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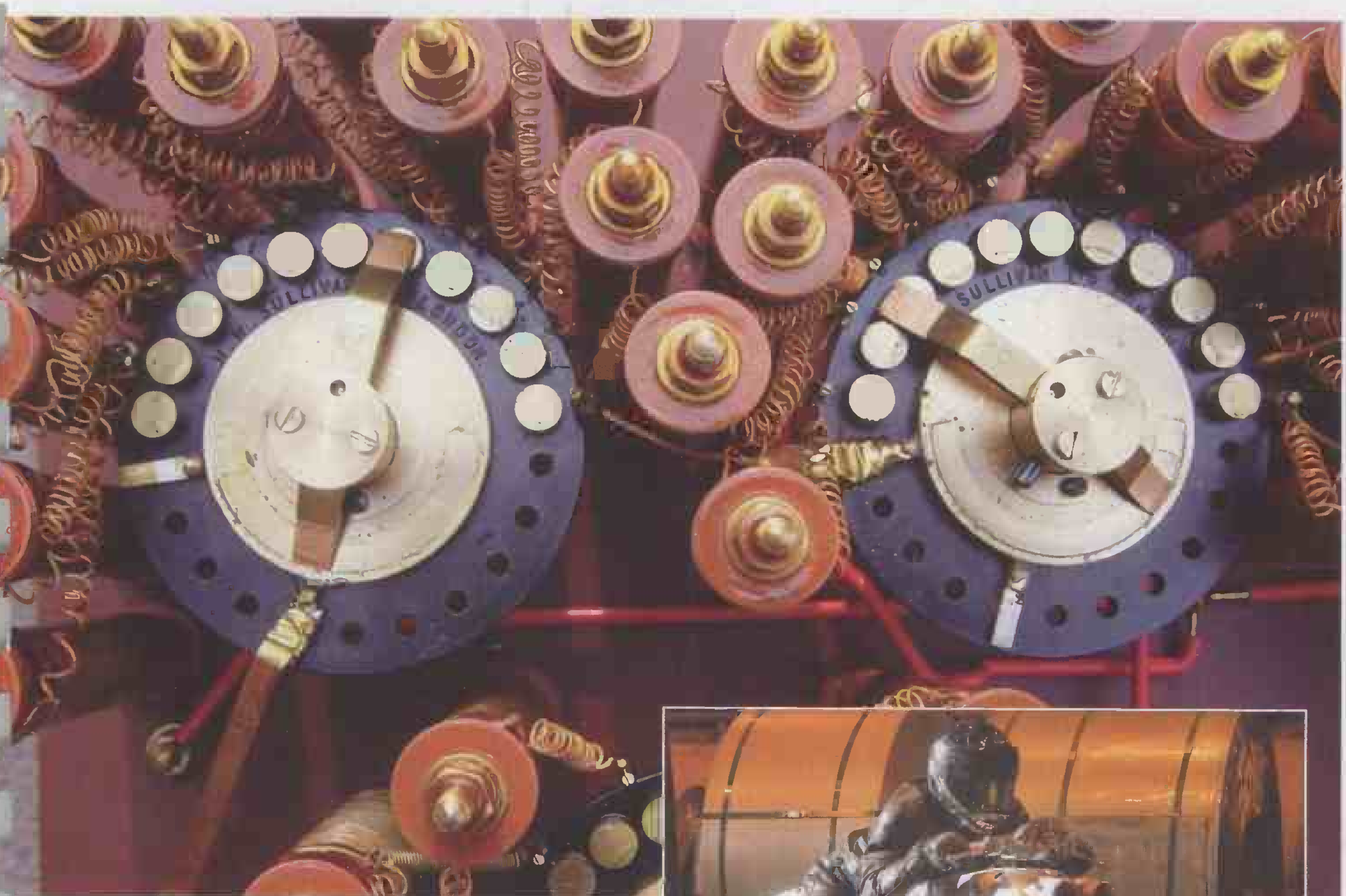

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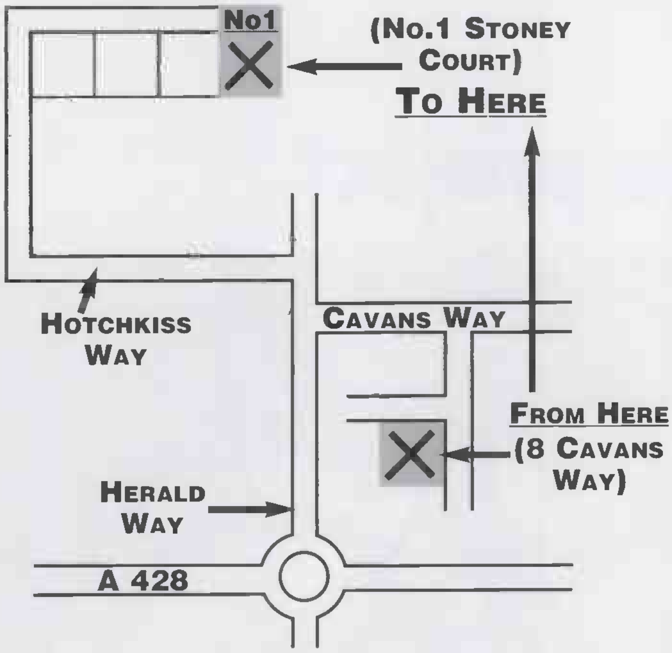

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Catt's whiskers

I had a feeling that Mr. Catt would stir up the readership, and I have not been disappointed. It appears that he has uncovered a few things that are close to the heart for a lot of you. The mailbag is growing as I'm writing this, so expect a large letters section next month. And fans can be assured that there are other projects in the pipeline from this esteemed author.

This month's issue has the usual varied collection of topics. After Alan Bate's series on bridges and impedance measurement, I thought I'd bring us all back down to earth with a bit of history and a practical bridge project from David Ponting. Also in this month we investigate the increase in capacity of re-chargeable batteries which is having a profound effect on portable electronic design.

Following on from part one, which we ran last August, Nigel Cook is again trying to disprove some established theories with his 'Electronic Big Bang'. Ever wondered what happened to sending data up power lines? Well J. LeJuene has discovered that he industry has moved on since the electricity boards sent codes out to switch on street lights.

I've had a letter in this month (that I will be publishing in the May issue) that points out the lack of fundamental principle knowledge in young graduates. Certainly, in the part of the electronics industry I work in – the same is true. Whilst the 'younguns' walk all over me when it comes to networking problems and even the use of complicated software – the basic stuff like how analogue and digital signals are transported and recorded on magnetic tape are completely alien to them. In fact, I was doing a 'master class' on how a video tape recorder works recently and was amazed that none of them had even the curiosity to take the lid off and see what all the whirring was about. I find all that more than a bit scary.

Phil Reed

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Laser-like light springs from fibre

Researchers have created a laser-like electromagnetic beam at the extreme-ultraviolet (EUV) end of the spectrum.

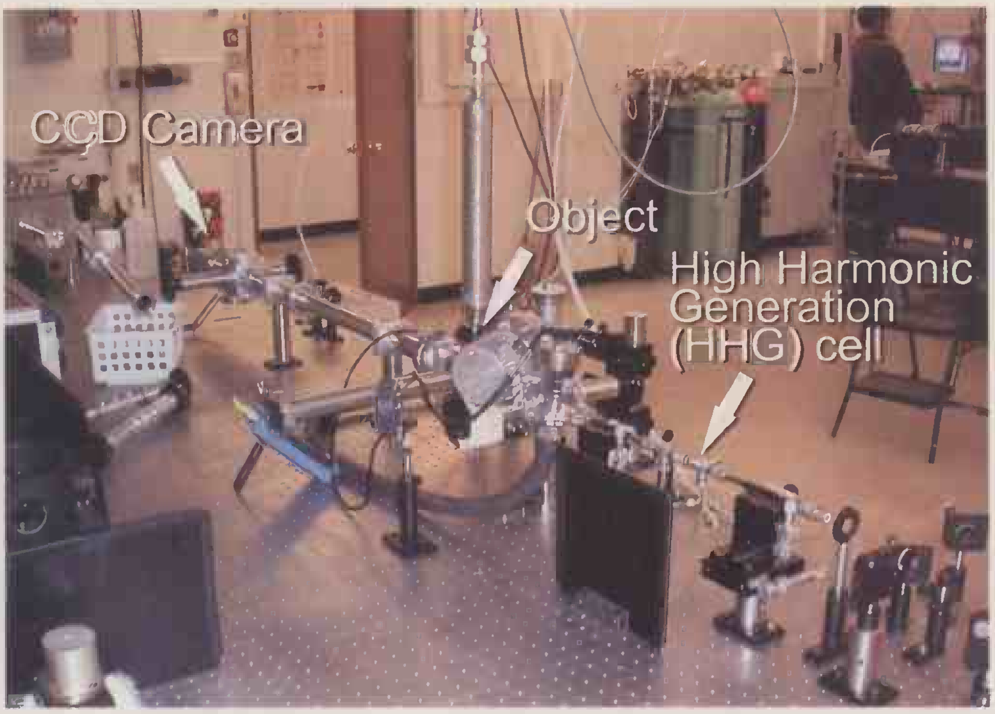
The team, led by Henry Kapteyn and Margaret Murnane of the University of Colorado, created the beam by firing a femtosecond laser through a gas-filled waveguide.

The energy splits gas atoms into ions and electrons, then accelerates the electrons. When the fast electrons later collide with the ions, EUV electromagnetic radiation is produced.

This is nothing new, except laser action, or anything approaching it, is normally impossible because differences in the velocity of light in and EUV out mean EUV is generated randomly and disruptive interference cancels much of it.

By creating ripples inside the diameter of the waveguide, the Colorado team coaxed the light waves from the laser and EUV beams into travelling at the same speed. This achieves a better phase match and the result is a well-synchronised stream of EUV photons at high energy.

"These waveguide structures are amazingly simple - just a modulated, hollow glass tube," said Murnane. "It is as if the laser beam surfs on the modulations and is slowed down."



This said, the EUV is still not a laser beam although the team sees this as a possibility with more development.

The EUV source is smaller than any other EUV laser design at these very short wavelengths, claims Kapteyn: "The waveguide fibre fits in one hand and the laser fits on a desktop."

