Thurlby Thandar Instruments) has introduced a digitally controlled version of its EL302 laboratory bench power supply. The 30V, 2A unit incorporates an opto-isolated RS-232 interface, and provides users with a basic programmable power supply that is sufficient for many applications where the sophistication and complexity of GPIB is not needed. Voltage and current levels are set digitally using either the RS-232 bus interface or the local controls. Setting resolution is 10mV and 10mA. The all-linear design provides a very low output noise level of less than 1mV, along with fast recovery from transients. The power supply can operate in both constant-voltage and constant-current modes. A simple command set allows remote control of voltage, current and output enable, along with readback of metering values and operational status. Local control is via three rotary encoders which provide rapid and accurate setting of voltage and current during bench use. The front-panel controls can be locked out when required, making the unit useful in production and test environments where settings must remain fixed. The EL302P costs £229.

TTi
www.tti-test.com
Tel: +44(0) 1480 412451



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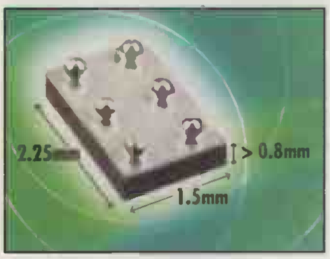
Dual Mosfet in small package

International Rectifier has introduced the IRF 6156, a 20V dual bi-directional power Mosfet in a common drain configuration. Housed in the firm's proprietary FlipFET package, the device is said to be 80 per cent smaller than devices in the TSSOP-8 package, with a profile less than 0.8mm. The small size makes the IRF6156 ideal for Li-ion battery pack safety and protection circuits for mobile phones, notebook computers, PDAs and digital cameras. Li-ion battery packs are flammable, and require protection circuits to prevent damage from over-charging. A protection circuit is also required to detect a short circuit condition, and disconnect the battery from the load. FlipFET packages use no lead frame or mould compound. In essence, the die is the package, and reduces thermal resistance from junction-to-PCB to 35°C/W compared to >60°C/W for SO-8 packages. All of the terminals are on a single side of the die, so stray inductance and other device packaging losses are minimised or eliminated.



International Rectifier
Tel: +44(0) 20 8645 8003

Digital scope has 200Msamples

The DL1640S from Yokogawa is the latest addition to the company's DL1640 family of digital oscilloscopes. It incorporates most of the measurement and display features of the top-end model, but with a price of less than £3,500. It includes 100kword of memory per channel, 200Msample/s sampling, and 200MHz bandwidth. Other features of the 4-channel scope include real-time digital filtering, dual-zoom capability for examining captured waveforms in detail, high-speed screen refresh, and smart search functions. A 6.4in. wide-angle TFT colour LCD screen is housed in a package measuring 220 mm wide x 268 mm high. As a result, the unit occupies less than an A4 size 'footprint' on a test bench or desktop. It weighs 3.9kg, making the oscilloscope easily portable. Captured data can be stored externally using a PC card drive or Zip drive; a floppy disk drive is also provided for internal storage. A wide range of interfaces includes optional USB and Ethernet connectivity.

Yokogawa
www.martron.co.uk
Tel: +44(0) 1494 459200

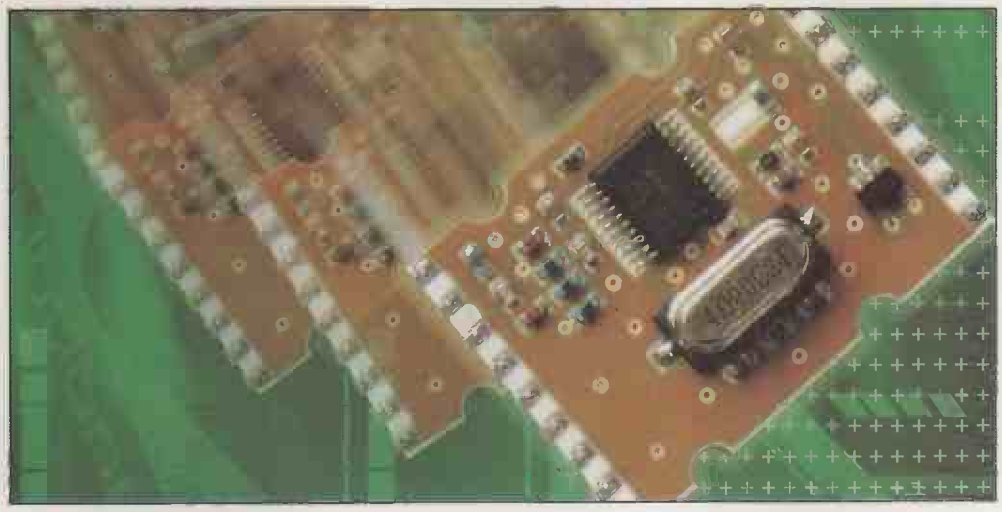
Compliance tester supports UMTS release 4

Tektronix has introduced its protocol test support feature for the latest release of the Universal Mobile Telecommunications System (UMTS) standard. The K1297-G20 protocol tester version 2.40 (V2.40) delivers compliance testing of UMTS release 4. The K1297-G20 V2.40 is equipped with test case development tools to enable definition and modification of messages and message sequences and to create scenarios that examine specific functions of network elements. In addition, the test automation feature enables engineers to perform regression tests to ensure intended standards specifications have been implemented correctly and that

Transceiver has crystal control

A radio transceiver from RF Solutions aims to provide wireless data transfer in applications such as security systems, EPOS terminals and sensor date logging. The FMRXQ1 is able to operate at either 433.92 or 433.33MHz and uses a crystal-controlled design. This, said the supplier, gives narrow band performance that is superior to SAW based wideband designs. Channel selection and interference rejection circuitry give the module reliable and robust performance. Mounted on a low profile ceramic dual-in-line PCB measuring 23x30.5mm, the modules suit one-to-one and multi-node wireless links. They are able to achieve data transfer rates of up to 20kbit/s over a line of sight range of approximately 200 metres. Low power requirements, 8µA in standby mode, makes them ideal for use in portable battery powered applications. FMRXQ1 transceivers require a supply voltage of between 3V and 5V and have a operating temperature range of –20°C to +70°C.

RF Solutions
www.rfsolutions.co.uk
Tel: +44(0) 1273 488880



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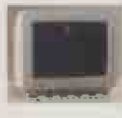

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BBC AM20/3 PPM Meter (Ernest Turner) + drive electronics	£75
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ANRITSU ML93A optical power meter	£990
ANRITSU Fibre optic characteristic test set	£POA
R&S FTDZ Dual sound unit	£650
R&S SBUF-E1 Vision modulator	£775
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TEK 2465 300 Mhz 300 MHz oscilloscope rack mount	£1955
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no unintended changes have been introduced. The monitoring capabilities of the K1297-G20 V2.40 are designed to provide a full set of processing applications and allow decoding to the bit level, enabling engineers to observe behaviour in selected interfaces in the network as they implement UMTS R4 specifications. The K1297-G20 protocol tester supports multichannel and multi-port protocol testing and incorporates a number of conformance test suites.
Tektronix
www.tektronix.com

2.4GHz uses Bluetooth protocol to plug and play

The BRM01 from RF Solutions is a 2.4GHz PCB mountable transceiver that uses the Bluetooth protocol to provide a 'plug and play' radio link. It is for use in serial cable replacement, telemetry, and process control applicatons. The module is able to achieve a maximum transmit rate of 460.8kbit/s in full duplex. Using a Bluetooth class one based radio protocol provides low-level radio link management and error correction functions that are completely transparent to the user, said the supplier. The carrier frequency hops at a rate of 1,600hops/s, which according to the company provides resistance to jamming. The transceiver has a maximum output power of 100mW resulting in a line-of-sight range of 200-300 metres when using the integral antenna; range can be extended by using an external antenna. The modules can be configured for point-to-point, point-to-multipoint and multipoint-to-multipoint architectures. The BRM01 requires a supply voltage of 4V to 5.5V and can be mounted directly onto a surface mount PCB.
RF Solutions
www.rfsolutions.co.uk
Tel: +44(0) 1273 4888880

Temperature sensors have PWM outputs

Analog Devices has introduced two digital temperature sensors with single-wire, pulse-width-modulation (PWM) outputs. The output of the TMP05 and TMP06 is a square wave; its duty cycle is proportional to the absolute temperature. Both devices offer accuracy to ±1°C max from 0 to +70°C, an operating temperature range from –55 to +150°C, and a supply voltage range of +2.7V to +5.5V. They are available in space-saving 5-lead SC-70 and SOT-23 packages. The TMP05 has a push-pull output (CMOS/TTL), while the TMP06 has an open-drain output.
Analog Devices
www.analog.com
Tel: +032 11 300635

Surface mount aluminium capacitors have 100V rating

The NACHL series of surface mount aluminium electrolytic capacitors from NIC Eurotech are housed in miniature cylindrical cases (V-chips). Capacitors are available with voltage ratings of between 10V DC and 100V DC and capacitance values that range from 0.47μF to 330μF. Load-life rating is 5,000 hours at their upper operating temperature of +105°C and minimum operating

temperature –40°C. Case sizes range from 4x6.1mm to 10x10.5mm depending on voltage and capacitance values selected. NACHL capacitors can be supplied either in bulk or tape and reel packaging for use with automatic insertion manufacturing equipment. All parts are available with an optional lead-free finish.
NIC Eurotech
www.niccomp.com
Tel: +44(0) 1280 813737

Multimeter has analogue bar graph

Wavetek Meterman's latest digital multimeter (DMM) measures temperature,

Point-of-load converter with fast transient response

Lambda's latest non-isolated DC-DC converter is a 5V input, 10A output single-in-line packaged unit with fast transient response and close line/load regulation. Aimed at point-of-load applications, the PL10 in the firm's Tarka range has a user-selectable output voltage range of 0.9 to 3.3V which is fixed by a single resistor. With an output voltage of 3.3V, for example, the response to a change from 50 to 100 per cent, is typically 80mV with a setting time of 40μs, said the supplier. The converter's synchronous design allows it to deliver efficiencies up to 94 per cent at a fixed switching frequency of 300kHz. The converters are available in two package styles: a SIL with 9 pins for through-hole insertion and a 5-pad SM for surface mounting. Both styles are supplied taped and reeled. Lambda is also introducing its PAE65 series of eighth-brick DC-DC converters which are available with output voltages from 0.8 to 12V. Output currents are up to 25A on all models up to 2.5V. The 3.3V unit with an output current of 20A is designed to deliver 66W of power.
Lambda
www.lambda-gb.com
Tel: +44(0) 1271 856666

Please quote *Electronics World* when seeking further information

capacitance, frequency and 4-20mA loop current percentage. The 10,000 count display with 0.25 per cent accuracy includes an analogue bargraph. Features include a neon backlight, for use in dim environments. The 38XR can be used for data acquisition using an industry standard PC running Windows.
Wavetek Meterman
www.metermantesttools.com

LDMOS power amplifier optimisation device

Xicor has introduced an RF power amplifier bias controller that integrates onto a single chip all of the critical functional elements needed for designs that optimise LDMOS power amplifier performance. The X9470 is designed to monitor and optimise the operating bias of RF power amplifiers in CDMA, WCDMA, GSM, EDGE, UMTS or other similar basestation applications. the X9470 will work with 2G, 2.5G and 3G systems as well as point to multipoint and wireless local loop systems. During a closed-loop calibration operation, performed between RF bursts, the device's instrumentation amplifier senses the power amplifier bias current and compares this with the desired value stored in EEPROM. A corrected bias voltage is then applied to the LDMOS power amplifier through the output amplifier that has low output resistance and according to the supplier, allows a simplification of the external low-pass filter. LDMOS bias current can be typically maintained to within 4 per cent of its desired value over time and temperature. Operating from a maximum V_{DD} of 30V, the X9470 features a 2-wire interface for programming bias settings and optimising IDQ set point, and bias error direction flag.
Xicor
www.xicor.com
Tel: +44(0) 1993 700544

32-channel PCI converter has A-to-D on each channel

Datel's 32-channel PCI-417N series boards use an A/D converter for each channel to avoid settling delays and speed limitations. Besides the increase in total system speed, the PCI-417N samples all channels in parallel at rates up to 80kHz per channel (5.12Mbyte/s aggregate rate). This concurrent A/D sampling enables time correlated applications such as medical ultrasound, digital signal processing sonar or FFT engine testing. Each input A/D converter digitises to 14-bit resolution, lowering system noise and increasing system dynamic range. Full scale input voltage ranges of ±5V or ±10V are selectable per channel. An on-board A/D memory system prevents sample loss streaming. The board's bus controller acts as a temporary DMA PCI bus master to blast blocks of A/D data while the host CPU concurrently processes previous data, all without dropping samples. A CD-ROM and users' manual with full software documentation accompanies each PCI-417N.
Datel
www.datel-europe.com
Tel: +44(0) 1256 880444
Datel

Mobile IC has imaging interface

National Semiconductor has introduced a GSM/GPRS handset module and chipset which includes audio, power management, a Bluetooth interface, imaging interface, baseband and RF. Both the chipset and module come with full development kits. The LMX3888 module features on-chip polyphonic ringer, speakerphone and stereo MP3 capabilities. The module is based on National's GSM/GPRS chipset, which consists of the LMX3413 analogue power unit, the LMX3415 digital baseband, and a complete quad-band, very low power radio. A dual-band module, National's LMX3888 is designed to provide phone manufacturers with a turnkey design for GSM/GPRS mobile handsets. It includes an integrated Bluetooth Link Manager, USB, CMOS camera interface, SD/MMC interface, voice recognition, handsfree speakerphone, MP3, EMS and MMS in a GSM/GPRS class B-10 product offering. It measures 33 x 38 x 3.6mm.
National semiconductor
www.national.com
Tel: +44(0) 870 242171

850mW video signal switcher

Rohm Electronics' multimedia IC is aimed at applications that require video signal switching. The BA7615N video signal switcher, as it is called, integrates a 6dB amplifier, a 75Ω driver and a mute function

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into a single SIP-10 25.2x10.5x2.8mm package. With four sync-tip clamp inputs, one output and three control terminals, it runs from between 4.5V and 13V and typically has 0dB at 10MHz frequency characteristics. Typical maximum output level is $3.5V_{p-p}$ and typical channel-to-channel crosstalk is 65dB at 4.43MHz.
Rohm Electronics
www.rohm.co.uk
Tel: +44(0) 1908 282666

8-bit addressable power driver IC

The A6259KA and A6259LKW ICs from Allegro MicroSystems combine a 3-to-8-line CMOS decoder circuit and accompanying data latches, control circuitry, and DMOS outputs in a multi-functional power driver. The devices are capable of storing single-line data in the addressable latches, or can be used as decoders or demultiplexers. Driver applications include relays, solenoids, and other medium-current or high-voltage peripheral power loads. The CMOS inputs and latches allow direct interfacing with microprocessor based systems. When used with TTL circuitry, they typically require appropriate pull-up resistors to ensure an input logic 'high'. Four modes of operation are selectable with the 'clear' and 'enable' inputs. The devices feature a 50V minimum output clamp voltage, a 250mA output current with all outputs on simultaneously, and a typical 'on' resistance of 1.3Ω. The addressed DMOS output inverts the data input with all unaddressed outputs remaining in their previous states. All the output drivers are disabled (with the DMOS sink drivers turned off) when the 'clear' input is low and the 'enable' input high. The DMOS open-drain outputs are capable of sinking up to 750mA. The A6259KA is housed in a 20-pin dual in-line plastic package. The A6259KLW is supplied in a 20-lead wide-body, small-outline package
Allegro Europe
www.allegromicro.com
Tel: +33 4505 12359

Power module design seminar on free CD-ROM

Victor is offering a free technical seminar on a CD-ROM which is intended to provide designers with information on the subjects of electrical, mechanical and thermal design; as well as control, mounting EMI and paralleling considerations. For a free copy of the CD see the website.
Vicor
www.vicroeurope.com

AC-DC supplies above spec currents

XP has available AC-DC switchers which it claims can repeatedly deliver twice their nominal output current for up to 10 seconds. The aim, said the supplier, is that the CPE and CPl families tackle the problem of having to over-specify AC/DC switchers in industrial applications where short duration, high peak loads occur. Both CPE and CPL switches are convection cooled, so the expense of providing forced-air cooling is avoided. Typical applications for the 100 to 240W power supplies are in switchgear, automation and motor control systems. CPE models are single output units rated between 100 and 240W with typical efficiencies up to 87 per cent. Output voltages are 24, 36 or 48V DC, adjustable by ±10 per cent, and maximum line regulation is 48mV and load regulation ±0.3 per cent from zero to 100 per cent load. CPL versions are dual output, 100 to 225W power supplies offering a standard +5V output for powering logic circuits, adjustable by ±10 per cent, and an isolated +12V or +24V output with high peak current capability.
XP
www.xpplc.com
Tel: +44(0) 118 984 5515