The source works down to 6nm wavelength. If this can be pushed to 4nm, the so-called 'water-window', it will be suitable for imaging biological structures and a desktop microscope for living tissues could be built, claims Colorado.

Newcastle strains its silicon

Research into strained silicon at the University of Newcastle is being transferred to Atmel's fab on Tyneside. Strained silicon has the potential to boost transistor speeds by up to 30 per cent.

Newcastle is one of the UK's leading research centres for fast CMOS processes. Professor Anthony O'Neill, leading a five-strong research team, hopes to get a production process up and running at Atmel within a year.

"Working with Atmel will allow us to take the product from the drawing board to marketable reality a lot quicker than relying on the limited resources available to universities," said O'Neill.

Atmel acquired its UK fab from Infineon over two year's ago. "This is great news for the North East because it brings real, commercial research and development to the region," said Atmel's MD Craig McInnes.

Strained silicon increases device speed by widening the lattice constant of the substrate. A few per cent increase in spacing can boost electron mobility by 20 to 30 per cent.

However, increasing the lattice constant is not a trivial task. The most common technique has been to grow a layer of silicon germanium, which has a larger constant. A layer of silicon is deposited on top of this, and as long as it is a thin layer it keeps the underlying lattice spacing.

Many of the big semiconductor firms have announced developments involving strained silicon, including AMD, IBM and Intel.

DSP lovers get SIG

Engineers using digital signal processing now have access to a special interest group dedicated to their field.

The DSP Forum has been setup by a group of companies to promote the sector and provide a twice-yearly conference and exhibition. The group also plans to offer a CD resource library and run a website. Associate membership of the group is free.

An initial meeting of the group is set to be held in Swindon in April. The group is looking for presentations on various subjects, including processor interconnect strategies, floating point processors, high speed data recording, FPGAs and software tools.

Sponsors of the DSP Forum include Act Europe, Aonix, Artisan Software, First Matrix, Green Hills Software, ILogix, OSE Systems, QinetiQ and VSystems.

Further details can be found at www.dspforum.co.uk or from Hazel Lawton on 01274 691935.

Mobile phone drivers are blind

Motorists are more accident-prone and slower to react when they talk on mobile telephones - even using hand-free kits - because they are intellectually blinded, claims research by the University of Utah.

It is not that the drivers fail to look at objects, they ignore them.

"Even when participants are directing their gaze at objects in the driving environment, they may fail to see them because attention is directed elsewhere," said psychologists David Strayer. "Phone conversations impair driving performance by withdrawing attention from the visual scene, yielding a form of inattention blindness."

The study concludes that that inattention blindness explains US findings in 2001 that users of hands-free and hand-held cell phones are equally impaired, missing more traffic signals and reacting to signals more slowly than motorists who do not use cell phones.

There was no impairment, the 2001 study found, of drivers who either conversed with a passenger or who listened to the radio or to books on tape.

Journal of Experimental Psychology publishes the new study in its March 2003 issue.

Notepad runs on paper power

A notepad calculator available in the UK is using paper thin battery technology from Israeli firm Power Paper.

Black n' Red notebooks, manufactured by John Dickinson Stationary, contain calculators and currency converters powered by the thin batteries. Lifespan is claimed to be 500 hours.

Power paper makes its batteries using a silk screening process with electrodes using standard zinc and manganese dioxide materials.

The 1.5V primary cell is around 0.5mm thick and, for a 55x55mm sheet, can supply 1mA of continuous current. The nominal capacity is claimed to be 30mAh. Internal resistance is 15Ω.

The battery is also flexible, and can be bent to a radius of 25mm.

Bike beast gets LED lights

US motor company Chrysler has made a concept motorcycle based around its 500-horsepower Viper V-10. Not only does it have four wheels, but its LED headlights steer with the handlebars. Each of the two lamps has six five-watt white LEDs from California-based Luxeon. Potential top speed is 420mph, claims Chrysler.

Image sensors get technical

The recent Photonics West conference saw the unveiling of two interesting image sensors, one from e2v Technologies in the UK and one from Sarnoff in the States.

Chelmsford-based e2v demonstrated a low light sensor capable of taking 1,000frames/s. The charge coupled device works down to a very dim 0.01mLux light level, claimed the firm, which corresponds to overcast starlight through an f/1.4 lens.

The firm does this by multiplying photo-electrons by a factor of 1,000 between the CCD readout and amplifier. It can actually count single photons, said the firm.

Meanwhile in the US Sarnoff Corporation demonstrated an ultra-violet CCD camera module sensitive in the 157 to 351nm range. The 1,024 pixel square, 14-bit sensor can run at up to 100frames/s.

QinetiQ sale to US firm approved

The acquisition of a third of QinetiQ, the Government's R&D agency, by US investment firm Carlyle Group has been cleared by the European Commission.

Carlyle Group is paying between \$140m and \$150m for its share in QinetiQ. In return QinetiQ gains access to \$450m in credit to fund further expansion.

"The strategic partnership with the Carlyle Group keeps QinetiQ on course to become a leading science and technology company," said defence minister Dr Lewis Moonie.

Carlyle has already said it plans to sell its share when QinetiQ floats on the stock market, as current owner the MoD is expected to do.

A flotation on the stock exchange is expected in the next three to five years.

Flying e-nose sniffs for US government

Researchers at Sandia Labs in New Mexico are developing an electronic nose for pilotless drones.

SnifferSTAR, as it is called, detects nerve gases and blister agents while operating on 0.5W and weighing 14g, claims Sandia.

While other gas monitors exist, "rapid analysis currently is not possible with any other package near this size", said researcher Doug Adkins.

Inside are several quartz surface-acoustic wave-based oscillators. Each is coated with a different layer designed to absorb a specific chemical.

Operating cyclically, first air is trapped in a chamber with the sniffer allowing time for molecules to be absorbed. Then a door opens allowing forward motion to flush out the old sample, bringing in a new one. The cycle repeats.

A radio link transmits data to ground-based signal analysis. "We have very few false positives," said Adkins. "The device ignores most common interferents."

The sampling process is repeated every 20 seconds, with 15 seconds intake and five seconds for analysis.

Sandia researcher Doug Adkins with nerve gas detecting SnifferSTAR in a wind tunnel.

Auction set for 3.4GHz

The Government has finally announced its plans to auction spectrum around 3.4GHz in order to allow broadband over fixed wireless access.

A two phase auction process will award 15 licences across the UK. The first phase is a multi-round auction, much like that used in 3G mobile and the 28GHz auctions, while the second phase is a sealed bid sale, lasting for up to 12 months.

A reserve price of £300,000 has been set for the three metropolitan licences covering London, Midlands and Northern. The other regional licences have a £100,000 reserve price. Bidders for licences need to place a £20,000 deposit.

The large area of coverage and cost of licences has been much criticised, and the auction format largely failed in the 28GHz auction. Several regions were left with unsold licences.

However, at 3.4GHz there is no restriction on the type of service that can be offered. This means backhauling of mobile phone services can be carried, which could provide an operator with much needed revenue early in their roll-out.

Licences will last for five years with an option to take two further five year periods.

Handheld for field trips

Gotive of Slovakia has developed this handheld for education and business.

Called H41, the GPS-equipped device is being employed in an EC-sponsored project involving remote accessible field trips.

Built in are the functions of a handheld computer, mobile phone, position transmitter, navigation device and a barcode reader and options include a smart-card reader, magnetic strip readers, printer and camera.

Power comes from Saft MP 174865 rechargeable lithium-ion cells. "The battery's characteristics enable customers to work all day without recharging," said Gotive sales manager Kamil Jadron, "and its fast recharge was another crucial point."

www.gotive.com
www.saftbatteries.com

Wireless LAN now legal at 5GHz

The Radiocommunications Agency has relaxed the rules governing three frequency bands in the 5GHz range. This opens the door to firms offering wireless LAN technology.

The three bands are 5,150 to 5,350MHz (band A), 5,470 to 5,725MHz (band B) and 5,725 to 5,875MHz (band C).

Band A will have a maximum EIRP of 200mW and is indoor use only, while band B has a 1W maximum for both indoor and outdoor use. Mobile equipment complying with these rules is licence-exempt.

Equipment without dynamic frequency selection must use band A while the technology is more fully developed, said the RA. Such devices will also have lower maximum power limits - 60mW for equipment without transmit power control and 120mW with TPC.

Band C is being looked at in terms of broadband fixed wireless access.

The IEEE802.11a standard makes use of the 5GHz bands, and is capable of transferring data at up to 54Mbit/s.

Since deregulation of the 2.4GHz band last June, firms such as BT have started setting up wireless 'hot-spots' to offer wireless access to the Internet at 11Mbit/s. Similar schemes are expected in the 5GHz bands.

Stephen Timms, UK e-commerce minister said: "Broadband is surging ahead in the UK, and this initiative will make it more widely available. We need to keep the momentum going and encourage greater use."

Chip monitors power supplies

Programmable logic firm Lattice Semiconductor has developed a chip for sequencing and monitoring power supplies.

The devices, called PowerPAC, can monitor up to 12 voltages supply lines and have outputs to control DC-DC converters and regulators. Interrupt signals can also be sent to microprocessors in the event of a power failure.

Lattice said existing power control systems are often badly designed and little more than resistors and capacitors.

"There's been a tremendous proliferation of power supply voltages," said Stan Kopec, v-p of marketing at Lattice, "yet there's no generic solution for managing these supplies."

A 16 macrocell block of programmable logic in the PowerPAC is programmed to bring up supplies in sequence and then monitor supply lines, noting any drops and issuing non-maskable interrupts to processors.

Test equipment maker IFR has unveiled this 26GHz spectrum analyser which it describes as a low cost device, although it still comes to $24,900 without any software options. The analyser is aimed at installation and maintainance of microwave links and tower-mounted transmitters.

Malvern-based ZBD Displays has unveiled its latest prototype zenithal bistable display. The 18cm panel has VGA resolution and holds an image indefinitely without power.

As only image changing requires energy, an e-book using such a display could run for two years on a pair of AA cells said the company.

Electronics World got a chance to handle the prototype and can confirm text can comfortably be read from the display.

Dark and blank lines in the image are due to ZBDs inexperience in manufacturing, which should be sorted out soon after it recently announced its first major co-development deal - with Hong Kong-based LCD maker Varitronics.