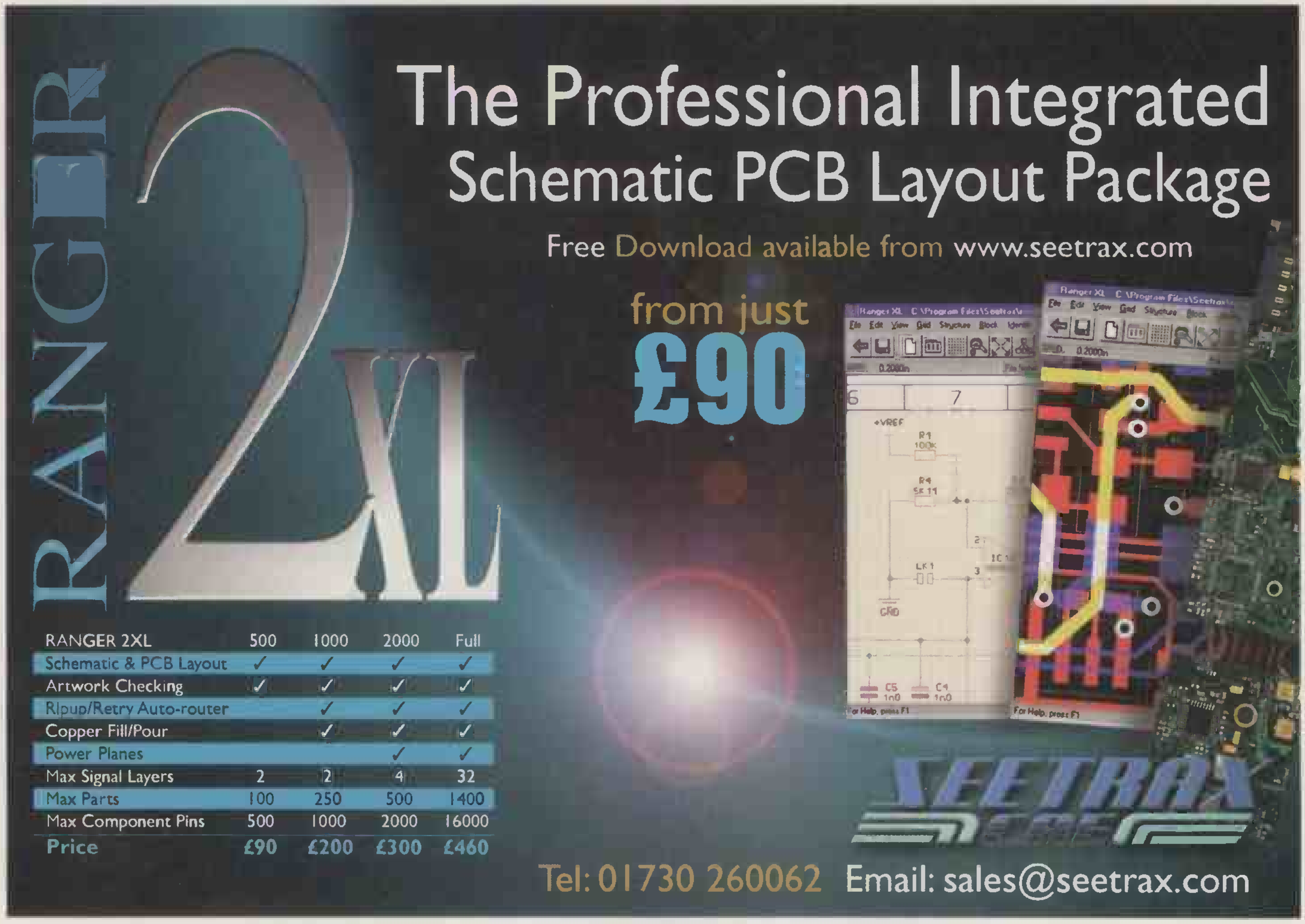
USB & serial Port PIC programmer

This professional quality PIC Programmer from Quasar Electronics is ideal for field and general use as it uses the USB or Serial port. It employs the latest FT232BM surface mount pre-soldered to the board and on-board firmware. All components (excluding ZIF Socket) supplied including a gold plated double sided PTH PCB (102 x 78mm) and free Windows Software interface.

The price includes a fully functional 9x/NT/2000/ME/XP software interface which is available for free downloading. Software accepts HEX files and has Program, Verify, Read, Blank Check, OSCAL and Fuse functions.
Quasar Electronics
www.quasarelectronics.com.
Tel: +44(0) 871 717 7168

8051 starter kit gets flash micro

Crossware has added to its 8051-based FLT-32 microcontroller trainer new software and a flash programmable Atmel chip. The microcontroller design trainer is used to teach microprocessor and control principals. The system incorporates a standard 8032 microcontroller and a text based command line monitor, which allows students to download and run programs from a host PC. The Crossware enhancements include an upgrade from the original 8032 chip to the modern Atmel T89C51RC2 microcontroller, which includes 32kbytes of flash programmable memory.
Crossware
www.crossware.com.
Tel: +44(0) 1763 853500 ■



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Max Parts	100	250	500	1400
Max Component Pins	500	1000	2000	16000
Price	£90	£200	£300	£460

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

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

Your submissions are judged mainly on their originality and usefulness. Interesting modifications to existing circuits are strong contenders too – provided that you clearly acknowledge the circuit you have modified. Never send us anything that you believe has been published before though.

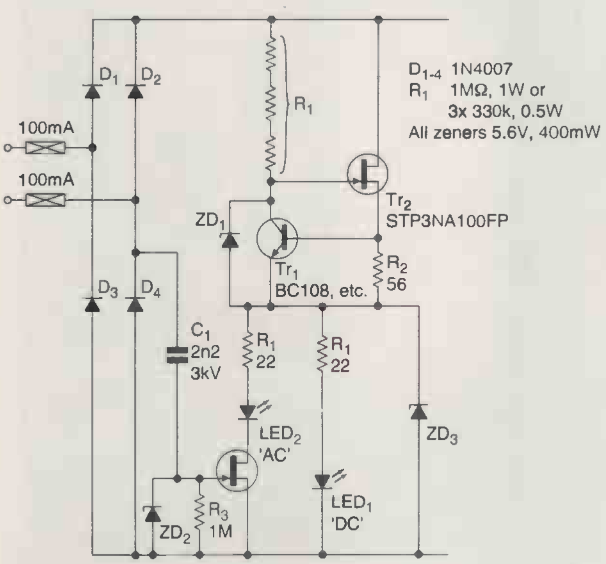
Don't forget to say why you think your idea is worthy.

Clear hand-written notes on paper are a minimum requirement: disks with separate drawing and text files in a popular form are best – but please label the disk clearly. Where software or files are available from us, please email Jackie Lowe with the circuit idea name as the subject.

Send your ideas to: Jackie Lowe, Highbury Business Communications, Anne Boleyn House, 9-13 Ewell Road, Cheam, Surrey SM3 8BZ *email j.lowe@highburybiz.com*

6-600V AC/DC LED driver

Any voltage between 6 and 600V will light an LED using this circuit. There are two LEDs, one lighting when the drive is AC, the other when the drive is DC.



This circuit will operate a LED with an applied voltage between 6 and 600V, AC or DC. Input voltage is rectified by $D_{1\text{-}4}$ and drives the LED through a constant current source. Multiple LEDs may be connected in series if the circuit is to he used to replace filament indicator lamps etc.

Current is sensed by the drop across R_2 which turns Tr_1 on, reducing the gate drive to Tr_2 This closes the loop and maintains a constant current through the LED.

It is important to use a high voltage 1W resistor fo[illegible] or use three 330k 0.5W resistors [illegible] series to avoid breakdown. Diode ZD_1 is a protection zener. An AC detector circuit comprising C_1, R_3, ZD_2 and the low-voltage mosfet Tr_3 lights LED$_2$ when an AC voltage is detected.

Direct current is blocked by C_1 and the negative half cycles are removed by ZD_2. Positive half cycles cause Tr_3 to conduct, lighting LED_2. This LED shares the constant current with no appreciable loss of brightness of LED_1.

Resistor R_3 discharges the gate source capacitance of Tr_3, preventing the LED lingering on when the AC voltage is removed. Capacitor C_1 must be rated at 3kV DC or higher. Zener diode ZD_2 also protects the gate/source structure of the mosfet against high voltages.

Both LEDs are on when AC is applied. The LED current is selected using I_{LED}=0.6/R_2. Values for three common LED currents are as follows: 2mA 270Ω, 5mA 120Ω and 10mA 56Ω. A suitable heat sink must be provided for Tr_2 as this device can dissipate up to 6 watts and will overheat if the LED is on for long periods.

Resistors $R_{4,5}$ with zener diode ZD_3 were added as it was found that transients were damaging white LEDs in the prototype when voltages above 400V were applied. No problems with red and orange LEDs were apparent and I can only assume that the white devices are less tolerant of short duration overload that may occur as the source starts up. Adding these components has solved the problem with white LEDs.

Warning

High voltages can be lethal. Do not attempt to build or use this circuit unless you are familiar with the standards, rules and recommendations relating to working with high voltages.

The voltage range of this circuit may be extended to around 800-900V if the bridge rectifier diodes are rated at 1600V and Tr_2 at 1000V. I suggest using BY228 diodes and a IRFBG20 or STP3NA100FP mosfet.

I have found this circuit useful for many applications, including replacing filament indicator lamps, discharging high-voltage capacitors, providing a constant current for high-voltage zeners and as a test lamp in electrical applications.

Note that as with all high-voltage test equipment, the unit should always be tested prior to use. Double insulation construction techniques should be used and 100mA fused test probes are required if the circuit is to be used as a test aid.

Alistair Borthwick
Edinburgh

Anti-sleep alarm

Inattention, daydreaming and sleep are all factors involved in accidents while driving. This circuit provides a short audible alarm every 5 minutes to prevent sleep or loss of concentration when driving. It works by providing three audible 'blips' of 1kHz - generated every 5 minutes.

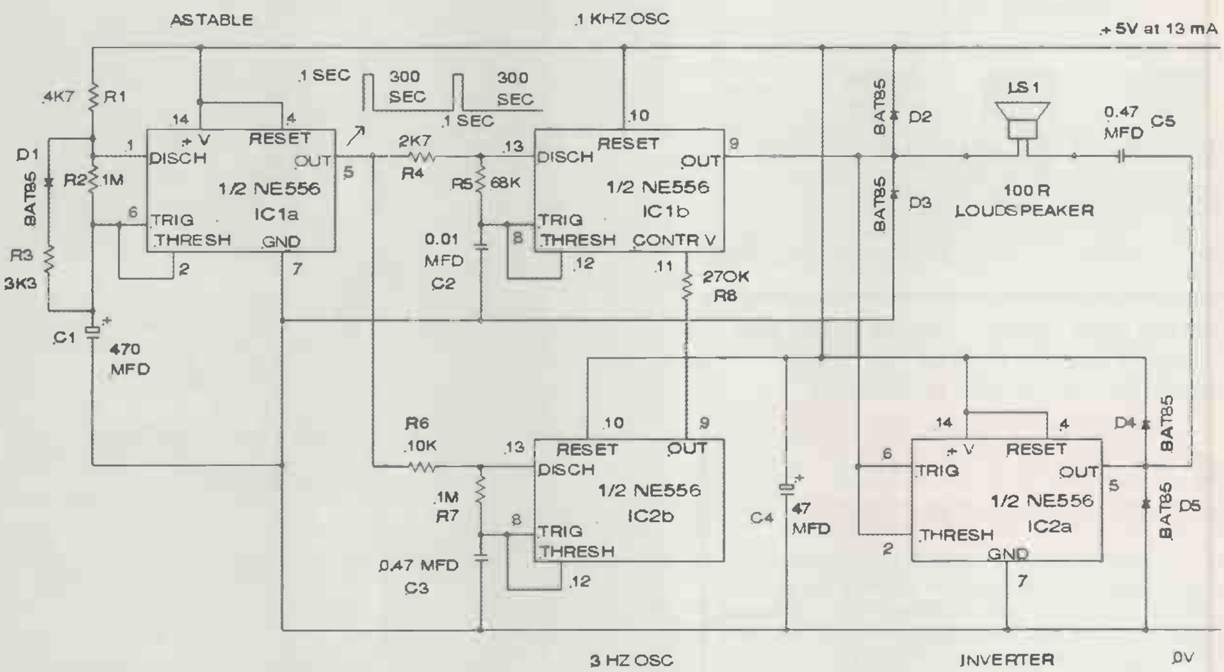
IC1a is wired as an astable oscillator and it produces the basic 1 second / 300 second timing cycle using a 470μF electrolytic capacitor C1. The longer 300 second period occurs as the capacitor is discharged via a 1MΩ resistor R2 into pin 1 IC1a, having been previously charged via a BAT85 diode D1 and the 3k3 ohm resistor R3 in about 1 second. For C1, use a good quality low leakage type as employed in switched mode power supply applications.

Two more astable oscillators, IC1b at 1kHz and IC2b at 3Hz, are enabled when the 'out' pin of IC1a is high. The control voltage input of the 1kHz oscillator (pin 11) is modulated by the 3Hz oscillator output via a 270kΩ resistor R8 to produce a distinctive tone. This circuit operates on 5v to 12v DC. Current consumption of the prototype was 13mA (no sound output) with a 5 volt supply. Sound volume and current taken increase with supply voltage. IC2a operates as a inverter, doubling the signal across the loudspeaker LS1. High speed BAT85 diodes on the 'out' pins suppress transients (D2-D5).

R. Turner
Birmingham UK

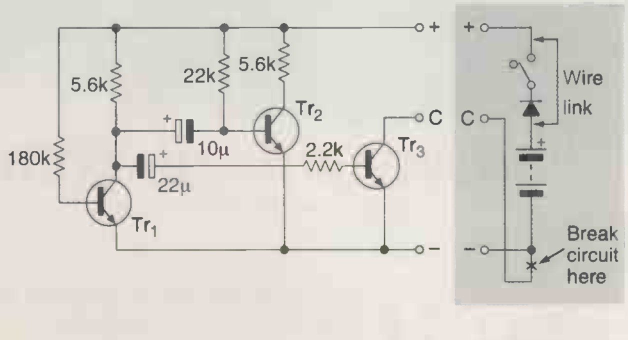
PARTS LIST

2	NE556 dual timer chips IC1, IC2
5	BAT85 fast diodes D1-D5
1	100Ω sounder LS1
1	470μF 25V electrolytic capacitor C1
1	47μF 25V electrolytic capacitor C4
2	0.47μF polyester capacitor C3, C5
1	0.01μF polyester capacitor C2
2	1M carbon film resistor 1/4W R2, R7
1	270k carbon film resistor 1/4W R8
1	68k carbon film resistor 1/4W R5
1	10k carbon film resistor 1/4W R6
1	3k3 carbon film resistor 1/4W R3
1	4k7 carbon film resistor 1/4W R1
1	2k7 carbon film resistor 1/4W R4
1	PC stripboard 80 x 50mm
2	14 pin DIL sockets
1	Battery snap for 9V cell



Tracking transmitter

A simple tracking transmitter-receiver can be constructed by adding this circuit to a standard remote control system used for electric gates, garage doors, etc. The circuit consists of a simple multivibrator, $Tr_{1,2}$, driving a switch. Tr_3.



Short pulses are generated by the circuit. These are transmitted by the remote control. Because the pulses are kept short, they do not to trigger the receiver.

As shown in the inset on the diagram, the remote control unit is modified by shorting out the safety diode and switch. A break is made in the circuit between the battery negative and the rest of the remote. The circuit connects directly to the remote battery and the negative supply of the remote connects to the collector of Tr_3.

Modification of the receiver is carried out by removing the relay and associated components. A simple millivolt meter is then connected to the appropriate point to indicate the signal strength.

Adding this circuit enhancement to a standard remote control unit as used for garage doors, etc.., turns the system into a simple tracking transmitter.

Amrith Ramjewan
Kwa-Zulu Natal
South Africa

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Please allow up to 28 days for delivery

Specifications

Switch position 1

Bandwidth	DC to 10MHz
Input resistance	1MΩ – i.e. oscilloscope i/p
Input capacitance	40pF+oscilloscope capacitance
Working voltage	600V DC or pk-pk AC

Switch position 2

Bandwidth	DC to 150MHz
Rise time	2.4ns
Input resistance	10MΩ ±1% if oscilloscope i/p is 1MΩ
Input capacitance	12pF if oscilloscope i/p is 20pF
Compensation range	10-60pF
Working voltage	600V DC or pk-pk AC

Switch position 'Ref'

Probe tip grounded via 9MΩ, scope i/p grounded

DRM reception using the RX-320

Last month, Roger Thomas reviewed the Ten-Tec RX-320 computer controlled radio receiver. This month he describes some modifications to the unit that enable it to receive DRM broadcasts. Conversion of this product is entirely at your own risk!!!

Just to re-cap, the 'RX-320 DSP PC radio' is manufactured by Ten-Tec in Tennessee, USA. It is a general coverage radio controlled by a PC, with frequency range of 100kHz to 30MHz. The radio is a triple conversion superhet and reception modes are AM, USB/LSB and CW. In the UK this radio is available from AOR TenTecDIRECT.

DRM background

The Digital Radio Mondiale (DRM) consortium was founded in 1998 and represents broadcasters, academic institutions and manufacturers. Its purpose is to develop a non-proprietary technical standard for the replacement of analogue AM (Amplitude Modulation) radio with digital radio, also called DRM. The International Telecommunications Union (ITU), International Electrotechnical Committee (IEC), and the European Telecommunications Standardisation Institute (ETSI) have all approved DRM broadcasts for frequencies below 30MHz.

As a replacement for AM, the existing channel spacing, medium and long wave 9kHz and 10kHz for short wave, is maintained. A DRM radio broadcast provides FM audio quality and most people will relate to the poor audio quality of AM music. Audio deterioration due to radio propagation fading or interference will not be so evident. Providing the DRM decoder software receives enough data correctly, it will be able to accurately rebuild the audio or data as it was originally coded. Also the display of the name of the radio station, programme text, and automatic tuning to alternative frequencies will make DRM receivers easier to operate. DRM can also transmit multimedia html pages and data.

Until there is a DRM receiver chip set, the only way for radio enthusiasts to listen to these broadcasts is to modify an existing short wave radio. This requires a signal from the radio before demodulation, to be fed to the soundcard of a PC for decoding. Suitable DRM decoder software has only recently become available (details later).

DRM modulation

The DRM radio signal consists of data transmitted using COFDM (Coded Orthogonal Frequency Division Multiplex). COFDM is a spectrum efficient digital modulation scheme employing equally spaced carriers across the whole of the radio channel (9kHz for long or medium wave, and 10kHz for short wave). The actual number of carriers depends on the mode and channel bandwidth.**Fig.1**.

Mode A is most likely to be used on medium and long wave using ground wave propagation. On short wave, mode B is for single hop and mode C for long path multi-hop. Mode D is the most robust and could be used for Near Vertical Incidence Skywave (NVIS) broadcasts where the radio signal is broadcast upward and the ionosphere reflects the signal back down. This mode is little used in Europe but is common in the tropical bands as it gives considerable coverage with a single transmitter located in the centre of the broadcast area,

Data to be transmitted is systematically spread across these carriers and each carrier is modulated using QAM (Quadrature Amplitude Modulation). QAM is a mixture of fixed amplitude and phase modulation. DRM incorporates error protection so that selective fading, or interference, with the subsequent loss of some carriers does not affect the overall transmitted data. Although we talk about a DRM signal having many carriers, when the DRM signal is viewed in the frequency domain,

Fig. 1.Summary of DRM broadcast modes.

DRM mode	propagation	carrier spacing	data rate	error protection
A	minor fading	42Hz	highest	lowest
B	as 'A' plus selective fading	47Hz	middle	low
C	as 'B' plus severe fading	70Hz	low	middle
D	as 'C' plus severe Doppler shift	107Hz	lowest	highest

the spectra of each carrier overlaps adjacent carriers.

A typical DRM short wave broadcast (10kHz channel and mode B) would have a data rate of around 21kbps (assuming 64-QAM). A medium wave broadcast that requires the less robust transmission mode A, may have a slightly higher data rate of around 24kbps - even though it occupies less radio spectrum.

DRM multiplex structure

The DRM multiplex is divided into three sub-channels:

1] Each transmission frame contains Fast Access Channel (FAC) data. This FAC 64 bit block contains information to allow the DRM software to decode the multiplex. FAC parameters include: spectrum occupancy, interleaver (0.4 or 2 seconds), MSC modulation mode, SDC modulation mode, number of services, language, audio or data, and programme type.

Whatever the spectrum occupancy or transmission mode, the DRM decoder always needs this FAC information first to know how to decode the rest of the DRM signal. Consequently the FAC is always transmitted in the same place using 4-QAM and at a fixed code rate.

2] The Service Description Channel (SDC) contains information about all the services available and is transmitted every 1.2 seconds. It is primarily intended to give the listener information about the tuned DRM radio station and is similar in operation to VHF-RDS. It includes the radio station name (up to 16 characters), alternate frequency and schedule information, coverage area, time and date.

3] As the name would suggest, the Main Service Channel (MSC) contains the data for all the services contained in the DRM multiplex. The multiplex may contain between one and four services, and each service may be either audio or data. Audio streams comprise compressed audio data and can also carry text messages over several audio frames. These text messages require very little bandwidth (approximately 80bps).

The MSC may use either 64-QAM or 16-QAM on each carrier. 64-QAM provides high spectral efficiency whereas 16-QAM provides a better performance in the presence of errors caused by poor propagation conditions.

Audio coding

DRM uses aacPlus™ Coding Technologies audio compression. This is a combination of MPEG AAC (Advanced Audio Coding) and SBR (Spectral Band Replication). SBR is a technique that increases bandwidth of the audio signal from a combination of a low bandwidth AAC signal and SBR data that reconstructs the higher audio frequency.

An AAC basic audio signal provides a frequency bandwidth of 6kHz, still better audio quality than standard AM (4.5kHz or 5kHz), plus the frequency enhancement using SBR extends this to 15.2kHz (equivalent to FM radio quality).

Radio modifications

We can no longer think in terms of demodulating either AM upper or lower side band with DRM as the data can occupy the whole radio channel. It is true that there is a simulcast mode with DRM occupying the upper side band and the lower side band carrying AM, but the majority of DRM test transmissions occupy the full channel. Consequently modifying radios for DRM usually involves replacing the IF filters with filters of a wider bandwidth. This modification can cause problems as noise or interference from the local oscillator could be introduced into the IF that were previously outside the AM IF filter pass-band and were thus attenuated.

Also the IF in most short wave radios is typically 455kHz and this has to be mixed with a 433kHz or 467kHz local oscillator (usually a crystal) to produce the IF centred on the 12kHz required by the Fraunhofer DRM decoder software (described later). It is not possible to feed the 455kHz IF signal direct to the soundcard as the frequency is much higher than a soundcard can handle, so the receiver's IF signal needs to be shifted down in frequency.

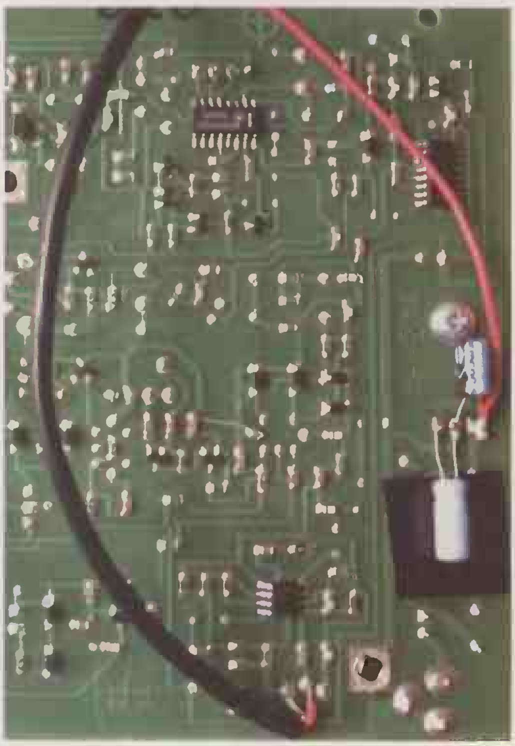
It is not feasible to connect the audio output from an AM receiver to the PC soundcard. A DRM signal is modulated in QAM, so both the phase and amplitude of the transmitted signal are needed to be able to decode the DRM signal. In AM demodulation all phase information is lost.

RX-320 radio

The RX-320 already has IF filters that are wide enough (15kHz) to accommodate a DRM signal and it has a final IF of 12kHz that feeds the internal DSP from the RF board. This makes the conversion very easy. Unlike the modifications required for other receivers there is no replacing of components or cutting printed circuit board tracks to insert components.

This conversion does *not* affect in any way the reception of existing modes or operation of the radio and you can continue to enjoy AM broadcasts (while they are still transmitted!) If you modify your RX-320, then you will be able to directly compare analogue AM and digital DRM broadcasts and decide if the inherent advantages of digital DRM broadcasts will lead to the demise of analogue AM radio.

Fig. 2. Underneath of RF board showing surface mount components and the position of screened cable for the 12kHz IF.



Taking the RX-320 apart

The RX-320 consists of two printed circuit boards, on top is the RF board and underneath the aluminium chassis is the DSP board. Both these circuit boards bolt onto the aluminium chassis using stand-offs.

The screened cable is the filter op-amp output carrying the 12kHz signal to the DSP IF board from the RF board. This is the signal that we also want to feed into the computer's soundcard so that the PC can decode the received DRM signal. The RF circuit board needs to be turned over so that a screened cable can be soldered to this 12kHz connector.

Unplug all the leads

and the telescopic aerial and remove the upper half of the case to expose the top board. The RF board is secured to the chassis by three screws, remove these and gently turn this board over so that the underside is visible with the surface mount components. Care needs to be taken as the external aerial socket is directly mounted to the printed circuit board and protrudes through the back panel.

DRM modifications

Solder one end of a screened cable core to the connector's middle pin and the cable screen to either side of this connector. Replace the board and three screws on the stand-offs. There is sufficient room for this cable to pass underneath the board. This new lead will need to be connected to a suitable jack socket. Note that the wire link visible in the centre of the photo was done by the manufacturer and nothing to do my DRM modifications, **Fig. 2.**

If you don't like the idea of drilling holes in the case to house the jack socket, then there is an alternative that I used on my RX-320. In fact, there are already two holes drilled in the front panel which are used to hold the Ten-Tec plastic logo. This plastic logo is not just stuck on to the front panel as you would expect but has two locating lugs that secure it to the front panel. To be able to use these holes, the manufacturer's logo has to be removed (sorry Ten-Tec).

On the rear of the front panel remove the glue that holds the plastic logo in place. When all the glue is removed gently push on the two plastic lugs to force the logo from the front panel. This will reveal two small holes of 3mm diameter and 13mm apart.

I removed the front panel by undoing the two screws that hold the panel to the internal chassis, and used a tapered reamer to manually enlarge one of the holes so that a 3.5mm jack socket could be fitted. The jack socket is the same size as the existing audio output sockets on the rear panel so that all the audio leads are interchangeable. Drilling holes in situ in not advisable as metal debris could fall on the circuit boards.

If you think that there should be the manufacturer's logo on the front panel, then remove the two plastic lugs so that the back of the logo is flush, and glue it in a suitable position on the front panel.

On the 3.5mm jack socket I wired a 0.1µF electrolytic capacitor in series with the 12kHz signal. This capacitor is intended to give some isolation between the radio and PC and should prevent any faults or interference from the computer being fed directly back to the RX-320's DSP, **Fig. 3.**

The second logo panel hole can also be used to our advantage. There is no indication if the RX-320 radio is switched on so I have used this hole, conveniently 3mm diameter, to accommodate a 3mm LED. It was possible to insert the LED directly in the hole but I used the reamer to slightly enlarge this hole to accommodate a suitable clip so that the LED is held more securely.

I used a high efficiency type LED with a 4k7 current limiting series resistor. The LED is wired direct to the voltage input of the voltage regulator – this is the red wire visible in Fig. 2. There are many other positions on the circuit board for finding a suitable voltage.

Glitches

The two electrolytic capacitors visible in Fig. 2 are not part of the DRM modification. I occasionally found that switching on of some domestic appliances caused a glitch in the mains supply and this produced a momentary drop in audio. This was not a particular problem when listening to AM radio but it did have, literally, an unsettling effect on the level of the DRM signal and sometimes caused the decoder software to lose synchronisation. Adding these capacitors to the input and output of the voltage regulator helped reduce the effect.

Audio connections

There are now two outputs from the RX-320 that need to be connected to the computer's soundcard - the normal demodulated audio from the DSP (rear panel) and the 12kHz IF signal (front panel). The audio line output of the RX-320 is connected to the line-input of the soundcard. The RX-320 line output volume must be set using the RX-320's control program and the mixer microphone input level set low otherwise the fixed amplitude audio signal could overload the soundcard's input, **Fig. 5.**

The PC's soundcard is used as a low cost analogue to digital converter – the 12kHz signal is treated as an audio signal, but remember that it is not demodulated audio. The 16-bit soundcard needs to support a 48kHz sample rate and must also allow duplex operation so that as the DRM signal is fed into the DRM decoder software it can output the decoded audio.

I have a SoundBlaster Live! 1024 PCI card and found no problems. However, some soundcards will not work,

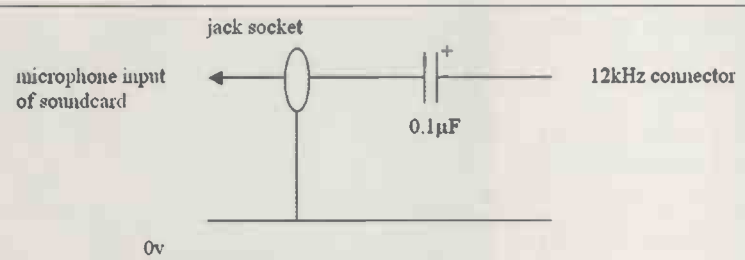


Fig. 3. 12 kHz DRM output jack socket wiring.

Fig. 4. RX-320 DRM modified front panel, incorporating the 12kHz output jack socket and LED.

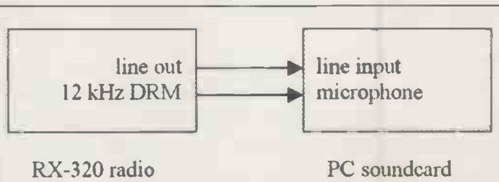


Fig. 5. RX-320 to PC soundcard audio connection.

particularly some of the integrated multimedia devices found on motherboards. The DRM web site has a soundcard forum for more information on this subject.

Mixer program

The Windows Play Control software is required so that the appropriate input can be selected and the output volume set. If the volume control is not visible on the taskbar it can be found in the Accessories/Entertainment directory from the Start/Programs menu (XP). With the SoundBlaster soundcard both volume and microphone have advanced option buttons - the microphone option has a +20dB boost, which should be disabled and the volume control has tone controls. Other soundcards may have different options, but any input filter options or automatic gain control should be switched off.

When the DRM decoder software is running the line-in and microphone input should be muted as the software decoder is sending the DRM decoded audio to the 'wave' output, and you'll need to adjust this wave slider as appropriate. The Play Control slider sets the overall volume.

If you select Line-in or Microphone on the Play Control when tuned to a DRM station all you will hear is high frequency noise. DRM COFDM signals do not have any discernible audio pattern. For normal AM audio - only mute the Microphone input.**Fig. 6.**

The Record Control does not need to be altered, as the above setting will work for either DRM or normal AM audio.

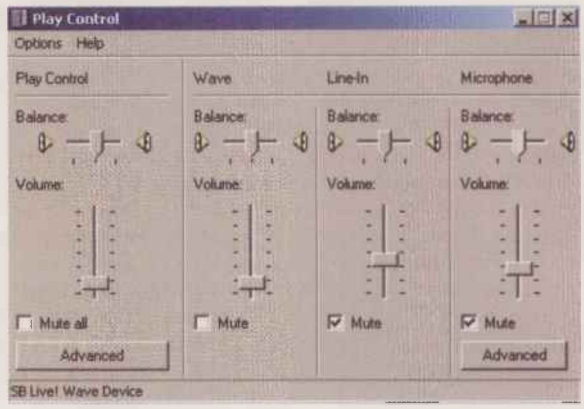


Fig. 6. Windows XP Play Control controls set for DRM.

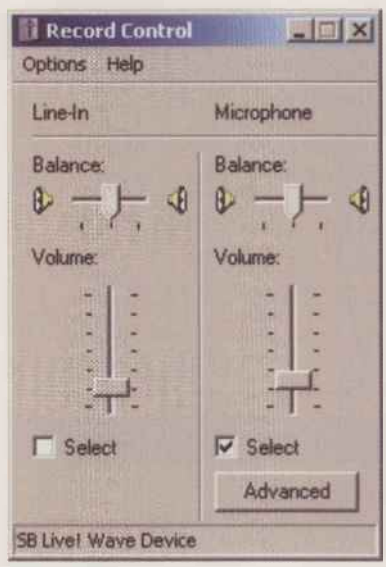


Fig. 7. Windows XP Record Control.

DRM decoder software

There are two programs available that can decode the data transmitted in a DRM signal and produce an audio output.

The DRM consortium decoder software is called 'DRM Software Radio' and is written by the Fraunhofer Institut Integrierte Schaltungen (Institute for Integrated Circuits). Fraunhofer IIS is a founder and leading member of the DRM consortium and wrote DRM decoding software, called 'FhG Software Radio', using the output from a modified AOR AR7030 receiver. This software and modified radio was sold to broadcasters and commercial organisations.

DRM Software Radio is a scaled down version of the commercial FhG Software Radio program and version 1.0.18 was eventually released on the 31st of December 2002. This software is for personal use and cost me £36.71 (60 euro). DRM claim that this software is sold on a not-for-profit basis. This 'nominal modest charge' for the software licence is to cover various royalty and licence payments, primarily for the audio aacPlus codec software, Fraunhofer software development costs and maintaining the drmrx.org web site. This software requires over 25 Mbytes of disk space and has over 570 individual files.

What has been left out of the DRM Software Radio version is all the different signal monitoring options – the only option available is to display the spectrum of the input 12kHz signal. The ability to save the decoded digital signal or audio to hard disk is not available.

Also missing are details on the DRM multiplex decoded from the FAC information. This is a strange decision as the FhG Software Radio displays this information. The software is aimed at radio enthusiasts and radio amateurs who would be interested in the more technical aspects of DRM. The software does display information on the individual services as a DRM multiplex may have up to four different services available.

Downloading the software

To get your copy of this decoder software you will need to go on-line to the www.drmrx.org web site and click purchase software. After a few information screens you are transferred to a secure transaction server for details of you credit card, address and e-mail. After successful payment there is a link back to the www.drmrx.org web site where the decoder software can be downloaded. This file is 13Mbyte and took me 50 minutes to download using a 56kbps dial-up modem. The small 'keyfile' to enable the software to run is e-mailed to you direct from VT Merlin Communications.

Support for the software is only available via the drmrx.org web site and that the web site will cease operation at the beginning of 2005. New versions are free to registered users to download from the web site.

Set-up

After the DRM Software Radio has been installed, there are very few items that need to be set up. The program prompts for your latitude or longitude and a disk directory. The reason for this is that as DRM is a digital transmission, the usual subjective SINPO (signal strength, interference, noise, propagation, overall merit) figures are no longer relevant. Instead the software can measure the quality of reception by the number of audio data blocks received correctly on a minute by minute basis. The DRM Software Radio software saves this information in a text file in the designated directory.