The Far East firm will use its production expertise to adapt ZBD' s technology for mass production. The deal does not include any production rights, but ZBD directors expect the Hong Kong company to sign a production contract in around six months.

ZBD is also developing grey-scale and colour versions.

Automated op-amp creation

Software that creates complete layouts for op-amp circuits has been unveiled by a Californian firm.

Ten different single-ended op-amp topologies can be synthesised by Barcelona Design's Picasso engine. These include layouts specific to low noise, high gain, and loop bandwidths approaching 1GHz.

Once the topology is decided upon, the designer can alter the layout and transistor sizings to optimise parameters such as power, unity gain bandwidth and area.

The firm said test results from actual silicon of standalone op-amps and more complex designs was used to develope the tool.

Circuits generated by the tool are suitable for chips using 0.18µm CMOS, said the firm.

The op-amp tool adds to the firm's existing software for creating voltage regulators, phase-locked loops (PLLs) and data converters.

Microphone inventor goes back to school

Jim West then and now.

Jim West, who co-invented the electret microphone in 1962 with colleague Gerhard Sessler at Bell Labs, has returned to university, now as a lecturer.

West spent more than four decades with Bell Labs, obtaining more than 200 patents. He also authored or contributed to more than 100 technical papers and several books on acoustics, solid-state physics and materials science.

After he retired in 2001, West decided he wasn't quite ready to hang up his tools. "One thing was clear: I'd had a great life in research. It wasn't broken, so why fix it?" he said. "So I set up interviews with universities."

As a result of this decision, West joined The Johns Hopkins University where he is now a research professor in the department of electrical and computer engineering.

West says he looks forward to engaging in joint research with faculty members in mechanical engineering, materials science and biomedical engineering and has no desire to slow down. "My hobby is my work," he said. "I have the best of both worlds because I love what I do. Do I ever get tired of it? Not so far."

In an electret microphone, thin sheets of polymer film, metal-coated on one side, are given a permanent charge to serve as the membrane and bias of a condenser microphone. Almost 90 percent of all microphones produced today are based on the principles developed by West and Sessler, claims the university.

The relentless pace of miniaturisation continues, as this latest power amplifier from Skyworks demonstrates. The multi-chip module is just 3mm on each side and contains passive components and and indium gallium phosphide hetrojunction bipolar transistor. Aimed at mobile phone applications it can exceed 28dBm output power in CDMA systems.

Tiny transceiver tiles

EMA from Glasgow has introduced a series of miniature, surface mount UHF transceivers called TileWare that are designed to work in the licence-free 433.92MHz band.

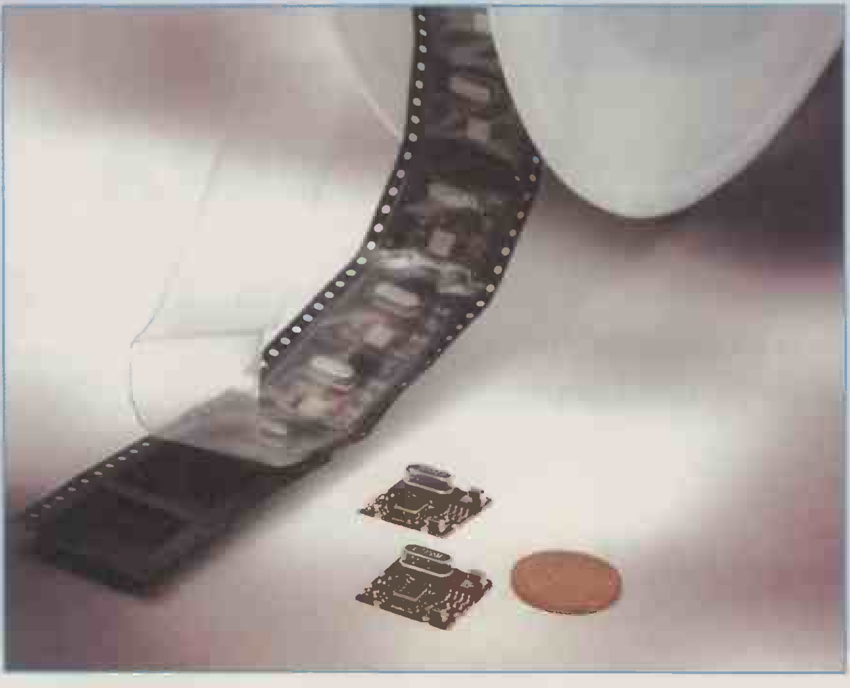
The 19x19mm assemblies are adjustment free and need no external components, said the firm. Because the device is surface mount, there is better control over the impedance of RF connections, said EMA.

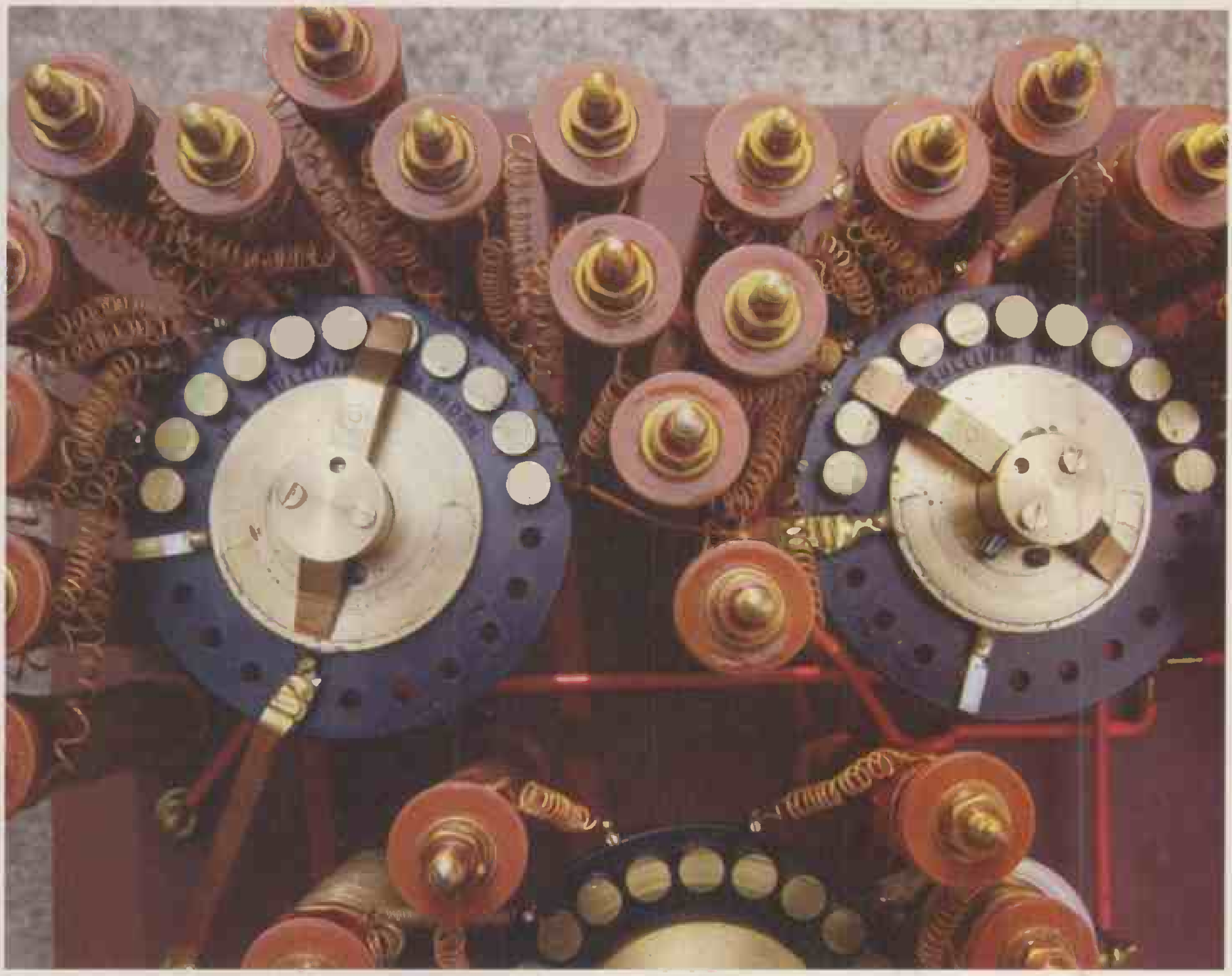
In polled mode power consumption is said to be around 300μA, while the receiver has -105db sensitivity.

Typical applications include remote keyless entry, data logging, mobile panic alarms, lighting control and short-range paging systems.

Moreover the transceivers use a lead-free solder process.

EMA said the 434MHz band is better than 868MHz for several reasons. 868MHz is already becoming overcrowded, the SAW filters are not as narrow-band, effects of stray capacitance and inductance are doubled, and it is not available worldwide.





Wheatstone revisited

David Ponting's resistance bridge represents a new look at the traditional Wheatstone configuration. It provides precise measurements from mega ohms down to milli ohms.

Heading picture shows close up of standard resistors and switching in a twentieth century bridge.

A Wheatstone bridge project? Oh come on! It's *so* last year. Well, maybe. But even in the twenty-first century, might not there be a new relevance for this rather special resistor network?

I recently went to a large antiques' fair and bought an original, early twentieth-century Wheatstone bridge for a fiver. I bought it because I knew that it contained a number of quality, low contact-resistance switches that would be surrounded by some highly accurate wire-wound resistors. *They* would certainly be useful, wouldn't they?

Unlike some bridges of this period, it also sported an internal centre-zero galvanometer designed to respond to micro amps. Surely I could find a use for that. Of course, it could all be burnt out inside with no usable resistors or galvanometer. But then it was only five pounds...

Having got it home, I couldn't rest until I'd had a quick peek inside. No burnt out resistors but it immediately became obvious that the galvanometer had long given up the ghost. Nevertheless, I spent several hours over the next few days thinking where I might find a use for it or its components.

I remember I'd used an almost identical bridge at school. After the tedium of kings and queens, world geography and Latin verbs, I'd found the physics lab a place of general delight where I had learned (if nothing else) some interesting things about Charles (later *Sir* Charles) Wheatstone.