The latitude and longitude determine where DRM reception took place, this identifies if the listener is in the designated broadcast target area or not. If you don't know your latitude or longitude the software comes with a database of airports(!) Select your nearest airport from the list, then enter your position relative to this airport and the software will automatically calculate your latitude and longitude location. **Fig. 8.**

It is not necessary to do this immediately as whenever the Start Record button is pressed the Record form appears and the frequency, latitude and longitude numbers can then be entered by the user. Pressing the Calculate button displays the list of airports.

Clicking on the Set-up button produces this simple form, **Fig. 9.**

The software automatically allocates the first soundcard it finds but the option is there to choose another soundcard if your PC has more than one. The spectral inversion option is required as it is possible with an AM receiver that the IF spectrum we are feeding into the soundcard is inverted. This inversion does not matter for demodulation of AM side bands, but it does matter when decoding DRM.

The Disable Multimedia option is required only if the decoder software is running on a computer that does not have an Internet connection and therefore may not have html multimedia support.

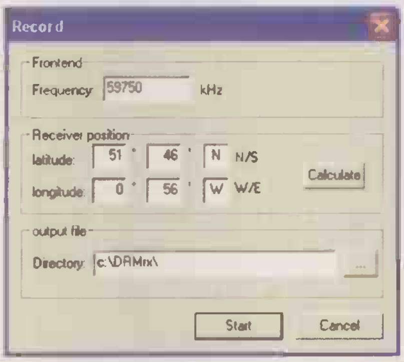


Fig. 8. Pressing Record on the main form displays this pop-up menu.

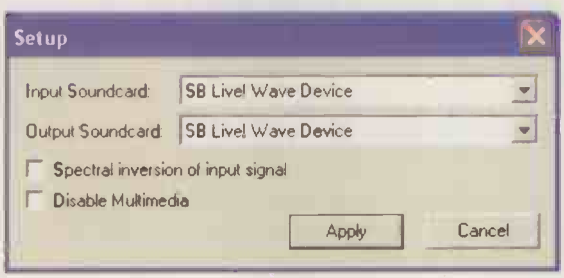


Fig. 9. Setup options form.

Cost of software

Personally I think the cost of this software may put some enthusiasts off the idea of modifying their radio equipment. It is not possible to know how successful any receiver modification has been until the DRM software has been purchased. Although viewing a DRM signal using spectrum analyser software may give the appearance that the signal is being received correctly centred on a 12kHz IF, this does not guarantee that the DRM software can properly decode the phase and amplitude of each carrier.

If the modifications don't work then you may be left with redundant software and a credit card bill.

'Dream' software

There is an alternative DRM decoder software that is free for personal use under the terms of GNU General Public License (GPL).

The Darmstadt University of Technology, Institute for Communication Technology have available for download a DRM decode program called 'Dream' - as in DR(ea)M. These Windows and Linux programs are written by Volker Fischer and Alexander Kurpiers and they should

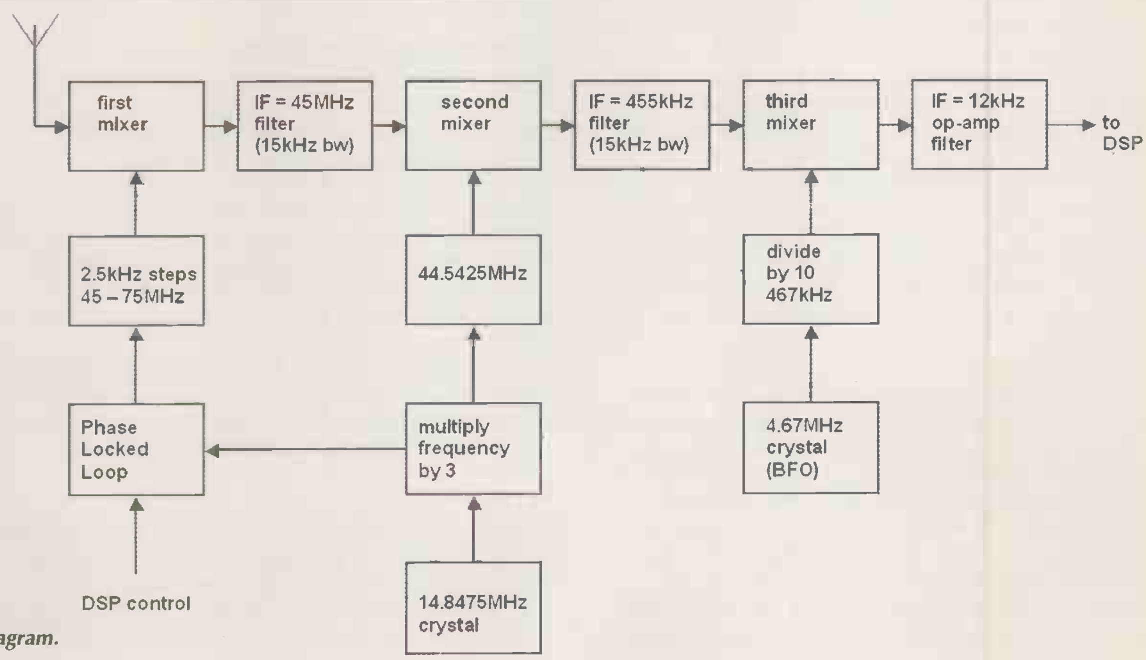


Fig. 10. RX-320 block diagram.

RX-320 tuned frequency (MHz)			RX-320 IF frequency	Fraunhofer software	Dream software
	15.443751	15.446250	6.0kHz	will not decode	will decode
	15.441251	15.443750	9.5kHz	will not decode	will decode
▲	15.441250				
15.440			12.0kHz	will decode	will decode
▼	15.438751				
	15.438750	15.436251	14.5kHz	will not decode	will decode
	15.436250	15.433751	17.0kHz	will not decode	will not decode

Fig.11. Effects on the DSP IF of tuning either side of a DRM signal centred on 15.440 MHz

be congratulated for putting these into the public domain. However there is no .exe file available from this site, only the Visual C++ source code. The reason for this is the Dream program uses open source code from several sites. Anyone is free to download and use the source code but the licence does not necessarily give the right to distribute the resulting binary or .exe file without paying royalties.

This version of Dream does not have any multimedia support and the SBR part of the audio codec is not yet implemented (only AAC decoding) so the sound quality is worse than the Fraunhofer program. However, as the source code is in the public domain, hopefully other programmers will help improve the software.

Unlike the Fraunhofer software, this DRM decoder software scans the entire sound card bandwidth looking for DRM signals and no particular IF is needed. It is this fact that makes it suitable for use with the RX-320 as we shall see later. For use with other receivers, then a down converter mixer circuit is still required but there is a wider choice for the local oscillator frequency as a mixer using a 467kHz crystal can be expensive. This software expects the DRM signal on the microphone input.

Triple superhet

As already established, the RX-320 radio is a triple conversion superhet with intermediate frequencies of 45MHz, 455kHz and 12kHz. The first local oscillator in the RX-320 operates over a range of 45-75MHz so the incoming radio signal is shifted up in frequency. As can be seen on the block diagram, this first local oscillator synthesiser is tuned in steps of 2.5kHz controlled by the DSP and the fine-tuning is done in DSP software.

Tuning the radio to a particular frequency requires the PC control software to calculate and send three parameters to the RX-320. The first is the coarse tuning and represents the number of 2.5kHz steps required to get as close to the required frequency as possible. The second parameter is for DSP software fine-tuning and represents the difference between the coarse and required frequency. Third parameter is BFO settings if the receive mode is SSB or CW, **Fig. 10.**

This coarse tuning causes a problem as there are received frequencies that produce a DSP IF that is not centred on 12kHz but either 6kHz, 9.5kHz, 14.5kHz or 17kHz. This is the DSP IF with offset plus or minus multiples of the 2.5kHz tuning step and the whole spectrum of the received IF signal is shifted accordingly.

The RX-320 DSP software then automatically adjusts for this frequency shift using the fine-tuning information calculated by the PC control software, but the Fraunhofer DRM decoder software requires a DRM signal centred on 12kHz. As we are not using the RX-320's DSP to decode DRM then selecting different filter bandwidths does not alter the 12kHz IF signal, only how the DSP software decodes the 12kHz signal.

Fortunately this multiple IF tuning is not as bad as it first appears, dividing any RX-320 received frequency (in kHz) by 2.5 (tuning step) that yields a remainder of 0 will result in a 12kHz IF. **Fig. 11.**

Channel spacing

The vast majority of short wave broadcasters use frequencies that either end in 0 or 5 (kHz), therefore for these broadcasts the RX-320 will produce a 12kHz signal suitable for the Fraunhofer DRM decoder. This is the internationally agreed ITU band plan of 5kHz channel spacing for short wave. There are a few short wave stations broadcasting, particularly in the tropical bands, that do not adhere to the 5 kHz channel separation, but practically all the short wave stations that we are likely to listen to in Europe will have this 5kHz spacing.

In the UK and Europe the current band plan for

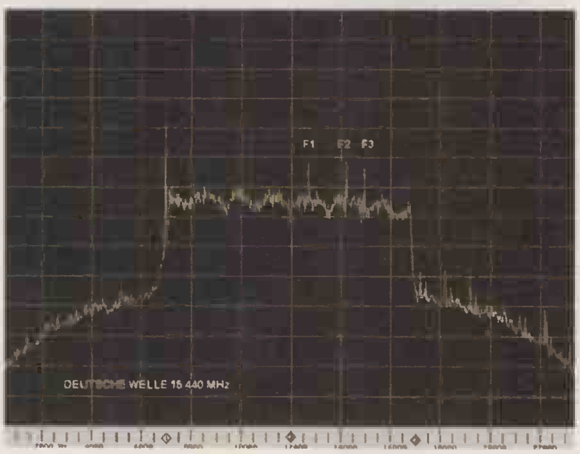


Fig. 12. Spectrum of 12kHz IF DRM short wave radio signal using Spectrum Lab software

Fig. 13. Frequency measurement of DRM FAC carriers

FAC	Measured Frequency	calculated frequency	actual frequency	offset
F1	12672Hz	672Hz	750Hz	78Hz
F2	14172Hz	2172Hz	2250Hz	78Hz
F3	14922Hz	2922Hz	3000Hz	78Hz

medium and long wave is based on 9kHz channel separation. At present in the UK there are no DRM stations operating in these bands and we are unlikely to have any before the widespread availability of DRM receivers.

It is possible due to the nature of the RX-320's synthesised tuning that there will be received frequencies that do not produce a 12kHz IF. On medium wave, frequencies such as 630kHz, 1170kHz, 1215kHz should be received correctly. As can be seen from Fig. 9, frequencies 1kHz either side of a frequency ending with 0 or 5 should also produce a 12kHz IF (such as 909kHz). Any DRM stations on these frequencies should be decoded by the Fraunhofer software. However there are frequencies such as 828kHz, 882kHz, 1053kHz that the Fraunhofer software will not be able to decode, but the Dream software should.

DRM can support single frequency networks so the current band plan will need to be altered. Also the DRM specification allows for many different channel occupation bandwidths including 18kHz for medium wave and 20kHz for short wave. I am sure that the DRM stations, once established, would push for this spectrum increase as it would allow DRM stations to broadcast in stereo and compete with VHF-FM radio.

Spectrum analysis

To view the DRM signal being fed into the soundcard I used the excellent Windows Spectrum Lab program written by Wolfgang Buescher, DL4YHF. This program is free software under the terms of the GNU General Public License and is a useful initial check to see if the radio modifications result in a 12kHz IF. As stated previously, you cannot assume that because the radio signal is correctly centred on 12kHz that it is suitable for decoding.

Some of the DRM carriers **(Fig. 13.)** do not transmit programme data but instead are used by the DRM receiver software to synchronise to the DRM signal. These Fast Access Channel (FAC) reference carriers have their amplitude boosted relative to carriers carrying data by a power gain of 2. The DRM software examines the amplitude difference between data carriers and these FAC reference carriers to help achieve synchronisation.

Screen shows the spectrum of a received 12kHz DRM signal sampled at 48kHz with averaging. The three FAC reference frequencies are marked F1, F2, F3.

The difference between the measured frequency and expected FAC frequency can be explained by the RX-320 IF not being exactly 12kHz or the soundcard may not be sampling at exactly 48kHz, probably due to crystal tolerances.

The spectrum plot also shows that there is no spectral inversion as the FAC carriers should be where, in conventional AM, the upper side band would be located. Carriers close to the band edge can also be boosted by a power gain of four, but not all broadcasters do this.

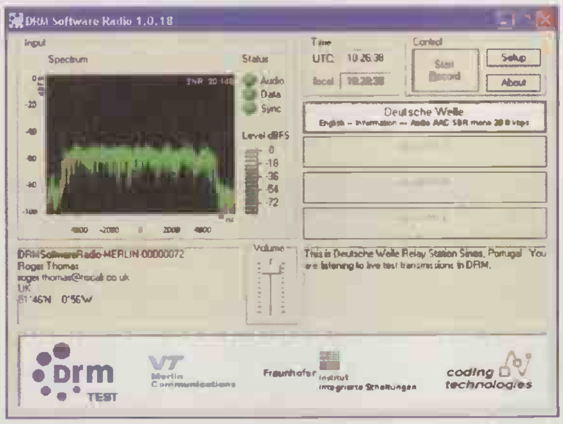


Fig. 14. Deutsche Welle 15.440MHz broadcast - the boosted band edge carrier is clearly visible.

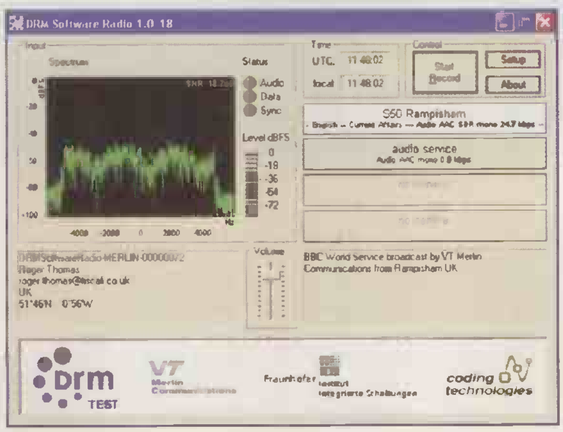


Fig. 15. BBC World Service broadcast from Rampisham, Dorset.

DRM stations received

For DRM reception, the signal to noise ratio (SNR), as measured by the decoder software, is the most important factor. Most transmissions on short wave require a minimum SNR of 12 to 18dB.

The following long-term DRM test transmissions have all been received using the RX-320. Not all transmissions were received on a daily basis, partly because these are test transmissions and are liable to change or cancellation and also radio propagation varies from day to day. Check the Radio Netherlands web site for the latest DRM test timetable.

The aerial used was a long wire feeding a broadband magnetic balun and the 50 ohm output from the balun is connected to the antenna input of the RX-320 using a metre of co-axial cable. The internal telescopic aerial was satisfactory for all the DRM transmissions but the long wire was slightly better for some of the transmissions.

Examples of DRM stations

The following screen shots are of DRM test stations as received using the Fraunhofer DRM Software Radio. Each radio station uses slightly different DRM parameters and this shows up in the audio data rate figure. In general the higher the audio bit rate - the higher the SNR needs to be to decode the audio. The text message is transmitted as part of the audio frames.

Deutsche Welle

Deutsche Welle broadcasts from a transmitter located in Sines, Portugal with these transmissions targeted at Western Europe. This DRM radio station is usually the strongest and most reliable of all the DRM test stations.

BBC World Service

BBC World Service is broadcast from a transmitter located in Rampisham, Dorset, UK and is operated by Merlin Communications. These broadcasts are directed towards Europe or Scandinavia, so reception here was sometimes poor and other times excellent. As these are test transmissions, different parameters and configurations are being tried. **Fig. 15.** demonstrates this - as the second audio channel does not have any bits allocated!

I have received the 9.78MHz broadcast with AAC mono at only 11.6kbps with audio quality no better than

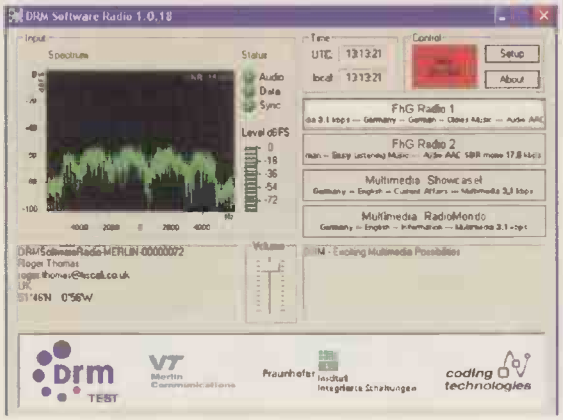


Fig. 16. Deutsche Telekom multimedia broadcast on 5.975MHz from Juelich, Germany.

Fig. 17. DRM transmitted web site from Deutsche Telekom.

Fig. 18. Example of DRM multimedia transmitted by Deutsche Telekom.

AM and broadcasts at a higher bit rate at AAC SBR mono 24.7kbps. The BBC also broadcasts DRM to North America using Radio Canada's Sackville transmitter (6.010MHz).

Deutsche Telekom

DRM multimedia broadcast from Deutsche Telekom (T-Systems), as the jingle says 'DRM ... the digital future of AM radio'. AAC SBR mono audio transmitted at 17.8kbps and multimedia transmitted at 3.1kbps. Although the number of DRM services is overstated, there is actually only one shared audio service, not two separate audio services as suggested. There are two types of multimedia transmitted - those pages associated with the audio service (Program Associated Data) and independent multimedia services. The Fraunhofer decoder software is able to display DRM multimedia pages but not the current version of the Dream software.

Radio Netherlands

The following screen shows the Dream software decoding the Radio Netherlands 15.170MHz night time broadcast from Bonaire, Netherlands Antilles. In case you are wondering where Bonaire is, it is a small island off the coast of Venezuela. These broadcasts were more difficult to receive.

Dream provides more technical information derived from the FAC of the received DRM broadcast than the Fraunhofer decoder, including various chart display options. The software also confirms the small frequency offset inherent in the soundcard sampling.

DRM reception report

Reception information can be saved to disk when using

Fig. 19. Radio Netherlands broadcast on 15.170MHz.

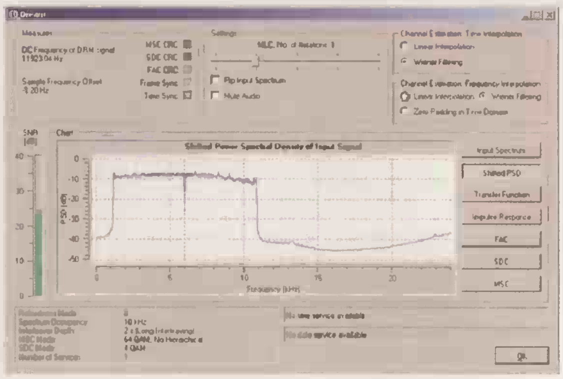


Fig. 20. Selecting the View option displays this form (Radio Netherlands broadcast 15.170MHz).

web sites

www.drm.org (DRM consortium site)
www.drmrx.org or www.drmswr.com (DRM software homepage)
www.codingtechnologies.com (aacPlus homepage)
www.qsl.net/dl4yhf (SpecLab homepage)
www.tu-darmstadt.de/fb/et/uet/fguet/mitarbeiter/vf/DRM/DRM.html (Windows Dream page)
www.tu-darmstadt.de/fb/et/uet/fguet/mitarbeiter/kur/linux-soft.html (Linux Dream version)
sourceforge.net/projects/drm (Dream source code files and Dream forum)
www.gnu.org/copyleft/gpl.html (information on General Public License)
www.audiocoding.com (MPEG-4 audio codecs)
www.merlincommunications.com (Merlin)
www.rnw.nl (Radio Netherlands)
www.rnw.nl/realradio/html/drm_latest.html (latest DRM timetable)

the Fraunhofer decoder by pressing the 'Start Record' button. An example of the contents of a DRM-Software-Radio.log is shown in **Fig. 21.** this shows reception of Deutsche Welle DRM broadcast from Sines in Portugal using the RX-320 and the telescopic aerial.

Listening to the broadcast I did not hear any fading or audio dropouts. The SYNC column indicates the number of FAC frames received correctly. Apart from minute 8 were one frame was not decoded, all FAC frames were received. The /10 in the AUDIO column indicates there are 10 audio frames per transmission frame in this broadcast. As there are 150 transmission frames per minute this results in 1500 audio frames per minute. The loss of a few audio frames does not cause any loss of audio output.

>>>>
DRMSoftwareRadio-MERLIN-00000072
Software Version 1.0.18
Starttime (UTC) 2003-01-01 11:04:34
Frequency 15440 kHz
Latitude 51°46'N
Longitude 0°56'W

CRC: 0x6252

Minute	SNR	Sync	Audio	Type
0000	21	150	1500/10	0
0001	21	150	1491/10	0
0002	20	150	1500/10	0
0003	20	150	1500/10	0
0004	21	150	1510/10	0
0005	20	150	1499/10	0
0006	21	150	1500/10	0
0007	21	150	1495/10	0
0008	21	149	1490/10	0
0009	21	150	1500/10	0
0010	20	150	1500/10	0
0011	19	150	1498/10	0
0012	19	150	1500/10	0
0013	20	150	1500/10	0

Fig. 21. Contents of file DRMSoftwareRadio.log of received DRM broadcast

<<<<

The format is –
License number and software version.
Start date and time in ISO 8601 format.
MINUTE: minute by minute signal analysis.
SNR: average signal to noise ratio.
SYNC: number of frames where the Fast Access Channel data was received correctly.
AUDIO: number of error free audio frames received / number of audio frames per transmission frame.
TYPE: 0 = AAC (audio).
CRC: Cyclic Redundancy Check.

DRM reception

The first thing that I noticed is that speech is clearer and the music quality is good. On reasonable strength signals there is none of the distinctive audio distortion caused by selective fading that we are accustomed to hearing on short wave, or any background noise. Watching the spectrum display you can see the turbulent effects of ionospheric propagation on the radio signal.

With a good signal strength the whole process of synchronisation and decoding can take between 10 to 25 seconds before hearing the transmitted audio. On weak signals the FAC information may be decoded but until the received signal level achieves a higher SNR then there is no audio but when there is no audio there is no noise - only silence.

When the signal strength drops below a critical SNR and audio data is lost due to too many data errors received the FhG software decoder software will for a very short time repeat the last good audio block, in the expectation that the signal level will recover. The Dream software simply mutes the audio.

On short wave DRM listeners will have to put up with an occasional loss of audio caused by a deep propagation fade, this will occur however good the receiver or decoder software. Worst case is the signal strength constantly varying around this critical signal level. The audio becomes very strange with short bursts of sound, then gaps.

When this happens speech can become incomprehensible. Listeners to such a broadcast may conclude that DRM doesn't work. This aspect of digital radio is going to be the most difficult to explain to the mostly non-technical general public. ■

Dinosaur computers

In 1962, main memory was either delay line or magnetic core memory. Logic was a completely different technology and comprised circuits made up by wiring together individual transistors and resistors. A limited communication channel between memory and processing, later called 'The Von Neumann Bottleneck', resulted inevitably from the use of two disparate technologies. Following on from an article in the January issue of *Electronics World* by Nigel Cook, Ivor Catt looks at what might have been, had anybody listened.

In R&D at Ferranti Ltd., West Gorton, Manchester, where we designed and built computers, there was an in-house one day conference in late 1962 to discuss the significance for computer design of the newly arriving integrated circuit which contained more than one component fabricated together on a single chip. Semiconductor technology looked set to take over the two previously separate roles; memory and processing.

Ferranti's brightest engineer, K. C. Johnson (Ken Johnson) drew a transistor bistable (= memory bit, now called SRAM) on the board, and pointed out that with a (totem pole of) one further transistor per bit, a full column of bistables could be searched in one cycle to look for the presence of one or more 'ones' stored as shown in **Fig.1.** (DRAMs had not been thought of then). This had a traumatic effect on me. It meant that the historic reason for separating processing from memory (via the "Von Neumann Bottleneck") had disappeared.

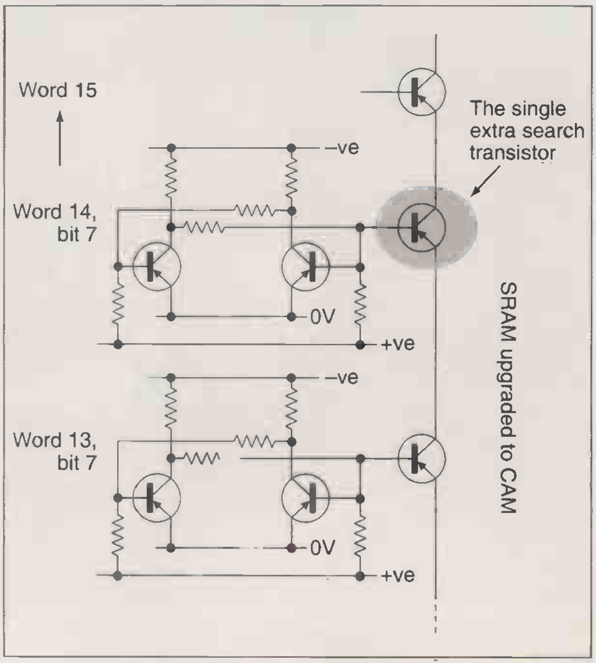
The first technically achievable stage in complexity would be for a single instruction to cause every word with (say) 1101 as its most significant four bits, to exit memory one at a time. That was called a 'Content Addressable Memory' or CAM. In England it was called an 'Associative Memory'. That was the next thing to fabricate after we had mastered the fabrication of semiconductor RAM.

These were comparatively primitive times. Note that even some years later, in 1966, the semiconductor house where I worked, Sperry Semiconductor, earned its spurs by successfully fabricating a copy of the Honeywell-Transitron 16-bit memory; a chip containing all of 16-bits of RAM, stored as 16 transistor bistables. This compares with today's 16Mbit RAM, a million times more on a single chip. The next step in sophistication, after causing the reading of words out of memory addressed by their content, would be to cause all words with a certain content to have a specified operation done on them in situ in memory, all in parallel.

Back to the future

Soon after success (i.e. a good yield) with the 16-bit memory chip, the first content addressable memory should have been built, in around 1968. Not only was it not built then; it has still not been built today, a quarter of a century later. The first step towards distributed processing, or array processing, has not been made. We remain stuck in 1966. My article on the problem, 'Dinosaur among the Data?'[1] was published in *New Scientist*, 6 March 1969, pp501/502, but only because the sub-editor, whom I visited, thought my article discussed the fashionable question;

Fig 1: SRAM upgraded to CAM.



"Can computers think?". I vividly remember his crestfallen face when he realised, too late, that he had been trapped into publishing an article on computer architecture, which had no meaning for him. There was already an embargo on discussion about advances in computer architecture. Programmers wrote books and articles urging that the hardware of computers be frozen for a decade so that the software problems could be sorted out. Meanwhile, Professor Michie and the like boasted that anything we would ever want to do would be achieved with the single processor Von Neumann Computer. He was widely admired for the wisdom of his statement, and for his ability to fathom the hi-tec future.

In around 1970, the late Gordon Scarrott promoted CAFS, a content addressable file system which was used for telephone directory enquiries. However, this was not the needed key breakthrough made possible by merging the two functions, memory and processing, in the single new (semiconductor) technology. Even so, CAFS was revolutionary enough for Scarrott's boss, the head of ICL, to try to fire him, only to be restrained by his board of directors. Hostility to innovation, however great its financial payoff, ran deep in both the computer and in the semiconductor industries, as it does today. Scarrott was cut off from the microelectronics industry where I worked for many years, so his proposed DAP, Distributed Array processor, was stunted, using conventional chips rather than a complete undiced wafer. So his machine had only 16 or perhaps 64 processors, rather than the million that I proposed. Such (coarse grain) arrays made up of a small number of powerful processors have discredited rather than promoted large scale (fine grain) array processors. Amdahl, who raised $200 million to fail with his massive brute force WSI programme in his company Trilogy, was so revered for this failure, that he was then flown over to England by the IEE to tell us that a five processor machine ran no faster than a single processor machine, concluding that there was no point in having more than one processor.

Fig 2: Cover page of Electronic Design, October 26, 1989

Water cooling spoof

Two months after I arrived to work at Motorola Integrated Circuit R&D in Phoenix in 1966, I proposed a very small (one foot cube) and therefore very fast computer using individual hand wired integrated circuit chips totally immersed in liquid in direct contact with the active integrated circuit chip surface. Short interconnections would make it fast, and liquid would extract the high power of the fast circuits. Walt Seelbach, deputy head of R&D, told me he thought my report was amusing, obviously thinking it was a spoof. That silenced me and I resorted to making only one innovative proposal in each of the companies that hired (and fired) me.

By 1972, after my latest firing, by CTL in England, I had enough material to patent the mature Wafer Scale Integration idea - a self organising, self repairing memory system on a whole wafer[2]. An inventor is wise to get himself fired for technical incompetence before patenting, because this makes it difficult for his employer to claim that it was while working for them that he came up with the brilliant technical invention. He is not acting dishonestly, because if he reports his invention while employed, any British hi-tec company management will make sure neither the company nor anyone else will ever profit from it. Rapidly escalating profitability in a company, which is what major invention threatens, puts the technology-free management at risk, because they lose control to the technocracy.

Many years previously, I thought it might be possible to insinuate innovation into such a conservative industry without the attempt being noticed and blocked. I planned to try in the following way.

Surreptitious

Even though computers were admired within and outside the industry for their unreliability; for the fact that if only one component failed, the whole £100,000 computer system stopped functioning; I thought that my Wafer Scale Integration (WSI) design of a self-organising, self repairing memory might not cause too much fear and hostility. I would propose a cheaper, because whole wafer, self organising, self repairing WSI RAM memory as a plug-in to replace the conventional, more expensive, less reliable RAM memory made up of individual RAM chips from a diced wafer interconnected on a printed circuit board. My memory would be cheaper because the expensive process of dicing (cutting up wafers) and then reassembling the chips would be avoided. Further, the novel, added advantage that the WSI memory would rebuild itself on switch-on, so that a RAM failure would be no worse than switching the machine off and then on again, should not generate too much fear and opposition. My WSI memory would take its place as a somewhat slower but larger than traditional RAM in the memory hierarchy, much faster than magnetic tape or disc memory. (It was installed in Tandem machines in 1989.)

I hoped to insinuate WSI plug-in replacement memory into IBM computers, IBM then being the big bully, equivalent to Microsoft today, and wait a few years for them to gain acceptance. The idea of WSI memory "would be understood by anyone earning more than £50,000 p.a."; people important enough to be unable to understand the idea of array processing, my real objective for WSI. My memories would have a search facility secretly hidden within them. I would later point out to IBM machine programmers (but not their bosses) that their memory search routines, which slowly, sequentially, searched a block of data in RAM for a particular pattern, could be massively speeded up if a jump to the search subroutine were captured by hardware and the search done in parallel by hardware in the WSI memory.

Sir Clive

After a delay of twelve years, when the patents had only a few years still to run, Sir Clive Sinclair set up Anamartic, a company which successfully developed WSI memory as designed by my 1972 world patents. The product came to market in 1989 amid industry acclaim (see **Figure 2**). However, after evicting Sinclair, the technology-free management in Anamartic played the role I previously feared from IBM management, and froze the product range at memory only, although memory should have been merely a demonstrator for the WSI array processor. Anamartic's WSI memory (see **Figure 3**) was left to compete with conventional RAM chips, which were generally sold below cost by Far East companies desperate to get market share and to keep their production lines running.

Anamartic, the company set up to develop and exploit my invention, fired me three times, losing the resulting court battles with me twice. During the 17 years it took for my patented machine to reach the market, the 10% of total cost that had preceded dicing the wafer had grown to 80%, so the argument for WSI RAM had collapsed, leaving Array Processing as the only potential winner for WSI because of its high speed and reliability. However, with Sinclair evicted, the accountants and the like who managed Anamartic preferred to stay with a product they could understand and therefore control, despite its inferior market potential both to its discrete RAM competition and to the WSI Array Processor, which was beyond their comprehension. Better for Anamartic to fail with products they understood than succeed with products they could not control. ("I am convinced that [refusal to develop new products] gives the best short and medium term career prospects to middle and upper management .... It is time that we faced up to discussing the career and security threat that a major innovation with major profit potential presents to a manager in a typical British company." - Ivor Catt, *Computer Weekly*, 18th May, 1978.) I well remember the triumphalism shown by Anamartic's Managing Director Jan van Riethoff when he took me into his office to fire me, thus demonstrating the victory of his profession, accountancy, over technical invention, even in a company set up to develop and exploit my invention.

For technical reasons which I forget, I could not have new ideas for the six months after Roethoff fired me. At age 50 I should have been no threat to the company that was developing my invention but had fired me, since it is well known that new, inventive ideas only occur to those who are below the age of 25. However, after seven months, an accident occurred. I had a brainwave, the Kernel Machine[3], which obsoleted Anamartic's earlier 'Catt Spiral' patents[4]. Obviously, had I taken the new patents to Anamartic, who had just fired me, I would have been dismissed as playing 'yah-booh' games. I decided on a threefold strategy. I would get Kernel published in British journals, and then take those publications to Japanese journalists, since Fujitsu had invested £2 million in Anamartic, that is, in the now obsolete 'Catt Spiral'. Once Kernel was published in the Japanese press, I would forward it to Fujitsu in the hope that they would rise to the bait.

Gone fishing

My first step was to get British publication. I got it into the *Sunday Times* and on the front page of the *Sunday Express* newspapers. However, my main objective was a thorough exposition in *Wireless World* or *New Scientist*. I successfully manipulated the internal politics of the *Wireless World* editorial matrix, and it was published, in March 1989[5]. This article is now on the www at http://www.ivorcatt.com/3ewk.htm . In June 2002 it triggered Nigel Cook's article on Air Traffic Control, subsequently published in the January 3003 *Electronics World*[6].

The second, alternative, thrust of my strategy, to have Anamartic read about Kernel in the press, came into play, and obviated the need to pursue the Japanese route. As I remember, Anamartic directors read the *Sunday Times* 'Innovation' article by Jane Bird, talking about the "first ever trillion flops computer". Unusually, there were technocrats among Anamartic's board of directors, some of whom had invested heavily in Anamartic. They instructed the Managing Director to re-hire me and

Fig 3: Part of Anamartic 'Wafer Stack' brochure

also to buy my new Kernel patents. Technology-free management, put in by major shareholders Barclays Bank, bit the bullet and rehired me. However, to admit that technical ideas embodied in patents might have commercial significance was more than good accountants could stomach. (My aphorism about all British companies applied to Anamartic, a British company; "Any attempt to influence a management decision on the basis of technological considerations is a political move against the established management structure of the company.") Management rehired me, but no mention was made of my patents. I was put in charge of 'Future Products' - a well known cul-de-sac, since British hi-tec companies do not have future products. I proceeded to submit regular reports recommending that Anamartic migrate from Catt Spiral to the Kernel Array Processor, until Anamartic fired me again (and I successfully sued them again), this time without using any lawyers.