He was born in 1802 and died at the age of 73. He started his career as a musician and invented the concertina. As a young man, Wheatstone built a factory making a handsome living through the manufacture of this particular musical instrument. But it was through his varied work on acoustics, telegraphy and cryptography that he was invited to become a Fellow of the Royal Society.

I recalled that at its symposia Wheatstone was initially so shy before his peers that he had to rely on his good friend Michael Faraday to present the width and wealth of his research. And out of all Wheatstone's many discoveries and diverse interests, the only thing to carry his name and for which he will always be remembered was actually designed in 1833 by someone else – an almost forgotten physicist named S. H. Christie.

Sir Charles' partial contribution to the bridge was demonstrating how this particular network might best be used in determining unknown resistances.

Figure 1 shows the usual set up. A battery of voltage V and internal resistance E supplies a current of e to the resistor network A, B, C and D, where the galvanometer of resistance G detects the current of g.

The bridge is said to be balanced when the resistor values are varied until no current passes through the galvanometer. At this time, it can be shown – what a *useful* phrase – that the product of the resistors A and C is equal to the product of the resistors B and D. Further, this relationship is independent of the value of V.

In the Wheatstone version of the bridge, A and B are usually referred to as 'the ratio arms' and D is the standard but variable resistance against which the unknown resistor C is compared. If the

Solving with six equations

First, assume that E, the internal resistance of the battery, is small enough to be ignored when compared with the resistances we want to measure. So Equation 1 becomes:

$$aA + bB = V$$

Or,

$$a = \frac{V \pm bB}{A} \qquad (7)$$

And,

$$b = \frac{V \pm aA}{B} \qquad (8)$$

From (2) and (4):

$$aA + gG \pm D(e \pm a) = 0$$

Or,

$$e = \frac{a(A+D) + gG}{D} \qquad (9)$$

From (3) and (5):

$$gG + C(d+g) \pm bB = 0$$

Or,

$$bB = C(d+g) + gG$$

But from (4),

$$d = e \pm a$$

Therefore,

$$bB = C(e \pm a) + gC + gG$$

From (6),

$$a = g + b$$

Therefore,

$$bB = C(e \pm g \pm b) + gC + gG$$

Or,

$$e = \frac{bB + bC \pm gG}{C} \qquad (10)$$

From (9) and (10),

$$\frac{a(A+D) + gG}{D} = \frac{bB + bC \pm gG}{C}$$

Or,

$$aC(A+D) + gCG = bD(B+C) \pm gGD$$

Or,

$$a = \frac{bD(B+C) \pm gGD \pm gGC}{C(A+D)} \qquad (11)$$

From (7) and (11)

$$\frac{V \pm bB}{A} = \frac{bD(B+C) \pm gGD \pm gGC}{C(A+D)}$$

Or,

$$VC(A+D) \pm bBC(A+D) = AbD(B+C) \pm gDAG \pm gAGC$$

Or,

$$b[AD(B+C) + BC(A+D)] = VC(A+D) + gAG(D+C)$$

Or,

$$b = \frac{VC(A+D) + gAG(D+C)}{AD(B+C) + BC(A+D)} \qquad (12)$$

From (8) and (12),

$$\frac{(V \pm aA)}{B} = \frac{VC(A+D) + gAG(D+C)}{AD(B+C) + BC(A+D)}$$

Or,

$$aA = V \pm \frac{B[VC(A+D) + gAG(D+C)]}{AD(B+C) + BC(A+D)}$$

Or,

$$a = \frac{1}{A}\left[V \pm B\left(\frac{VC(A+D) + gAG(D+C}{AD(B+C) + BC(A+D)}\right)\right] \qquad (13)$$

Substituting (12) and (13) into (6),

$$\frac{1}{A}\left[V \pm B\left(\frac{VC(A+D) + gAG(D+C)}{AD(B+C) + BC(A+D)}\right)\right]$$

$$= g + \frac{VC(A+D) + gAG(D+C)}{AD(B+C) + BC(A+D)}$$

Or,

$$VAD(B+C) + VBC(A+D) \pm VBC(A+D) \pm gABG(D+C)$$

$$= gA[AD(B+C) + BC(A+D)] + AVC(A+D) + gA^2G(D+C)$$

Or,

$$g\{A[AD(B+C) + BC(A+D)] + ABG(D+C) + A^2G(D+C)\}$$

$$= VAD(B+C) \pm AVC(A+D)$$

Which resolves into:

$$g = \frac{V(DB \pm CA)}{G(BD + BC + AD + AC) + ABD + ACD + ABC + BCD}$$

(where A is not zero).

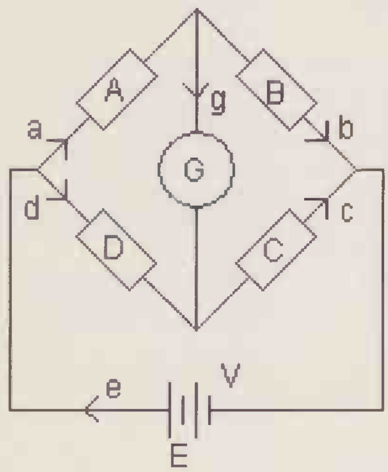


Fig. 1. The usual Wheatstone bridge set up. It's said to be balanced when no current passes through the galvanometer, i.e. the product of resistors A and C is equal to the product of resistors B and D.

A/B ratio and the value of *D* are known, then *C* can be calculated.

Big deal! Measure *C* using your £25 digital multimeter which you bought last month and which will also measure voltage and current, and probably frequency, capacitance and transistor gain as well.

But will your modern multimeter read resistance to a potential accuracy of better than 0.0002%? Or measure the resistance of a few inches of hook-up wire? If not, read on.

You see, what the physics teacher probably never brought to the class's attention was what happens when the bridge is *not* balanced. It needs a little mathematical pursuit but the results are interesting and illuminating.

To proceed, it is necessary to re-introduce another physics favourite: Gustav Robert Kirchhoff (I had to look him up to find his given names and immediately discovered that I had always mis-spelled his family name by leaving out one 'h').

Anyway, Kirchhoff is not much of a heavyweight in this area as his so-called 'Laws' don't go much beyond common sense and a restatement of Ohm's. But they often help to structure the equations relating to component networks. If Kirchhoff's Laws seem to have slipped your memory they are:

1. In any complete route through a resistor network, the algebraic sum of the products of current and resistance in each of the conductors along the route is equal to the algebraic sum of any voltage sources included in that route.
2. In a network, the algebraic sum of the currents that meet at a point is zero.

So, going back to Fig. 1, it is possible to apply Kirchhoff and obtain a number of relationships:

$$eE+aA+bB=V \qquad (1)$$
$$aA+gG-dD=0 \qquad (2)$$
$$gG+cC-bB=0 \quad \text{all from Law 1;} \qquad (3)$$

and,

$$e=a+d \qquad (4)$$
$$d+g=c \qquad (5)$$
$$a=g+b \quad \text{from Law 2.} \qquad (6)$$

With six equations, it is possible to solve for six unknowns, of which 'g' is the one of interest here. If you want to see how this is done, take a look at the panel entitled 'Solving with six equations'.

If you decided not to study the panel, I can reveal that in terms of the various resistances whose values are assumed to be known, the galvanometer current 'g' is given by:

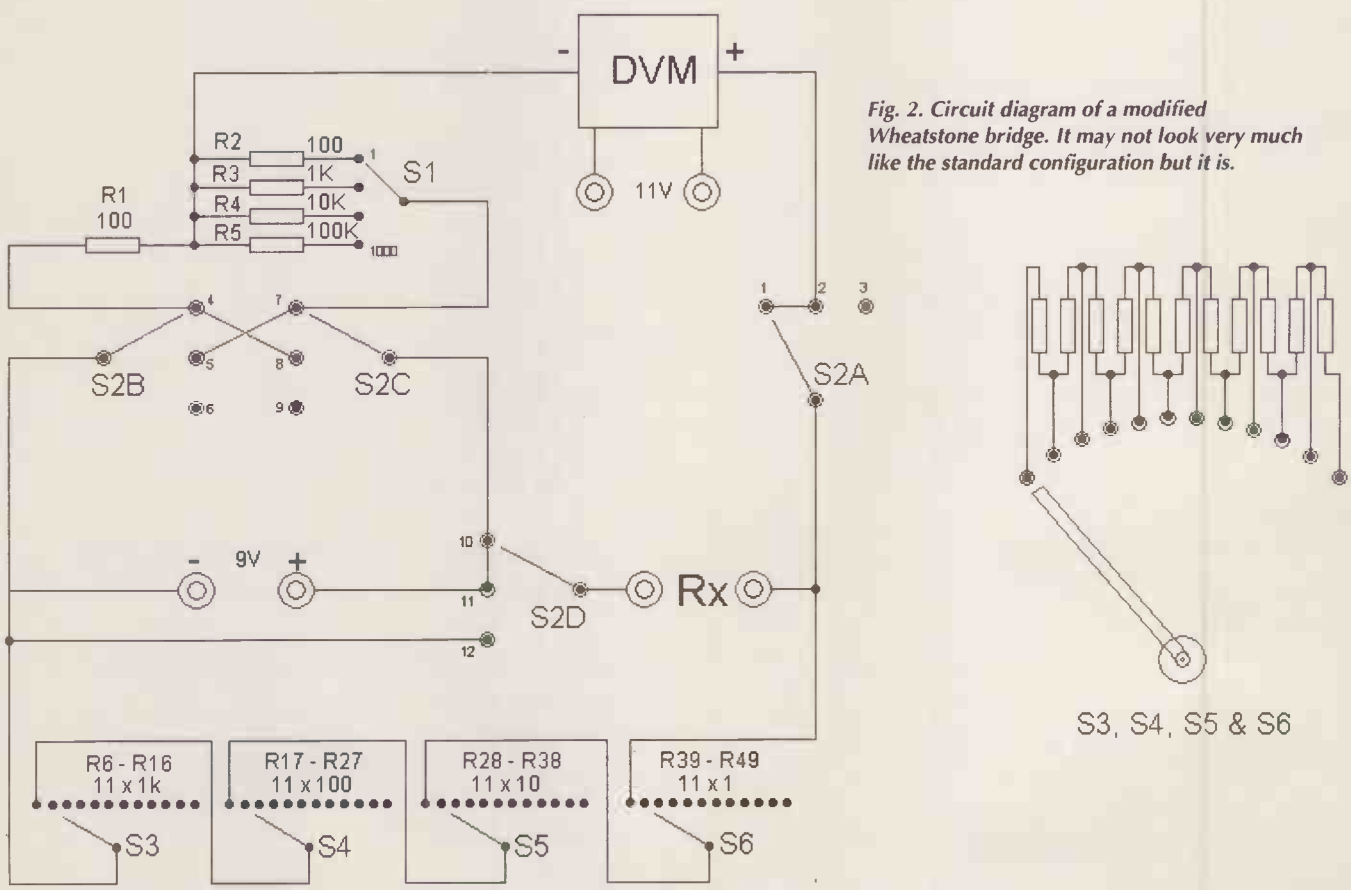


Fig. 2. Circuit diagram of a modified Wheatstone bridge. It may not look very much like the standard configuration but it is.