That is where we stand today, leading to the January 2003 article in *Electronics World* by Nigel Cook about Air Traffic Control[6], an

The New Bureaucracy

It is helpful to discuss the reason why professionals in the computer industry seemed happy to freeze the computer's architecture for half a century. The "anti-manufacturing-industry" psychosis discussed by Martin J Wiener in his book "English culture and the decline of the industrial spirit"[8], expanded with a vengeance into hostility to hi-tec. My early peers in the computer industry soon migrated into paper, that is, into programming, away from degrading hardware. They then ganged up with humanities, which is anti-science and has traditionally governed Britain. Lacking technical, or hardware competence, it was helpful for both parties that the digital computer's architecture be frozen, making it a controllable, standard device for bureaucratic manipulation (by technology-free programmers and by technology-free managers and politicians), so this is what happened. The architecture of today's much-vaunted digital computer is identical to the von Neumann computer of 1950. Its architecture makes no concessions whatsoever to the radically different technologies now used in its make-up. (I have made this assertion more than once in the past and not been contradicted, so by now we should all take it as fact.) This fact is concealed by the total lack of appreciation of, or discussion of, this fact. The result is that no computercrat less than 30 years old knows that the architecture of his machine has been frozen for half a century, in defiance of increasingly pressing financial and performance imperatives. Generally, they have floated further and further away from the machine proper on a cloud of ever higher-level software packages. It is as though the horse and carriage had been miniaturised and constructed out of aluminium, or some other material more modern than wood, drawn by specially bred dwarf horses, or poodles, while nobody noticed that something irrational and uncommercial was happening. In such a case, the vested interest obstructing progress would have been skilled (dwarf?) drivers of horse drawn carriages, not programmers and politicians.

application which needs an array processor; ideally my Kernel Machine, whose patents have run out.

Thus, my public campaign for the array processor began with my article in *New Scientist* in 1969 entitled 'Dinosaur among the Data?[1]' I argued that computer applications of the future would need an array of processors and that the single processor (von Neumann) machines like those of twenty (now fifty) years earlier would not meet our needs. Next came my March 1989 article in *Electronics World + Wireless World* entitled 'The Kernel Machine', where I discussed the many applications which needed a large array of processors. The latest publication in the list is by Nigel Cook in *Electronics World* January 2003, where he argues that Air Traffic Control must use an array processor. A tangential article was 'The New Bureaucracy', published in *Wireless World* December 1982[7]. (See box).

Liquid cooling

The reason why the Von Neumann computer has minimal problems with heat extraction is because, with only one processor, it does so little computing. Computing consumes power because every time a logic line is raised to the value 1 and then discharged back to the value 0, some electric charge has been dumped down through five volts, thus losing energy. In contrast, memory, which is what virtually the whole of a Von Neumann computer does, does not in principle consume power, especially a DRAM.

A million processor Kernel Machine consumes a helluva lot of power while working, that is, while computing. A liquid is chosen from the wide range available which boils at the fastest switching temperature for the transistors used. Using boiling liquid on the surface of the chip gives a thermal clamp, so that all components operate at the single boiling temperature. This means that the larger logic swings previously needed to tolerate temperature variations across the machine are not needed. The resulting lower logic swing leads to lower power dissipation. The advantage is startling because power dissipation is more than proportional to voltages used, in the same way as the power dissipated in a resistor depends on the square of the voltage across it. Weirather and Go did the research for me in Motorola R&D to prove conclusively that direct chip contact liquid cooling is perfectly viable, and published a paper on it. Since then, liquid cooling has been totally ignored. This is partly because the USA went lunatic. Liquid cooling is unsuitable slopping around half way to the moon, as is the high power and high speed, which liquid cooling makes possible. There is not much to compute on the way to the moon anyway. However, the core reason for blocking liquid cooling is that we dare not depart from usage of the Ancients, and the way they designed and built computers in 1950. They didn't use on-chip (or for them on-valve) liquid cooling, so why should we?

GEC's contribution to Britain's Defence

The British government set up the National Research Development Corporation (NRDC) to support new invention and new hi-tec industry. On March 1, 1973, the NRDC wrote that Catt Spiral "could be of fundamental importance in the design, construction and operation of future digital processors and stores" (i.e. computers) - quoted in *The Spectator* in 1974[10]. This interest by our government, plus government funding, caused me to leave teaching remedial English and return to the electronics profession I had abandoned. I needed to learn the latest technical buzz-words, some of which change every few years.

I was hired by GEC in Borehamwood, and given the task of designing and building the prototype Fast Fourier Transform (FFT) for Nimrod, the British airborne early warning equivalent of AWACS. Both Nimrod and Tornado had four or eight of these massive boxes of electronics to do the job in parallel in order to achieve the required speed. I told my boss Ian Deegan that "Property 1a", the Catt WSI invention which followed Catt Spiral and was the subject of a government funded project at Brunel University, was ideal for the FFT job, and he agreed. The problem was, how to infiltrate technical innovation into a military system funded by the MoD and designed and developed in Britain.

"Property 1a", the WSI approach, had massive advantages over the approach we were using with conventional chips, interconnected on boards, interconnected on the back plane in a box measuring two feet by one foot by one foot. "Property 1a" would be self repairing and so more reliable. It would be smaller, lighter, consume less power and therefore less fuel. Using this approach to WSI in the FFT would pave the way to our capturing the world airborne digital signal processing market, both military and commercial.

I asked Ian Deegan what was the best way to try to infiltrate it into a conservative company like GEC. He said I should get the advice of the 'Man in the Green Coat', a Welshman. The Man in the Green Coat told me that it would be very difficult to innovate in GEC, and the best chance was to propose it to Whitehead, the GEC Chief Scientist, so I sent the proposal to him. I sent further copies for a period of six months. Finally I received Whitehead's reply, which was that GEC did not see an immediate application for my proposals and if they were to move in that direction, GEC would expect to buy in from the USA.

An Indian engineer at GEC told me a funny story about Whitehead. GEC was concerned that graduate engineers who joined GEC tended not to stay very long. To improve their morale, young engineers on the staff were invited to a wine and nibbles party. Chief Engineer Mariner walked among the assembled engineers. The Indian asked Mariner; "What has our Chief Scientist Whitehead done?" Mariner replied that Whitehead was the grandson of the great Alfred North Whitehead. The Indian then said; "But what has he done?" Mariner said; "He and I worked our way up through the company together from the bench." Again, the Indian said; "But what has he done?" Mariner answered; "I'm not going to answer any more of these f***ing questions," and stormed out of the party.

I heard that a man in the MoD was keen on my ideas. I phoned him and asked what the procedure was to propose a technical innovation in a MoD funded weapon being designed and built with MoD funding in GEC. He replied that I needed to convince the staff at RSRE Malvern. He set me up to lecture to the 150 technical staff at Malvern, and their response to my lecture was very positive. I then waited two years and asked what the next step was. Only then did I find out that there was no next step. There is no procedure for suggesting that a British technical innovation being developed with British Government funding be introduced into a British weapon system being developed with British Government funding.

A few years later, the Nimrod project was abandoned after £1 billion of taxpayer's money had been spent and the British forces bought the US alternative, called AWACS - the darning sock on top of a Boeing.

Some years later, I approached GEC again with my WSI proposals. This time, the Chief Engineer Ash and the head of software 'Elbow' invited me to a meeting and expressed interest, saying they would send one of their engineers to discuss the matter further with me. Sure enough, a bright young engineer appeared later in my garden in Redbourn. I asked him how it was that GEC were pursuing the matter. He replied that he was very bright and had done very good work on detachment in Gloucestershire, gaining a high technical reputation. On return, he now represented a threat to the management. They had sent him to meet me in the hope that the two threats, he and I, would cancel each other out. Since there was no point in his losing his job, I said the obvious way out was for him to give a negative report on the proposal. I heard nothing more from GEC. ■

References

1 Dinosaur among the Data? *New Scientist*, 6 March 1969, pp501/502 - see http://www.ivorcatt.com/31.htm
2 *Wireless World* July 1981, p254.
3 *Electronics World March* 1989, see http://www.ivorcatt.com/31.htm
4 *Wireless World* July 1981.
5 See http://www.ivorcatt.com/3ewb.htm
6 See http://www.ivorcatt.com/3ew.htm
7 See http://www.ivorcatt.com/31.htm
8 Martin J Wiener: "English culture and the decline of the industrial spirit", pub. CUP 1982, see http://www.ivorcatt.com/31.htm
9 Computer Worship, Ivor Catt, pub. Pitman 1973
10 *The Spectator*, 9th February 1974, p179

Artificial Intelligence

Prof. Donald Mitchie at Edinburgh promised the moon with the conventional single processor computer. Thus, he blocked advances in computer architecture. I corresponded with him, and nobody, including the government. suckers funding what he called 'Artificial Intelligence' (AI), which turned out to be telling the difference between a cup and a saucer (I promise, on my word of honour!) cared a bit when he failed to deliver two years later what he had promised - getting a computer to detect the difference between a cup and a saucer. They continued to admire his dynamic forward looking work. For me, the primary effect was that advance beyond von Neumann was blocked by programmers like Mitchie calling themselves 'Artificial Intelligence', and saying that the processor would keep getting faster, so one processor would always be enough. In the journal *Computer Weekly* I have published that AI blocked advances in computer architecture.

Years later, a government report said AI was a waste of time and the funding was totally stopped. Around that time, a Walla called Prof. Aleksadner of Brunel, later Imperial, tried to climb aboard my 'Catt Spiral' juggernaut, because that was where the funding had migrated to. Later, his idea, praised in the media, was for a computer to tell whether someone was smiling or not. He called it AI. Like Mitchie, he gained a lot of media acclaim. So AI died.

Years later, a bunch of kids gave the term to another activity entirely, a more reasonable activity, which was more like computers aiding the human, rather than replacing him. (One is religion, the other is technology.) They gained funding.

Around this time, a man with a quasi-religious attitude to hi-tec turned up named Sinclair, and grabbed the Catt Spiral, ostensibly to make money and suchlike, but his hidden agenda (like the one Nigel Cook is drifting towards now) was to make a computer in the image of Man, the old Tower of Babel fixation. While I welcomed Sinclair's support, I worried that he might come upon my more forceful stuff against AI, perhaps in my book[9] 'Computer Worship'. At any moment during our very successful partnership, which lasted for many years and brought innovative product to market with acclaim, he could have dismissed me as a heretic. After all, religion is more important than business, as I found much earlier in 1965 when another AI freak, Dr. Narud, head of R&D in Motorola Phoenix, tried to fire me for heresy. He loved the 'hot box', which was a box stuffed with chips and shaped like the human brain. You can see it in the last chapter of the Motorola bible on IC design. Narud insisted that the last chapter discuss neurons and include pictures of neurons. The Motorola bible was later replaced by the Carver Mead Caltech bible, which contains a chapter on 'The Glitch' at the insistence of Chuck Seitz. The Glitch had little relevance to IC design either.

LETTERS to the editor

Letters to "Electronics World" Highbury Business Communications, Anne Boleyn House, 9-13 Ewell Road, Cheam Road, Surrey SM3 8BZ e-mail j.lowe@highburybiz.com using subject heading 'Letters'.

EMC is Attainable

It is refreshing to note that Ivor Catt has lost none of his ability to write a thought-provoking article (EMC - A fatally flawed discipline? *EW*, March 2003). He quotes examples which show there is much confusion, disinformation, and disagreement in the EMC Community.

He contends that the formal test Requirements for electromagnetic compatibility are inappropriate for use with modern equipment. Moreover, he points out that those who set the standards are either unable or unwilling to advise engineers as to how to design equipment to meet those requirements.

With good reason, the Don White manual does not feature in his list of recommended reading.

Having been involved in the design of electronic equipment during the entire period covered by his reminiscences, I can understand his frustration. However, his approach is wrong.

When he discovered that his computers at West Herts College were tripping the earth leakage detector, he could have put his considerable talent to work to solve the technical problem. His objective could have been to reduce the amplitude of the switch-on current surge created by the mains filters to a level below the threshold of the earth leakage detector, without reducing the efficiency of the filters. Instead, he chose to waste time by trying to change the regulations.

On a more fundamental level, by his repeated use of the word "magician", Ivor shows that he himself has succumbed to the propaganda that the subject of EMC is too complicated for the average engineer. The message propagated by the specialist is that only the elite few are gifted enough to understand the phenomenon: for everybody else, EMC is a form of black magic.

I would contend that EMC is a branch of science, and that a review of electromagnetic theory and circuit theory will reveal that the coupling of interference can be analysed just as easily as any other aspect of design. I invite Ivor to visit www.iandarney.pwp.blueyonder.co.uk browse through the contents list, and click on the hyperlink to section 5.2.

Ian Darney
Bristol
UK.

Wrong tree

A fatally flawed attack upon a discipline in engineering which has proved itself of value many times over and which has undoubtedly avoided catastrophes and which saves billions of pounds cannot simply be ignored. I refer of course to the article on page 44 of the March issue of this journal by Mr. Ivor Catt.

Whilst it can be argued that there are certain EMC directives, which in the light of today's state of the art and use of digital technology are somewhat arcane, this is not a valid pedestal from which to launch

In defence of Mr. Miller

Well, here we go... I read with somewhat amusement the article on audio amp compensation in the March issue, so here's my take.

The author claims that eliminating the Miller capacitor is to be desired, yet his summary contradicts this view. Indeed, his sentences are inherently contradictory to each other. On one hand the author waffles his words about "...small price to pay for a design which minimises the differential signal, hence improves linearity", yet he claims his actual results show higher distortion and noise. Of course, this is not surprising as the Miller compensation technique is used because it has been consistently shown to be an excellent way to compensate an amplifier. Indeed, one of its very desirable features is that it pole splits the response of the amplifier. That is, it converts what would otherwise be a two pole response into an essentially one pole response, because it moves one pole to a much higher frequency where it can usually be ignored. Without Miller compensation, poles usually interact in complicated ways, making compensation, over all component variations, quite difficult. And to continue..., there is also a somewhat vacuous claim that a 25mV signal at the input of a Miller input verses a 2mV signal of a PLIL input, had to be "...kinder to the transistors...", yet there was no support at all that this actually made any difference in the sound of the amplifier, or indeed that apples were being compared to apples. In fact, the author noted, "high frequency distortion may increase".

Whether or not a competently designed amplifier would suffer from this alleged "problem" is debatable as even in the early 80's amplifiers[1] were commercially available with slew rates of 100V/µs and 20kHz THD at <0.02%.

So, on we go...to a more technical note, it is difficult to see how the author has justified his simulations. All but one of the graphs show some sort of closed loop gain response. It is well known, that to determine stability, one is usually required to examine the loop gain of the system, that is the gain around the loop. From the text of the article, it is not clear at all how even this stated closed loop gain was obtained. For example, the loop gain of fig 7a, is principally determined via the emitter loop of T1. For example, applying an input via its base will not result in the same loop gain, and in general results can be substantially different. Indeed, Probably, the simplest way to obtain the real loop gain of an amplifier is by placing a voltage source in series with the loop[2].

As the article stands, it is difficult to make any conclusions on its arguments until it is ascertained what the real loop gains of the systems are, and how the graphs were constructed. In summary, the article seems strong on rhetoric, but lacking in objectivity. There was no technical evidence presented that supported the view that Miller compensated amplifiers had any unresolved issues at all.

Kevin Aylward
Peterborough
U.K.

References:

1: Studiomaster MOSFET 1000, 1981
2: Automatic loop gain plots, SuperSpice Example AutomaticLoopGain

such an attack. EMC engineering, or any engineering including the EMC aspects as part of its plan, is not some vague furry object with no sound rules, it is a necessary and logical part with very visible and clear methods and objectives.

There are many aspects into which I could delve here, at the expense of many column-centimeters (feet, if some prefer), but let me illustrate simple but real situations in totally different environments which but for EMC evaluation could have resulted in a massive waste and/or ongoing problems or disputes.

Situation 1:
Two sub-contractor companies were to design and build separate units, which were to be flown on a particular satellite mission (I do not intend to name the companies nor the mission, but this is a very real project which was under my examination at the time).

This issue concerned conducted EMC: a power source in the first unit using space-qualified switched-mode supply modules, followed by a number of linear regulator circuits one of which was required to supply some +32Vdc with less than around 10μV of noise to the second unit. The design was sound as far as the data sheets of the devices concerned initially showed: it was only when those features were examined that a problem was discovered and the design adapted accordingly. The switched-mode power module operated at a number of kHz and produced approximately 80mV worst-case ripple entering a three-terminal regulator, which had, on the face of it, an 80dB ripple-rejection capability. This meant a worst-case regulator output ripple of 80mV - 80dB = 8μV, within the specification for the second unit. However, the three-terminal regulator concerned had a ripple-rejection quote on its data sheet when measured at 50 or 60Hz and, due to the low input-output headroom this meant that its internal error amplifier operated at a low bandwidth and did not provide anything like 80dB of rejection at the SMPS operating frequency - the rejection there was only of the order of 40dB, a one-hundred-fold increase of output noise being the worst-case result. Clearly another 38dB minimum of filtering was required in either the first or second units, or both. This was finally resolved by extra filtering before the linear regulator and an input filter in the second unit (remember space and mass are important criteria in space applications).

The application of a proper EMC analysis to this situation illustrated the problem and enabled a proper cure to be effected - and none of this with reference to the "bible" of Don White. It was also conducted sufficiently early in the project as to avoid significant and costly re-design and re-working.

Some may say that the above work was just a part of correct engineering practice - and indeed it was - it just happened to be termed "EMC analysis" of the design in question. No cagey business practices here.

Situation 2:
For a period of some months an on-site amateur radio club was experiencing a phenomena which basically precluded the use of the 144MHz and 432MHz amateur bands due to a very high level of wideband noise during non-working (free time) hours. The issue was brought to my attention as a member of the Club, even though I did not make frequent use of these facilities. Initial investigation eliminated any issue of conducted EMC issues, therefore, attention was directed at radiated-EMC possibilities.

Using a mobile station it was discovered that the noise source could actually be detected up to 2km distant from the Club premises and upon further tests using a Yagi directional antenna at various locations in the vicinity, the source appeared to be in the very same premises. It was decided to use an EMC-lab portable receiver together with its DF antenna to attempt to locate the source of the wideband noise. Admittedly, this was not a life-critical issue but was one that

2003 marks the centenary of Alan Blumlein's birth.

At the time of Alan Blumlein's death I was six years old so, understandably, I was unaware of his original work in the fields of Sound, TV and Radar engineering. My ignorance was partially corrected over the ensuing ten years as I struggled to understand first radio then television principles, culminating in building a TV from Government surplus radar indicator units, in time to watch the Coronation of Queen Elizabeth II. That it worked, was a minor miracle.

From 1947, when I bought my first copy, Wireless World was and still is, essential reading for me. It introduced me to sync separators, longtailed pairs, bootstrapping, Miller integrators, the block-busting bootstrapped transitron miller integrator and heavean knows what other goodies that became the bedrock for my career in electronics and computing. Wireless World has enabled me keep pace with developments since migrating from the bench to the desk and into retirement. Thanks for that.

Blumlein's name cropped up with impressive regularity, during my formative years, arousing my curiosity. This was not only in the context of television, but also in audio as I struggled to build an ultra linear audio amplifier out of government surplus bits, let alone the two that I would need to experience stereo. All efforts to learn more about him, apart from the occasional references in Wireless World, came to naught. He hadn't even had any books published whereas O. S. Puckle and M. G. Scroggie had Timebases and Foundations of Wireless, respectively. In retrospect, who could have resisted such evocative names?

I knew Blumlein had worked for EMI so, when I got a menial job at EMI, I expected to find out more, but was disappointed. The people I worked with had never heard of him. The trail went cold until a few years later, when I found myself working with a group of people who had worked at EMI with people who had worked with Blumlein. They were a happy team, pushing the Germanium semiconductor technology of the day to the limit and succeeding, well ahead of their time. But I still didn't find out anything about Blumlein. The trail went cold for almost ten years. Then, unexpectedly, there he was again! At the time, I was working for an American company and looking at a map of their factory site I saw a road called Blumlein Way. Subsequently I discovered that the President of that company had met Alan Blumlein, whilst working on the magnetron during the Second World War. Blumlein's engineering work permeated electronic measurement instrument technology at that time and probably still does, quietly, in the background even in this digital age with concepts of feedback, gain stabilisation, delay lines, pulse generation, ramp generation etc. My interest in his work received a new boost, but the trail went cold, this time for thirty years. Robert Alexander's excellent and well researched, book "The Inventor of Stereo: The Life and Works of Alan Dower Blumlein" has gone a long way towards satisfying my curiosity about what made him tick. It has closed the loop to my Indicator Unit TV of fifty years ago, but it leaves me with new unanswerable questions. What else would Blumlein have achieved, had he not met with such a horrific and untimely death? Would he have stayed in the field of "hands on" electronics or would he have ascended to senior company management; started his own company, academia maybe, or even migrated into politics? We will never know what we missed.

In addition to the legacy of his patents, Alan Blumlein certainly left a lasting impression on those who worked with him. What was the secret of his success and can we still learn from his example? I have the impression of a business manager and an enthusiast who never ceased to be an engineer, who never shrank from challenge or criticism, who pushed himself to the limit, who wouldn't quit and who encouraged others to do the same. In other words he was an ideal role model for people embarking on a career and who want to succeed. But how do they learn about his example? Robert Alexander has done all the spadework. Now it just needs someone to turn his book into a film. It might be a bit late, but an accurate film recreating the life and works of Alan Dower Blumlein would be a fitting tribute to him and all the other unsung heroes of the 20th century electronic revolution, now the cloak of secrecy has been raised. 2003, his centennial year would be a good time to start. It could be done but who is up to the challenge?

Bryce Kearey
Crowthorne
Berkshire
UK

required the proper approach to find and resolve the problem.

Since the appearance of this problem only occurred during non-working hours, there was not much of a time restriction placed upon this EMC investigation! Nor was there any significant outlay of funds necessary for it to be conducted.

The outcome was that an elderly computer system used by a video club on the same premises to handle loan registrations and other administration was found to be radiating a large amount of 'hash' and, together with its un-shielded set-up it was proposed that it be either replaced or properly enclosed (some grilles and shielding required etc.), and the club committee concerned agreed to take the necessary measures and used our advice in implementing these after which the problem was resolved without recourse to constitutional clauses or any other discontent. Not a whisker of any trouble in resolving this situation either.

EMC conducted emission tests do not assume that an incompatibility (we are after all discussing compatibility between systems here, which is the 'C' in the abbreviated term) is caused by a single wire (re: box "The fatal flaws"), but rather the entire circuit. A supply and return wire do not necessarily take the same physical lay-out path, so one can view this as one long line and, if they are not co-located they may well form a wonderful antenna. Nothing in this is in contradiction with Kirchoff's Laws.

As regards 'grounding', there is nothing in EMC 'law' which states that individual sub-modules which utilise high frequencies must be grounded in any particular manner; I would agree with Mr. Catt that grounding internal modules in an equipment where the wavelength is less than the grounding methods used is asking for trouble. What should be examined finally, however, is the method and effectiveness of grounding the entire finished and enclosed unit and also the filtering where appropriate of the signal and power lines coupling to that unit. That is what we do.

I note the apparent assumption that "EMC wallahs sweep through frequencies one at a time"; perhaps it has been forgotten that the use of a spectrum analyser is quite effective in looking at a wide range of frequencies for and in the same test environment. Individual frequencies are only examined one at a time when there is an identified potential problem source at that frequency or at a related, possibly harmonically-related frequency.

As to the suggestion that "EMC wallah's thinking ... resort to averages" and that they "just don't know ... if a digital system loses one bit ... [can] be catastrophic", I have to say that this takes the food right out of the bowl. In situation 1 which I describe above, the very reason for ensuring that the supply line concerned ended up 'clean' was that this line fed a CCD sensor and this sensor, in turn, fed an ADC: the whole issue at stake was the importance of ensuring that no ripple or noise could exceed the value represented by one third of the least significant bit of that ADC's resolution, since otherwise the whole instrument would be drastically reduced in its effectiveness. This is

Personal critique of *ELECTRONICS WORLD*

I wish to provide a few thoughts regarding the current state of *Electronics World*. I am a 61-year old individual in California who has read the magazine for many years, under both its current and older name of *Wireless World*. Currently I am nearing the end of a two-year subscription period. I must say that, to my taste at least, the overall quality of the magazine has gone downhill in recent years. I'm not exactly sure why this is so. Perhaps the higher technical level that the magazine took on in years past has fallen out of favour, and you have found it necessary to lower the technical level in order to find enough paying readers. Or maybe the technical capabilities of your staff have diminished. Or perhaps you just cannot find enough good material to publish, though this seems unlikely. (I should say, however, that I seem to detect some improvement in the most recent issues and I hope this is not just a statistical anomaly.) The latest issue I have received contains more than 10 pages of "New Product" information. This wasteful use of valuable space should be reduced, especially in light of the fact that many of these products can be of little more than very passing interest to most readers. And I know from my own professional experience that most of these pieces are little more than re-prints of material sent out by the producing companies in search of what amounts to free advertising. At the very least I believe you should use smaller print and much smaller photos in this area of the magazine. And remember that readers such as myself are not likely to be very interested in new instruments that cost upwards of a thousand dollars or more, unless they are so novel as to merit attention on that basis alone (and that is quite rare in my opinion). I am currently building some apparatus that makes use of the article on page 50 of the August 2002 issue. This article, I believe, is along the lines of what you should be publishing more of. It highlights an area that MANY of us are interested in - the more efficient and practical use of microcontrollers, the PIC series in particular. This article is relatively well done, makes microcontrollers easier to use at a practical level, and is of interest to both professionals and hobbyists. If you can find more such material, and publish it, you will likely receive more praise from technical types such as myself. One area that could stand improvement is your up-front recognition of the authors of good articles like this one. Why not put the author's name up 'in lights' at the head of the article? If you do that it will encourage more people to write for you. We all like recognition for the good work we do, and your magazine provides a platform for good authors to be recognized by their own community. One name I used to look for from issue to issue was Pat Hawker. His contributions were many, and of uniformly high quality. You should try to get new traditions started along the same lines, and a big tool for doing that is to provide author recognition in the biggest way possible. (I still am not sure who the author of the referenced article of August 2002 is. Perhaps Roger Thomas?) Neither the article itself nor the Table of Contents makes it at all clear. The bottom line is that if a magazine like *Electronics World* is to survive and prosper, it MUST publish several high-quality technical articles in every issue. A suggestion: Make a list of every technical issue of current practical interest that you can think of. Then send that list out to all prospective authors, soliciting their writings on the subjects on that list. Ask readers to provide candidate subjects for the list. The list might start with subjects like: PIC microcontroller usage, Practical USB devices Practical FireWire devices, Radio gadgets that make use of unlicensed spectrum, Electromagnetic theory for mere mortals, Relativity for mere mortals and how it relates to EM theory and a regular column on the practical application of the latest chips from semiconductors manufacturers. For less experienced readers, a regular column that discusses some basic part of current circuit theory (e.g., voltage-doubling and tripling power supply circuits, how to get started with PIC assembly language, how to use your PC to log and analyse experimental data, etc, etc). How antennas really do what they do. An aspect of digital signal processing. Current practical battery technologies and how they differ. How multilayer digital networking protocols are designed, and how they can be implemented at home. How the 802.11b protocol works, etc. I hope these ideas are of some use to you, because I really would like to see your magazine grow and prosper. And especially at a solid technical level. In the USA, the old (and excellent in its time)Gernsbach magazine *Radio Electronics* has died and so has *Popular Electronics* and (latest) *Poptronics*. Over a period of years, they slowly made their publications less and less interesting to people like me by making their technical level lower and lower. I hope you don't expire down the same senseless path.

Bob Nelson
California
USA

If you remember, the August 2002 issue was my first with EW and there were lots of mistakes. One of which was not putting Roger Thomas' name 'in lights' at the head of his article. As regards your article ideas – some of these are already in the pipeline.- Ed nothing like the odd scratch on an LP record or a bit of interference on an old AM radio, or such-like.

Another 'fundamental flaw' in an EMC approach to engineering activity to which Mr. Catt refers is that of calculation rather than measurement: in situation 1 above the problem and its solution was essentially achieved by calculation and confirmed by measurement; in situation 2 above the problem and its solution was essentially achieved by measurement and subsequent calculation. As in other branches of electronics engineering, both calculation and measurement have their equally important roles to play.

Finally I propound that EMC engineering analysis is in no way a "flawed discipline" and in fact is a part of the process of ensuring that various electrical and electronic products in a given environment may co-exist without mutual interference, and that such issues are addressed by all responsible engineers whether they be "microwave plumbers" or "D.C. suppliers" or whatever lies in between. The most important contribution to this effort is communication between engineers and experts in the different disciplines involved; perhaps it could be the case that Mr. Catt has had a few too many experiences of bad communication with previous colleagues (which can always happen) but I give him the benefit of the doubt that certain experience and reflections upon it can direct ones' views.

EMC approaches are no more a way of making money than any other discipline in engineering - we all design things to achieve something which somebody, somewhere, pays for. The different disciplines together achieve the final result.

I think Mr. Catt is miauwing at the wrong branch.

Eima Burdd.
Rijnsburg
Netherlands

EMC - A Flawed Discipline

I read Ivor Catt's piece with enormous interest, but I query awhether it should perhaps have appeared in the April issue. I am in two minds whether the author is a foresighted genius or a weird but clever anorak type significantly lacking presentational and diplomatic skills. His swift departure from quite a few jobs does suggest the latter!

I am not a professional engineer and so I have some difficulty in following a direct flow of logical thinking in the article. My discerning of Mr. Catt's statements and arguments is basically that EMC "gurus" do not understand elementary science and engineering, rather that they apply esoteric solutions to the finished product in an attempt to make it EMC-proof. I think what he is calling for is a symbiotic partnership between the design engineers, the EMC engineers and the production engineers. These three disciplines are substantially different spheres of engineering, each requiring specialist techniques and a fair amount of the black art, and that in consequence the overlap may not be extensive. Indeed, taking Mr. Catt's argument *ad reductio absurdum,* the EMC gurus have screened and/or filtered their engineering knowledge so well that they are incapable of applying relatively simple engineering solutions to the problems of EMC.

In fact your good periodical has printed quite a few articles on how EMC can be substantially reduced by some fairly inexpensive changes to the circuit design and physical layout and so I would have thought by now that the symbiotic message had penetrated most serious manufacturers (or what is left of them in the UK).

Are his comments on the "torpedo-proof" line printer to be taken seriously? How can any printer, armour plated or otherwise, require 750 amps and at what voltage? Should there be a decimal point somewhere, for example between the 7 and the 5? All I know is that the laser printer (plastic cased) which is printing this letter consumes 1.8 amps maximum at 240 volts AC because that is what the rear plate says.

Would Mr. Catt also explain the connection between ex RAF radio operators and EMC. There is what the lawyers call a *lacuna* in his flow of words. More accurately, *lacunae* because there appear to be a large number of them. Would he also explain why it is

Identity Crisis

Mr C.Holwell asks for details of the TK20 drive motor (Identity crisis *EW* March 2003) and while I have no details of this particular model I have some on models of a similar vintage.

The TK6,14,17,19,23 and 27 have motors with four connections and the in the various models are connected to the several versions of the mains transformers in the usual complicated Grundig manner. Some transformers are 110/130/220/240v, some 110/220v, some have adjustable tappings for 50/60Hz operation, however there are no capacitors employed in these arrangements.

The TK40,42,45,46,47, TM60, 64 etc. have three connections with transformers with a similar range of voltages and frequency as the previous list. The internal connections of the motors are not shown in the diagram so it is not possible to determine the resistances of the stator windings, however capacitors are employed in these models and changed for the 50/60Hz range.

Mr.N.L.Smith
Stoke-on-Trent
Staffs

Motors

If the motor referred to in the letter in last month's issue is designed to run directly from mains, then it is of a type I think known of as 'PAPST' , an inside-out induction motor seen only rarely in makes other than older mid European marques.

I am at this moment using an outer rotor motor to power a small pillar drill (For PCBs etc.), it is only a little larger than the motor often found in older Grundig tape recorders, yet seems to be rated at about 1/10Hp. The 'inside out' design confers several advantages, the chief one being the ease with which the symmetrical stator could be directly wound with a larger number of poles when compared with small motors of conventional layout, resulting in lower speeds and extraordinary torque. While owners of other machines were delighted when they discovered that their machine sported a 4 pole motor instead of the all too common, cheaper single winding two pole variety, the motor in Grundig tape recorders had poles running into the teens.

Since the windings are 'inside' the poles, less wire is needed and so smaller gauge wire can be used. Also the rotor surrounds the stator, (generally consisting of a cylinder of iron moulded around a copper 'squirrel cage') and so it serves to magnetically screen the motor, a distinct advantage in tape recorders. Lastly, as well as running slowly enough to directly drive the capstan (often actually forming the drive spindle of the motor itself), the outer rotor had sufficient inertia to form the flywheel needed to iron out wow and flutter, and could be used to drive the spools (for tape take up, and fast forward and reverse) via idler wheels or belts.

My particular example (gleaned I think from an odds and ends box at a radio rally for 50p) also has three wires, one pair of resistance 150Ω and the other of 230Ω. Since the other pair reads 380Ω, the connections are to two windings commoned at one end. As was suggested a capacitor is needed and '2μF' is marked helpfully on the rotor, but this is definitely a capacitor 'run' motor, i.e. the higher resistance winding must be left connected to the supply via the capacitor. A description of connections with the same resistance between each pair is mysterious, and suggests star or delta connected three phase windings.

The outwardly similar variation seen so often nowadays in videos, disk drives and small fans in fact has a multi-pole permanent ring magnet on its inside surface, and since it can only be driven by a (usually integrated) multi-phase driver, it is a very different beast.

A. Ziemacki
Rotherham
UK

More Grundig

Please find enclosed a. copy of the complete schematic concerning the Grundig TK 20 tape recorder.

All details of the motor's circuit are given; the capacitor (C 32) is a. self-healing MP dielectric : 1.2 microfarad 230 volts AC service.

Hoping all this will answer Mr. Holwill's query,

Paul de Lattre
Tilff Belgium

Duly passed on to Mr. Holwill - Ed

impermissible to measure susceptibility to EMC by measurement rather than by calculation. If the measurement is flawed then the premise behind the technique is flawed and so would be the calculations. Surely the essence of all science and engineering is the ability to measure the parameter under investigation consistently and accurately. If that cannot be done then one must rely on the black art of intuition and hope, which is not science but which might lead to discoveries that then advance the science.

I found the whole article more like one of those brain teasing questions in *Round Britain Quiz* on Radio 4, you know "What is the connection between a sacked engineer, a bizarre line printer that appears to consume more current than a domestic household and an engineering company substantially staffed by milkman?" I think we should be told more.