Photograph of the completed design described in the article.

Completed project, showing the interconnections between the DVM and the two PCBs.

$$g = \frac{V(DB \pm CA)}{G(BD+BC+AD+AC)+ABD+ACD+ABC+BCD} \qquad (14)$$

which doesn't seem very interesting at all.

But look again. If V has a real value, i.e. in this context greater than 0, 'g' can only be zero if $DB=CA$ which proves the well-known Wheatstone relationship. Further, only at balance is the value of V immaterial.

When *near* balance is achieved, the products CA and DB are pretty well equal, so each term of the right-hand side of equation (14) can be divided by either AC or DB as convenient.

So:

$$g = \frac{\dfrac{V(DB \pm CA)}{DB}}{G\left(\dfrac{BD}{DB}+\dfrac{BC}{AC}+\dfrac{AD}{DB}+\dfrac{AC}{AC}\right)+\dfrac{ABD}{DB}+\dfrac{ACD}{AC}+\dfrac{ABC}{AC}+\dfrac{BCD}{DB}}$$

which resolves finally into:

$$g = \frac{V\left(1 \pm n\dfrac{C}{D}\right)}{G\left(n+2+\dfrac{1}{n}\right)+(A+B+C+D)} \qquad (15)$$

where n can stand for the ratio A/B or D/C.

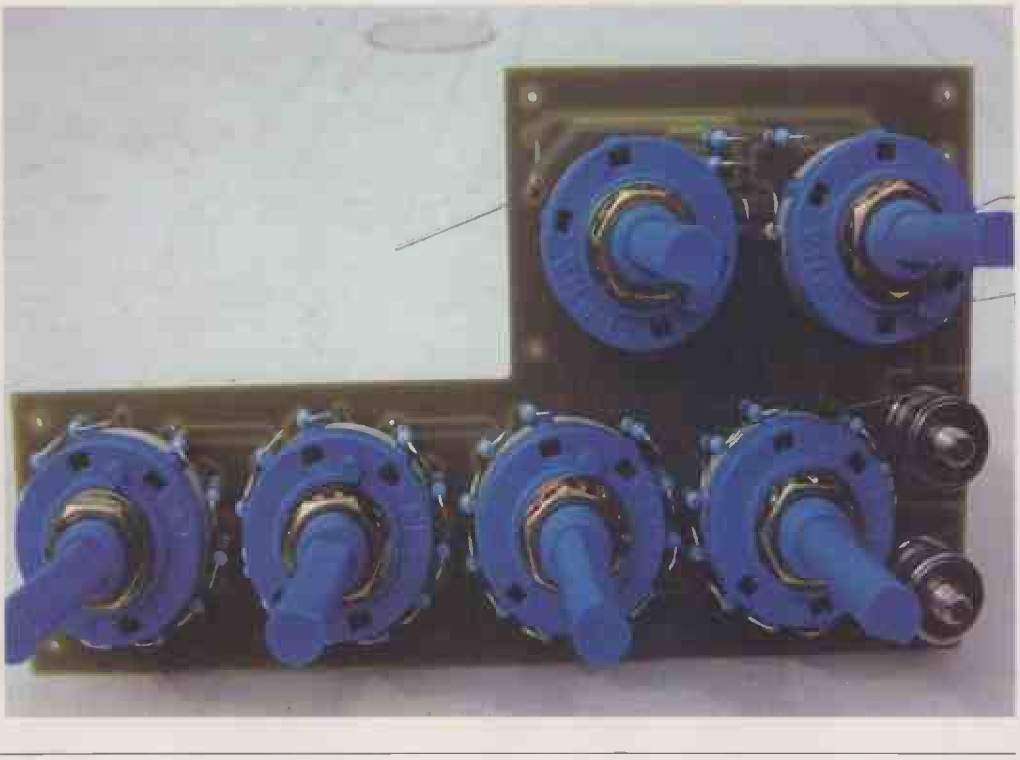
To achieve the highest sensitivity as balance is approached, it is necessary for 'g' to be as big as possible. A fraction is large when the top line is large and/or when the bottom line is small. All that can be done to increase the value of the top line in equation (15) is to make V as big as possible. So a sizeable value for the applied voltage *is* important for good sensitivity as we near the point of balance.

Making the bottom line small has greater possibilities.

Consider the second term first. The sum of A, B, C and D will be small when each of the individual bridge resistors has as small a value as possible. However, if a large value resistor has to be measured then it would appear that at least one of the other resistors will need to have a similar size. Further, a small value for all the bridge components implies the use of high currents, which might well damage the item being tested – not to mention the standard resistors.

The first term of the denominator, $G(n+2+1/n)$, is a bit trickier. Simple calculus (see the panel entitled 'Calculus') shows that the minimum value of the function $(n+2+1/n)$ is 4 and that this occurs when n is 1. Unfortunately this value 4 is multiplied by G, the galvanometer's resistance which must therefore be kept as small as possible. But that requirement is in direct conflict with the need for a highly sensitive galvanometer whose construction usually relies on a coil of wire rotating in a magnetic field.

In general terms, the greater the number of turns in this coil, the



Early stage in the design, with potentiometers and resistors fitted.

more sensitive the galvanometer. But the more turns the greater its resistance, which is the very parameter we are trying to keep small. Oh dear.

Further, while the galvanometer needs to be ultra-sensitive when balance is imminent, it must be bullet-proof when the balance is miles away. In the original Wheatstone bridges of a century or so ago, that usually meant employing some sort of multi-position switch so that low sensitivity could be selected initially and then be increased as balance was approaching. The only problem there was that a new user, starting on a fresh job, was likely to overlook the fact that the sensitivity switch had been left set to maximum by the previous operator with the outcome that this oversight would invariably result in a very bent galvanometer needle, the smell of burning and the new user being fired.

Even designing a Wheatstone bridge in the twenty-first century would appear to offer few simple answers; just a lot of opposites to be resolved by compromises that will fully satisfy none. In any case, where today are you going to buy a robust, ultra sensitive, centre-zero galvanometer that will produce sizable deflections for a current flow of a micro amp or two? Well, this may be possible.

If you make a minor re-arrangement of equation (15) you get:

$$g = \frac{V\left(1 - n\frac{C}{D}\right)}{G\left[\left(n + 2 + \frac{1}{n}\right) + \frac{A+B+C+D}{G}\right]}$$

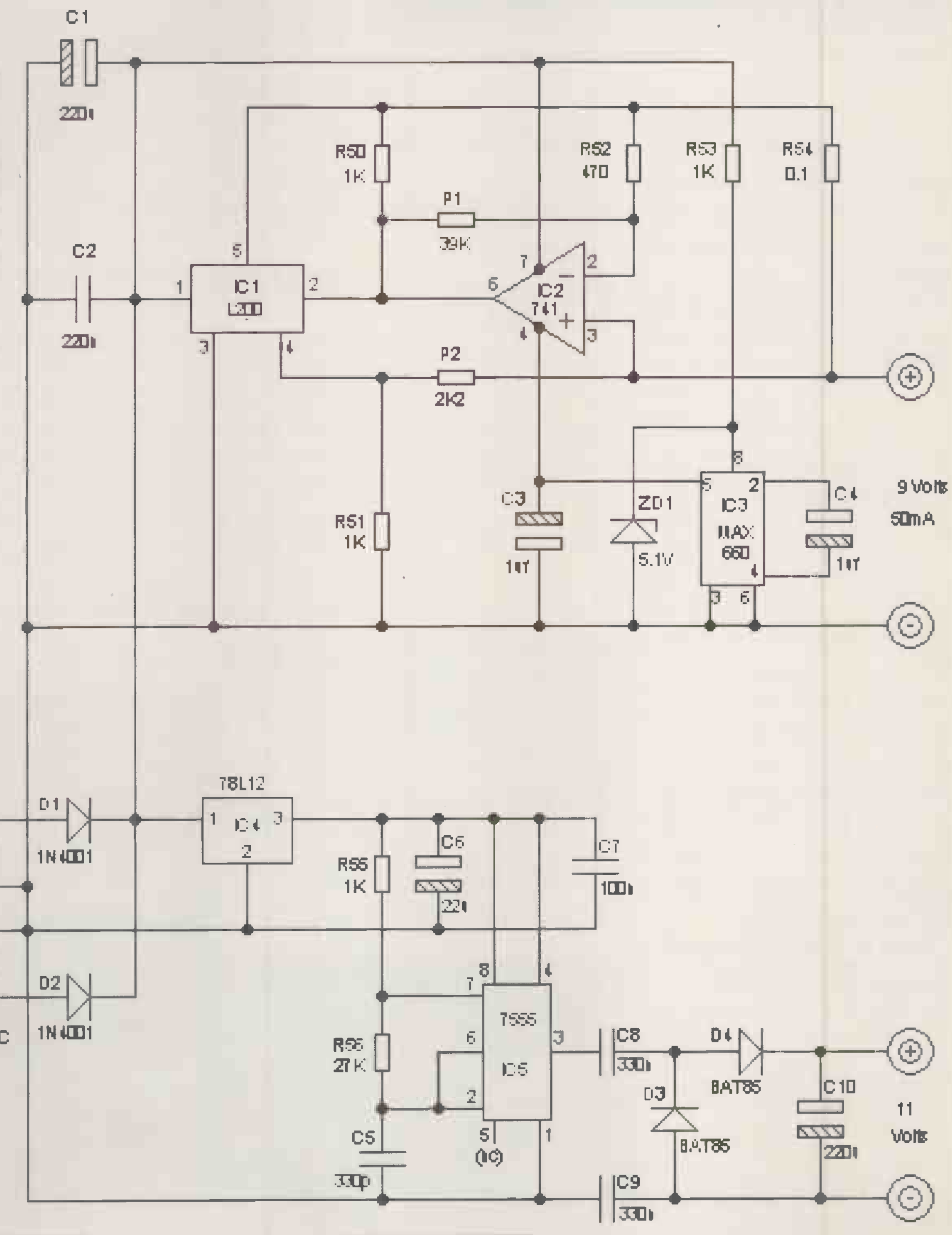


Fig. 3. Due to the display module used, two independent power supply rails are needed. The top section of the circuit produces a stable 9V to run the main bridge. It incorporates a DC-to-DC converter to provide a negative voltage for the 741 op-amp. The lower power supply runs the DVM.

or,

$$gG = \frac{V\left(1 \pm n\frac{C}{D}\right)}{\left(n + 2 + \frac{1}{n}\right) + \frac{A+B+C+D}{G}} \qquad (16)$$

This doesn't look like much of an improvement but the left-hand side of equation (16) is the product of the galvanometer's resistance and the current flowing through it, which is of course the voltage across it. Now whereas finding a robust but sensitive *current* detector in this day and age might be very difficult, equivalent *voltage* meters are relatively cheap and potentially so much more sensitive than were their ancient micro amp counterparts.

What is more, if we choose a digital voltmeter module, its input impedance 'G' is guaranteed greater than 100MΩ, resulting in a significant value for 'gG' even when the current flow is very small. And even more: the term $A+B+C+D$ is now divided by 'G' making the resulting value tiny even if the resistor being measured is of the order of mega ohms. In fact, a modern DVM panel meter module is an almost perfect practical solution. So this may be the time to leave the theory and get on with the practice.

Figure 2 shows the circuit diagram of a modified Wheatstone bridge. It may not look very much like the standard configuration but try and ignore the switches for the moment. Think of R_1 as A, R_2 as B, the whole range of potential resistance R_6 to R_{49} as D, and the unknown resistor R_x as C. Resistors R_1 and R_2 are both 100Ω so R_1/R_2 gives n=1. Hence when the bridge is balanced, R_x will have the same value as the selected resistors from the chain $R_{6\text{-}49}$.

Operating S_1 once will now make R_3 (1kΩ) the B resistor; the ratio R_1 to R_3 will result in n=1/10. Now, when the bridge is re-balanced, the resistance R_x will be the face value of the resistor chain *multiplied* by 10. Or arrived at from another direction, when gG is zero in equation 16, nC/D must equal 1. So $C=D/n$, or $R_x = 10(R_{chain})$.

Similarly with S_1 in its third position, the ratio of R_1 to R_4 (10k) will be 1/100 and R_x will have the value of the chain multiplied by 100. And for S_1 in its fourth position the multiplying factor will be 1000.

Consequently, with the greatest resistance of the chain being 12 221 ohms, the maximum value for R_x which can be balanced, is in excess of 12MΩ.

Now consider S_2. With this switch operated once from its shown position, R_1 becomes resistor B and one of the resistors R_2, R_3, R_4 or R_5 becomes resistor A. For A=R_2, the ratio of A to B once again gives n=1, but for the other values A=R_3, A=R_4 and A=R_5, the ratios for n are 10, 100 and 1000 respectively.

Consequently, at balance, the value of R_x will be 1/10th that of the chain when R_3 is A, or 1/100th with R_4 as A, or 1/1000th with R_5 as A. In other words S_1 selects between factors 1, 10, 100 and 1000 whereas positions 1 and 2 on switch S_2 determine whether the face value of the chain at balance is multiplied by or divided by the selected factor.

Again considering the greatest resistance of the chain (12 221Ω) and dividing by 1000, measurements up to a little more than 12Ω can be achieved on the lowest scale which means that 1/100th or even 1/1000th of an ohm can be balanced to fair accuracy. You could, for example, select virtually any old piece of hook-up wire lying around on your bench and determine its resistance.

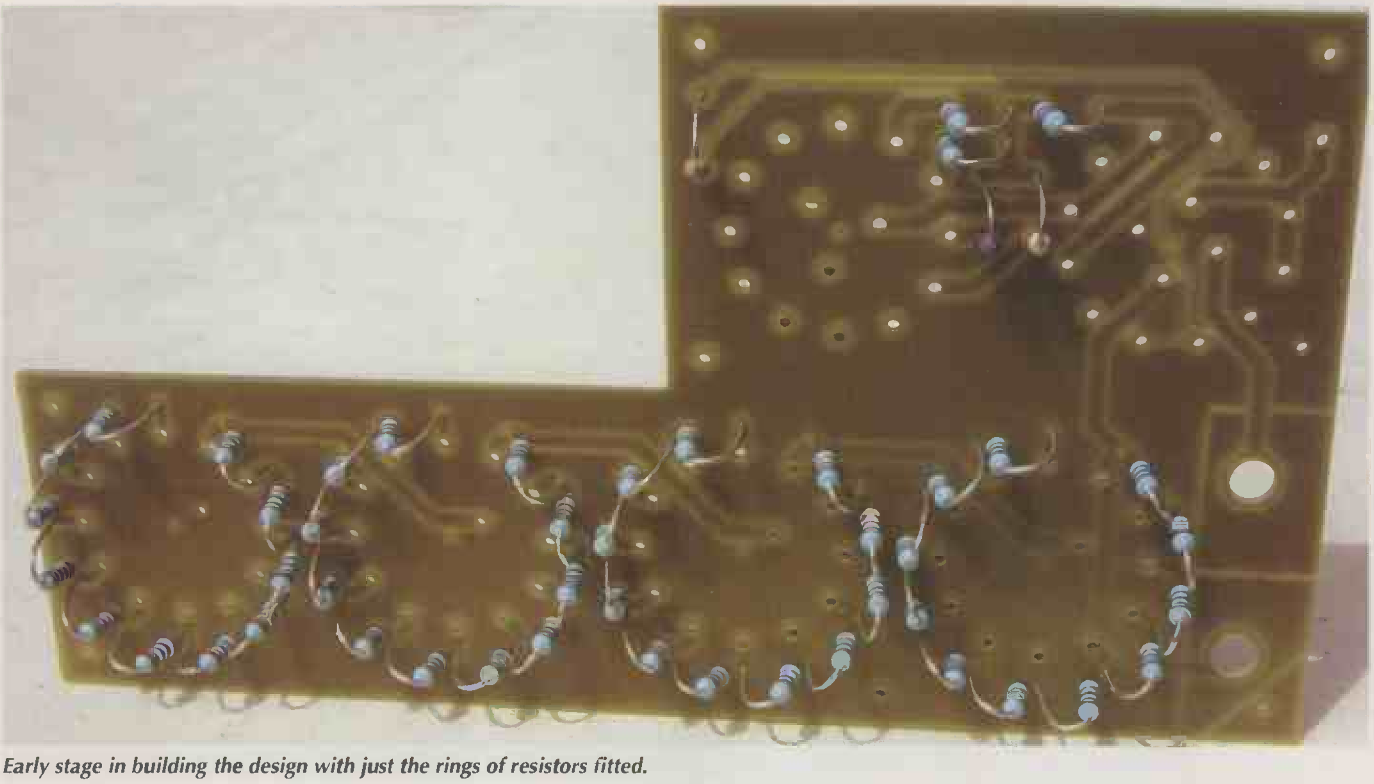
Switch S_2 is a three-position switch. In its third position, the R_x terminals are connected directly – and independently – to the ends of the resistance chain. Hence, as a bonus, the proposed unit can also be used as an accurate resistance-substitution box providing resistances from zero to 12 221Ω in 1Ω steps.

In a sense the switching circuit is the easy part. What is much more subtle is the double power supply needed. Its circuit diagram is shown in **Figure 3**.

The top section of the circuit produces a stable 9 volts to run the bridge. As I pointed out earlier, for best sensitivity the voltage across the bridge should have as large a value as possible. In practice however, this voltage is limited by two factors: first by the maximum that can be applied to the input of the DVM, which in turn depends on the 7106 analogue-to-digital-and-driver/display chip used in the module. For this device, the maximum recommended input is 15 volts.

However, it is also necessary to consider a second factor. The minimum resistance of the A-plus-B branches of the bridge is 200Ω. If there is no resistance being measured across the terminals, this 200Ω is effectively the only load presented to the voltage, V. Under these conditions, the current flow will be V/200 which means that the wattage of *each* of the resistors must be V^2/400.

If the circuit design is limited to the use of 0.4W resistors for A and B that have to be de-rated by 100% to ensure that they will not get hot and change their resistance, the value of V works out at 9 volts.



Early stage in building the design with just the rings of resistors fitted.

Hence the upper power supply in the diagram is set up to limit its output voltage to the safe value of 9V.

By the way, from the above it can be seen that the greatest electrical stress on the bridge's ratio arms occurs when the factor switch is on 1, the function switch is on multiply or divide and no resistor is being measured. Under these conditions R_1 and R_2 may get warm. Consequently when the bridge is switched on but not being used, it is good practice to leave the factor switch set at something other than 1.

The upper section of the circuit is built around a L200 voltage regulator. This not only controls the voltage, but can also be configured to provide current limiting as well. This is the purpose of the 741 op-amp and the resistor network around it.

DC-to-DC converter IC_3 is a very useful device, which will provide a negative voltage numerically equal to its positive input. This provides a negative supply to the 741 op-amp, allowing it to operate right down to zero volts.

An original Wheatstone bridge, fitted with an integral galvanometer.

An original Wheatstone bridge, without galvanometer.

It is possible to imagine a situation where the bridge is being used to measure the resistance of, say, a few inches of hook-up wire and the chain is set to 0000. In these circumstances there is pretty nearly a dead short across the supply voltage. Using the upper power circuit shown, the voltage and current are both limited: if the current demand exceeds about 50mA, the current will freeze and the voltage reduce to zero while for current demands lower than about 40mA, the voltage will remain at a constant 9 volts.