Michael O'Beirne
Surbiton
Surrey

Catt sinks

Ivor Catt's seamen who may have borne painful witness to his printer's impunity to torpedo attack, "EMC", EW March, reminds me of the occasion when, during competitive trials in foreign parts, various companies were trying to hawk military radios to the local army. One of our competitors' salesmen was obsessed with the claim that their loudspeaker/amplifier accessory, which plugged into an h.f. man-pack, was capable of surviving a bomb blast. I enquired what utility this was unless they made their radio operators equally as robust.

David Bridgen
Camberley
Surrey
UK

The Catt Came Back

Welcome back Ivor Catt! Now that was a really enjoyable piece on EMC, especially on the why of things and how the decisions are made.

That Fourier article; more please, quite thought provoking. Very much food for thought there. It seems that all is not quite as it should be. Come to think of it, this might explain why house-bricks have sharp edges that stick up! Does Gibb's tombstone have ears on it as well?

As to more please; I thought that "Joules Watt" was extinct, so it was a pleasure to read that letter in the March issue. A long time ago it was a pleasure for me to struggle through his dissections and illumination of the more obtuse aspects of the theoretical body of knowledge. At this point I must declare an interest; can you please persuade him to dissect the dark corners of FM? As a radio amateur I am beginning to suspect that in being forced to 12.5Kc/s NBFM channel spacing we have been "sold down the river". Something is wrong and unless someone can "do the numbers" on this for me I am urinating into the wind. It starts with 2.5k of deviation plus 3k of audio all doubled equals eleven Kc/s. That is the conventional sum for the bandwidth required. Looking at some equipment that was accused of vile distortions (Tait T300 series used on the GB3ES repeater at Hastings), I find that the receive IF filter is only some 7.5k wide at the nose. This does not compute. Neither does it look good on the bench. Perhaps "Joules Watt" knows the rules? What is more, you might even talk him into enlightening us.

William R. Blankley, G8CMK.
St *Leonards on sea*
East Sussex
UK

EMC - A fatally flawed article ?

Went into W H Smith - Spotted leading article 'EMC - A fatally flawed discipline'.Quick read - Verdict - Buy to digest. Bleagh . Where was the meat ? It reads like the counter person in a fast food restaurant moaning about their cruel lot ! (Could not find the bun (or the point) either) .

Far too much about defence industry rip-off's. We have all heard the stories that a $1 screwdriver purchased by the Pentagon costs $200. Perhaps the editorial staff are Egyptian (Too much blind CATT worship??)

Too much rudeness about GEC (and Weinstock). At least he ran a fairly stable, profitable company for many years (and so was able to provide the shilling of convenience Mr. Catt was willing to take (and did Mr. Catt back the engineer who said 60dB was enough - or did the free thinker just sit on his hands?) GEC (Marconi) was all but destroyed and the pension funds of thousands have been damaged (perhaps forever) by some who thought they knew better...

Part of the problem is that EMC is a broad subject (and it has been around for a long time!) The first EMC regulations were late 19th century, relating to 'Flicker' or voltage fluctuations and pre-date the RAF airborne radar operators!

The work of CISPR dates from the 1930's, when as radio became more widespread the importance of interference generated from the growing number of items of electrical equipment was swiftly recognised. This work still carries on today, and generates international standards and guidance documents. The work of CISPR was the basis of BS800 - the compulsory RFI compliance document for much electrical equipment which pre-dated the current European legislation by many years. (You can tell when something has started to fail and no-longer meets these limits by the lines on the telly and the crackles on the radio - It may be a relay or the thermostat in your neighbour's gas boiler!) If Mr. Catt hat read some of the widely available reference material it might not have taken him quite so long to discover some of the BUZZ WORDS (e.g. LISN) and the basic simplicity of the concepts involved rather than whinging about the inaccessible 'Don White Bible'.

Some of this work may seem dated as processor speeds romp away, but that's the standards world for you! - Ah yes microprocessors! There are all sorts of pulse (and hence broadband tests) that are applied to digital systems e.g. IEC 1000-4-4, the fast transient test for example.

As regards RCD's, students and computers, the RCD is an excellent device , however the implications of their use are sometimes not even fully appreciated by those who manufacture, recommend and install them. The most common RCD ratings are 100mA (protection from fire) and 30mA (protection from electric shock). The typical RCD will trip at a continuous leakage current of half these values. It's all a question of choosing a suitable value.

Filters and product safety - product safety standards do not normally dictate a design. They will say what is not regarded as acceptable (e.g. leakage current @ 50Hz). The filter network I designed for Spark Ignition Systems was an industry first, and went into production.

(The management wanted to use a large expensive commercial filter - Because it seemed easiest, just not cost effective or sensible...!)

Also I was instrumental in getting the standards re-written to more sensibly test the product (Yes, Mr. Catt, it can be done)

Finally EMC compliance does not involve hiring an expensive consultant / expensive tests. (Type testing is only mandatory for Transmitters, and is supervised by the Radio Communications Agency). If you have the B***S to stand by your own test results, design notes and reports that in many cases can be enough.

Yes I Design things, make them meet safety standards, test for EMC compliance, then re-design if required. (And I used to work for GEC (Marconi).

You can find some background at one of my websites http://jprdesign.port5.com (no WWW!)

Will sign off now as run the risk of becoming as incoherent (spatially or temporally) as Mr. Catt! And if you feel the need for some factual (and amusing) articles on EMC or Product Safety I'm your man....

And finally, the article on Fourier Synthesis raised the status of the magazine purchase! ■

John Blythe
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THE ART OF ANALOG LAYOUT

Roy Alan Hastings

This text aims to provide students with a broad understanding of the issues involved in successfully laying out analog-integrated circuits - ranging from the mechanics of layout to essential information about many related areas, such as device physics, processing and failure modes and effects.

Oct 2000 ▲ 559 pages ▲ HB
Code PEAR 0 13 087061 7 **£30.99**

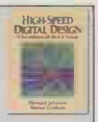
DESIGN-FOR-TEST: FOR DIGITAL INTEGRATED CIRCUITS AND EMBEDDED CORE

Alfred L Crouch

An introduction to the basic concepts of Design-For-Test, an area in chip design.

July 1999 ▲ 350 pages & CD-ROM
Code PEAR 0 13 084827 1 **£59.99**

HIGH SPEED DIGITAL DESIGN



Howard W Johnson & Graham Martin

Re-issue

Focusing on the field of knowledge lying between digital and analog circuit theory, this text sets out to help engineers working with digital systems shorten their product development cycles and help fix their latest design problems. It covers signal reflection and crosstalk.

820 pages ▲ HB
Code PEAR 0 13 395724 1 **£44.99**

RF CIRCUIT DESIGN: THEORY & APPLICATIONS

Reinhold Ludwig; Pavel Bretchko

This practical guide intorduces RF circuit design fundamentals while emphasizing a circuit based approach. It provides MATLAB routines to carry out simple transmission line computations and uses a PC-based commercial RF circuit simulation tool to demonstrate actual circuit behaviour.

Oct 1999 ▲ 656 pages ▲ HB
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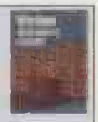

Bob Zeidman

Verilog is one of the most used hardware description languages. This text contains a library of useful code for those users who do not want to recreate identical code for common tasks.

Jul 1999 ▲ 450 pages ▲ PB
Code PEA0 13 081154 8 **£79.99**

PASSIVE COMPONENTS FOR CIRCUIT DESIGN

Ian Sinclair

Designed for technician engineers and anyone involved in circuit design, this text provides an introduction into a key area of analogue electronics. It covers all component types capable of power amplifications, including: resistors, capacitors, transformers, solenoids and motors.

Nov 2000 ▲ 301 pages ▲ PB
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ELECTRONIC PROJECTS FROM THE NEXT DIMENSION: PARANORMAL EXPERIMENTS FOR HOBBYISTS

Newton Braga

A guide to making and using paranormal research electronics. It describes practical electronic circuits to be used in experiments involving instrumental transcommunication (ITC), the electronic voice phenomenon (EVP), and paranormal experiments involving ESP, auras, and Kirlian photography. White and pink noise generators for use in instrumental transcommunication (ITC) experiments; Kirlian photography; plasma experiments; extrasensory perception testers; magnetic fields sensors.

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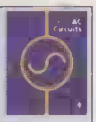

Clay Rawlins

A step-by-step approach to AC circuits for beginners, providing thorough coverage of theory and practice. The text provides individualized learning goals covering electronics concepts, terms and the mathematics required to understand AC circuit problems.

2nd Edition ▲ Oct 2000 ▲ PB
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INTERFACING WITH C

Mike James & Howard Hutchings

An exploration of interfacing personal computers using C. An introduction to C; loops and data conversion; data acquisition using C; essential mathematics; convolution; digital filters; Fourier transforms; correlation; Kalman filters; data conversion; investigating the spectral and time-domain performance of z-transforms using computer-managed instruction; introducing audio signal processing using C; standard programming structures. Dewey: 005.71262

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3rd edition ▲ Jul 2002 ▲ 335 pages ▲ PB
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Ian Sinclair

A collection of all the key data, facts, practical guidance and circuit design basics needed by a spectrum of students, electronics enthusiasts, technicians and circuit designers. It provides explanations and practical guidance, and includes new sections on SHF techniques and intruder alarms.

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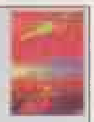

Trevor Wilmshurst

Aimed at junior undergraduates, this textbook offers comprehensive coverage of analogue electronic circuit design with two full chapters devoted to the use of SPICE in circuit simulations. programmes leading to IEng MSc Electronic conversion type courses.

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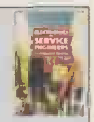

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From simple mathematics and circuit theory to transmission theory and aerials, this text provides the range of knowledge required to service electronic and electrical equipment. Questions and worked examples illustrate the concepts described in each chapter.

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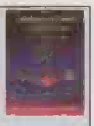

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Engineers are often faced with the need for small quantities of a certain board design for construction of a small number of devices. This book describes the process of making a printed circuit board, from the conversion of a schematic diagram into a board layout to the making of the board itself.

Jul 2002 ▲ 251 pages ▲ PB
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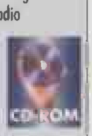

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3rd edition ▲ Feb 2002 ▲ 289 pages
150 line drawings ▲ PB
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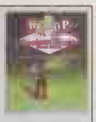
Clive Maxfield

Comprehensive introduction to contemporary electronics - friendly, funny and quirky. Whether you're an engineer, hobbyist, or student who needs a thorough and up-to-date electronics reference or a non-technical person who wants to understand more about this electron dance that has seemingly taken over the world, this book is the answer. Hundreds of diagrams that clarify even the most difficult subjects.

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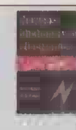
SW Amos & R S Amos

Aimed at engineers, technicians and students working in the field of electronics, this dictionary provides clear and concise definitions, including TV, radio and computing terms, with illustrations and circuit diagrams.

4th edition ▲ March 2002 ▲ 394 pages ▲ PB

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Radio Society of Great Britain

Only a basic knowledge of electronics is assumed for this collection of electronics projects, and it is ideal for all electronics and DIY enthusiasts and experimenters. Designed by the RSGB, the UK radio amateurs federation, the projects are clearly explained step by step.

Nov 2000 ▲ 336 pages ▲ PB

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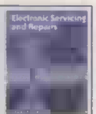
Trevor Linsley

Updates the previous text taking into account changes in the City and Guilds courses 2360 and 2240. Also features hardware topics, testing and fault diagnosis, PLCs and CAD software, and new chapters. Health and safety; electronic component recognition; electronic circuit assembly techniques; electronic semi-conductor devices; electronic circuits in action; testing electronic circuits; digital electronics; electrical circle theory; electronic systems; communication systems; security systems; sensors and transducers.

3rd edition ▲ Aug 2000 ▲ 261 pages

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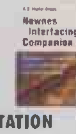
Tony Fischer-Cripps

Provides the fundamentals of electronics, transducers, computer architecture and interfacing techniques needed to use a simple PC or PLC-based system for the collection of data previously only obtainable from expensive dedicated equipment.

Aug 2002 ▲ 320 pages ▲ HB

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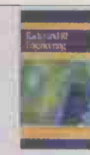
Steve Winder & Joseph J Carr

With a mass of information and data for students, radio and telecommunications engineers, RF circuit designers, radio hobbyists and technicians, this guide covers all aspects of radio and communications engineering from low frequencies to microwaves, with an emphasis on mobile communications.

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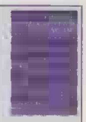
Stuart Ball

Providing an introduction to the design of embedded microprocessor systems, this edition covers everything from the initial concept through to debugging the final result. It also includes material on DMA, interrupts and an emphasis throughout on the real-time nature of embedded systems.

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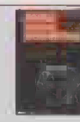
Marty Brown

Providing an easy-to-follow, step-by-step design framework for a wide variety of power supplies, including linear, switching and quasi-resonant switching. There is also discussion of design topics such as magnetics, feedback loop compensation design and EMI/RFI control in straightforward terms.

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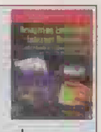
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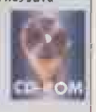

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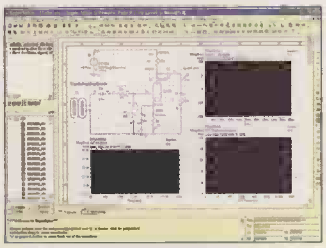

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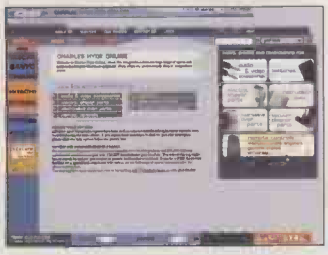

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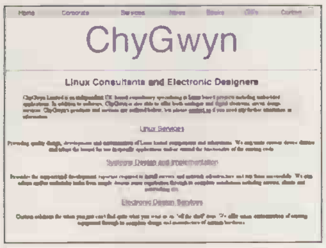

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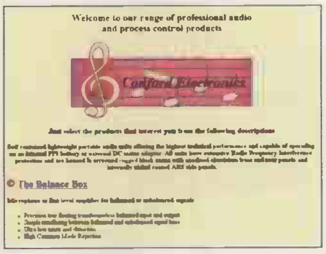

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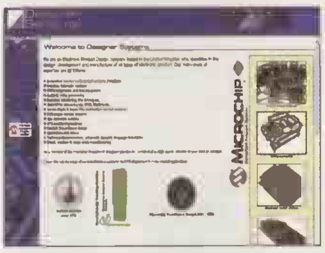

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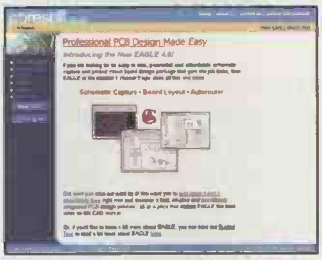

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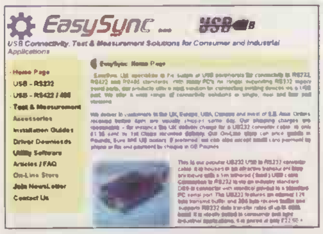

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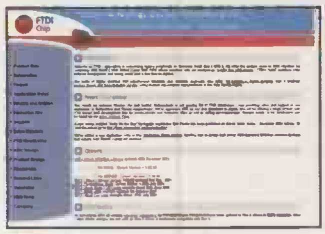

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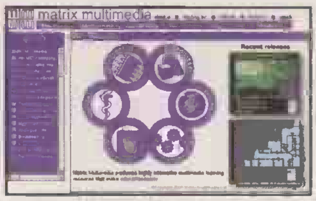

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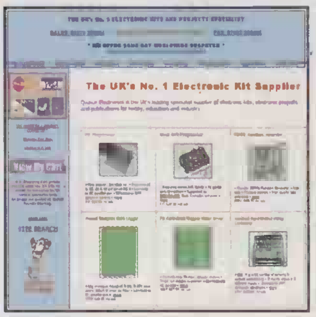

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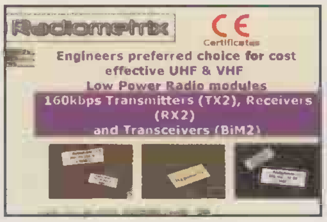

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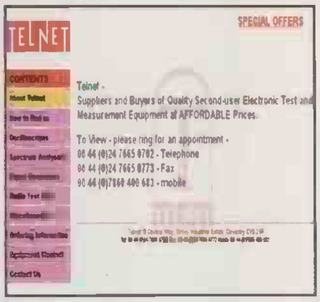

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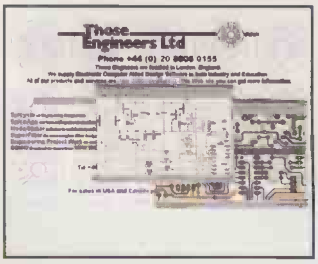

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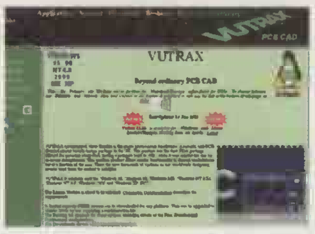

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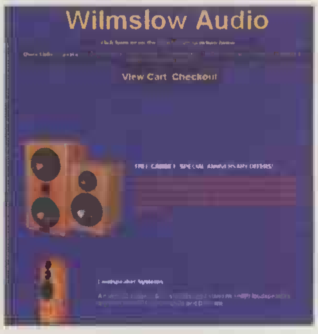

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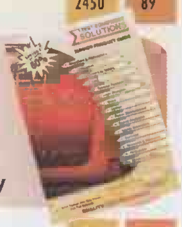

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