Incidentally, the two resistors that determine the sizes of the output voltage and current are P_1 (current) and P_2 (voltage). In the circuit diagram, these are labelled as 'potentiometers' because they could be made variable if required, although the fixed values given here are appropriate for use in this circuit.

The lower power supply is designed to run the DVM and reveals the major drawback of the recommended PM-128 panel meter module: it must be powered by a supply completely independent of the voltage to be measured.

In particular it *cannot* have a common ground with it. This usually means a separate supply via another winding on the mains transformer needing its own rectification and smoothing. To avoid this duplication, the single rectified output of the transformer is voltage-regulated to 12 volts by the 78L12 and smoothed by C_6 and C_7.

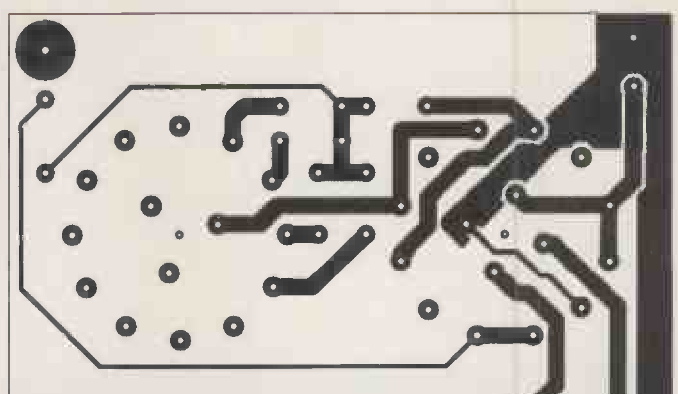
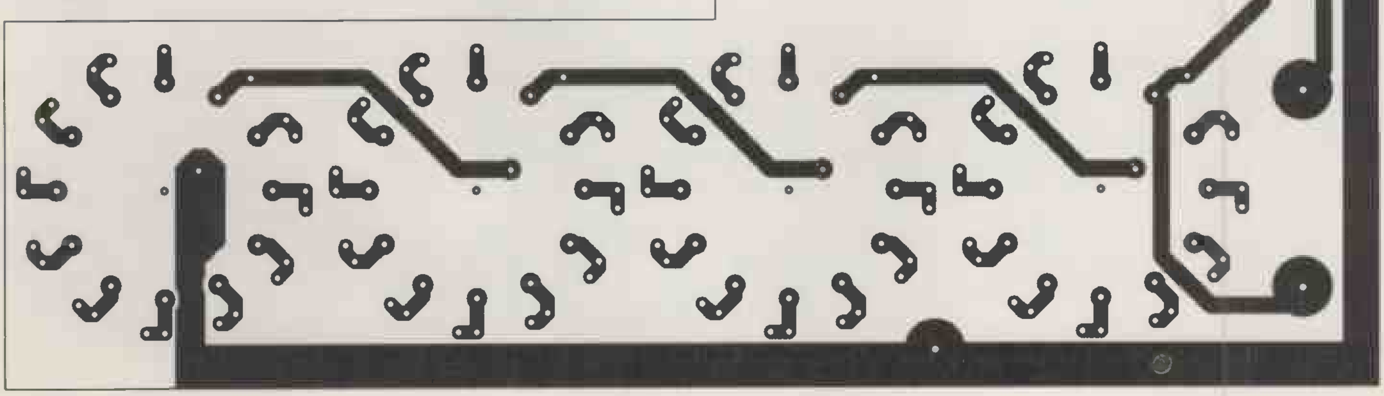
The 7555 IC is configured as a free-running oscillator whose frequency is about 80kHz. Because R_{55} is so much smaller than R_{56}, the duty factor of the resulting square-wave is close to 50%. As the CMOS version of the 555 timer is being used, the output signal at pin 3 is virtually rail-to-rail.

Capacitors C_8 and C_9 provide DC isolation while Schottky diodes D_3 and D_4 act with minimal loss as full-wave rectifiers in a voltage-doubling

Calculus

If $y=n+2+1/n=(n^2+2n+1)/n$, then $dy/dn=[n(2n+2)-(n^2+2n+1)]/n^2=[n^2-1]/n^2$.
For maxima and minima, $dy/dn=0$, giving values for n of +1 and −1.
Differentiating again results in $d^2y/dn^2=[n^2(2n)-(n^2-1).2n]/n^4=2/n^3$.
When $n=1$, d^2y/dn^2 is positive. Therefore for this value of n, the function $(n+2+1/n)$ is a minimum and has the value 4.

Fig. 4. First of the two single-sided printed circuit boards This is the copper pattern.

configuration. Capacitor C_{10} smoothes the resulting DC to provide about 11V. The circuit is quite capable of supplying the 1mA or so necessary to run the DVM independently.

Making up the printed circuit boards

There are two, single-sided printed circuit boards: **Figure 4** shows the copper pattern for the switching section – which, to avoid stray parallel resistance, should *not* have a copper fill – and **Figure 5** the PCB for the power supplies.

Except for the obvious positioning of the resistors of the chain, **Figs 6** and **7** show the placement of the other components on these two boards. There should be few problems in making up either PCB and all the components are readily available from the usual suppliers.

It is probably easier to start building the 'switching' PCB by fitting the resistors of the chain first. I'll comment later on the accuracy of measurements using this bridge, but I would suggest that while 0.1% resistors will improve accuracy, for most applications R_6 to R_{49} need be no more precise than 1% types; but they should be at least that.

All these 44 resistors need to 'stand up' in groups of 11 around their respective switches. Having completed the rings of resistors and checked that there are no track-to-track shorts from solder splashes, switches $S_{3\text{-}6}$ can be fitted after cutting away the plastic 'non-rotation' pin on the thread side of each switch.

Before proceeding – and assuming you have other means of measuring resistance – connect an ohm-meter to the ground line and to pin 1 of switch S_6. Verify that operating the four switches results in resistance values from near 0 to 12 221Ω. In practice, the '0000' position will result in a value a little greater than zero due to unavoidable accumulative resistance from partial connections, switch contacts and copper tracks.

When the resistor chain has been checked, R_1 to R_5 can be fitted. There are real advantages in making these five resistors 0.1% types and they must be at least $^1/_4$ watt. Rapid Electronics has just introduced a new range of 0.1%, 0.4W resistors that can be bought in one-off quantities in a wide range of values.

After fitting components R_1 to R_5, switches S_1 and S_2 should have their plastic 'non-rotation' pins cut off and then be soldered in place. Unfortunately, unlike the four switches of the chain, it is possible to fit S_1 and S_2 into the PCB when they are wrongly rotated.

Figure 6 illustrates the correct positioning of each. In the diagram, each switch has an arrow drawn which indicates its most anticlockwise position. The arrow also represents the *opposite* side of the flat face of the switch's spindle.

Now the power supply PCB can be built. The standard transformer for which the board is designed is a fully encapsulated miniature component and intended for direct PCB mounting. It has two secondaries, each rated at 15V AC and 50mA (a total power rating of 1.5VA).

It is good practice to fit the three 8-pin DIL integrated circuits into sockets rather than solder them directly into the board.

When the power supply PCB is complete, ensure that nothing can come into contact with the mains-carrying tracks below the transformer and then temporarily (taking the usual care) connect the primary winding (or series windings) to the mains.

Check that there is a stable 11V supply at the two pads to the left of

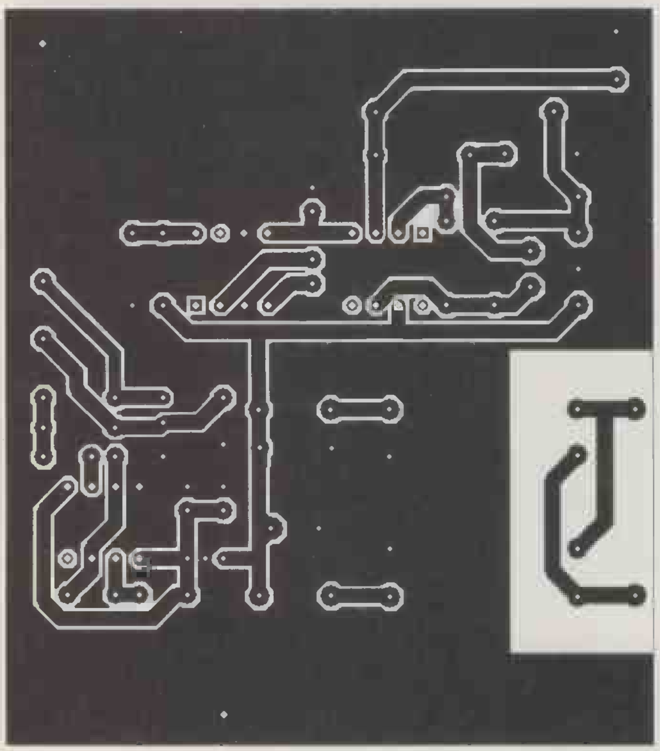


Fig. 5. Circuit board for the two power supplies.

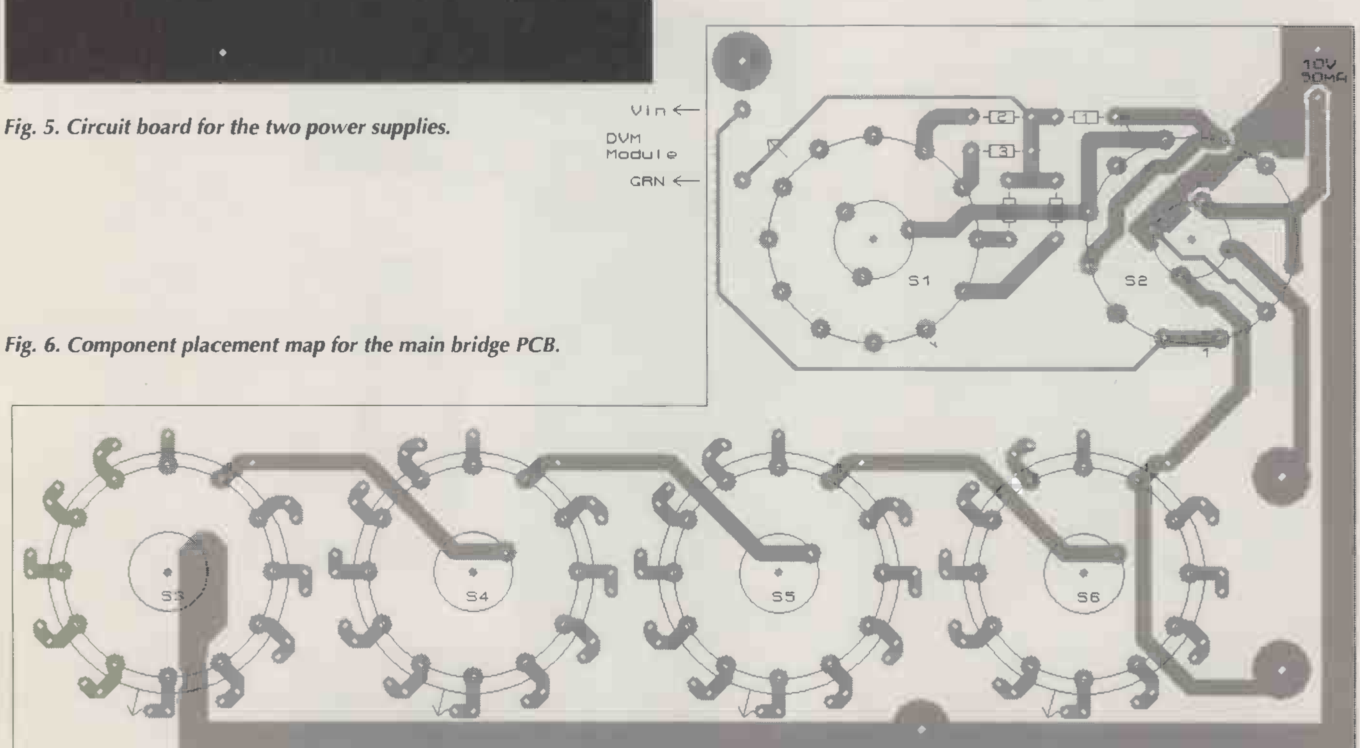


Fig. 6. Component placement map for the main bridge PCB.

the board and make sure that this is independent of the ground fill. Also check that there is a stable 9V between the pad in the top right corner of the board and the ground fill.

If these tests are positive, connect a 150Ω, 1/4W resistor across this erstwhile 9V supply and determine that the voltage then reduces by around 0.75V.

When both boards have been proved to function correctly, they should be piggy-backed together using two, 30mm spacers for which there are corresponding screw holes in each of the PCBs. Then solder two vertical wire links to join the two boards via the corresponding pairs of pads at the top right corner of both boards. This provides the 9V necessary to run the bridge section.

The front of the case should now be prepared. **Figure 8** can be used not only as the scales for the front panel but also as the drilling template for the six switches, the two binding posts and the space that needs to be cut out to accept the DVM panel meter.

When this mechanical work is completed, the front panel can be fitted over the six switches and secured using the switch nuts. The pillar of each binding post must be long enough to allow good contact with the copper side of the upper PCB while still allowing the terminal connectors to reach the front face of the box. Each binding post needs a suitably sized spacer (about 17mm) between the underside of the front panel and the top surface of the switch PCB.

Fit the DVM module in place and make the four connections from the two pads at the top left edge of the switch board to V_{in} and GRD on the module and from the two pads in the centre of the left hand edge of the power PCB to +V and –V on the module.

The whole unit is now ready for testing.

Using the bridge

Set the factor switch to 1 and the function switch to X. Carefully reconnect the mains to the transformer primary pads on the power supply board. The DVM should read –1. Connect a 5600Ω resistor across the binding posts and switch the chain to the same value.

You should get a numerical display other than –1. Now balance the bridge by increasing or decreasing the value of the chain.

With early bridges it was often difficult to determine whether the chain resistance had to be increased or decreased to progress towards balance. With this design, making this decision is easy: if the display includes a negative sign, the chain's value is too small and must be increased; if there is no sign, the chain's value is too great and should be decreased. This is true whenever the bridge is being balanced and is independent of the positions of both factor and function switches.

Continue the test with the 5600Ω resistor. It is probably easiest to start any new measurement with the factor switch at 1, the '1000s' switch (S_3) at 5, and all the other chain switches at 0. With the 5.6kΩ resistor you should find that 5 on Switch S_3 is the highest position which still gives a negative display.

Leave this selection and turn to the '100s' switch (S_4). Find the highest number on this switch which still gives a negative display and leave it set at that. Repeat the same procedure with the '10s' and then the 'Units' switches.

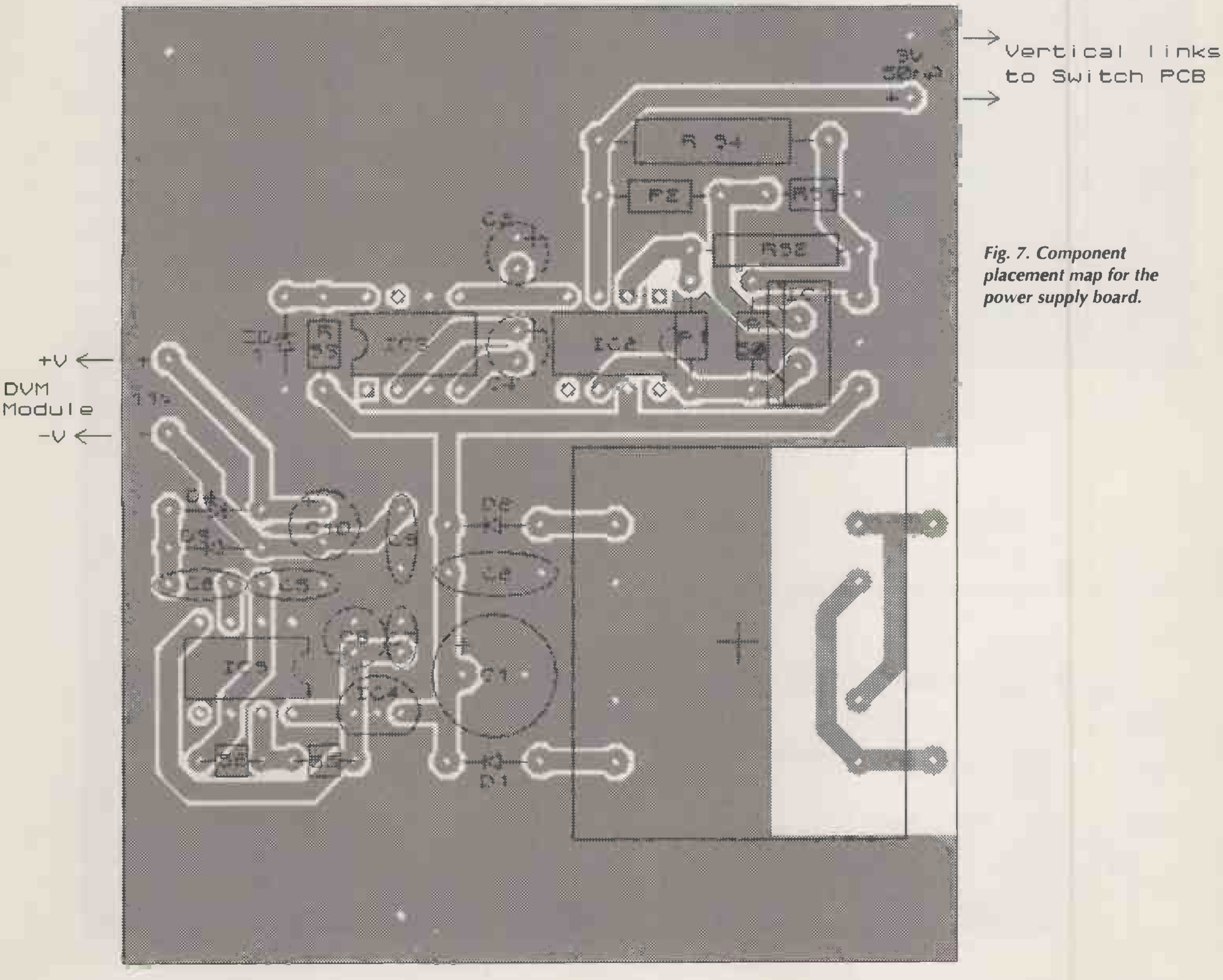


Fig. 7. Component placement map for the power supply board.

In all probability you will not be able to get a precise balance of 000 even using this last switch. Instead you may find that one position gives a small negative value and the next a small positive one.

Clearly the value of the 'tenths' must be somewhere between these. Suppose the closest to 000 which can realised with the 'Units' switch is –003 at one position and 003 at the next. Then it would seem feasible that a good estimate for the first decimal place will be half way, or 0.5Ω. If however the figures are –003 and 007, then the value is probably 0.3.

To generalise the rule: if the negative figure is $-a$ and the positive one is b then a good estimate for the decimal place figure is $10a/(a+b)$.

Accuracy issues

The design still employs many compromises, the first being the value of the ratio resistors A and B.

As I wrote earlier, the highest sensitivity is obtained when the ratio n is 1, i.e., when bridge-arms A and B are equal. Consequently the 'multiply-by-one' scale has the highest sensitivity. But no greater than the 'divide-by-one' scale.

So what happens if you use both the 'multiply-by-1' and then the 'divide-by-one' scales to measure a resistance whose real value R lies somewhere between 1000 and 12 000Ω? Suppose the value P is obtained for the first test and then Q for the second.

Unfortunately P and Q will *not* be the same! They should be but they won't because A and B will not be perfectly matched. However, if you take the arithmetic mean of P and Q, the result is a value for R which – theoretically at least – is accurate to 0.0002%. See the panel entitled, 'Determining the error.'

Consequently if 0.1% resistors are used, x has a maximum value of 0.2Ω. So the percentage error in R is 0.0002%. This accuracy will not be achieved because of other factors such as the resistance of connections, tracks and switching contacts as well as uneven errors in the resistors of the chain. But it does indicate that the result obtained by this simple averaging of two readings is remarkably accurate.

And not just accurate. Try going back to the measurement of our 5.6kΩ resistor. You may notice that its value is now slightly different from previous tests. This is to be expected.

Without allowing your fingers to short the leads of the resistor, try touching it after the bridge has been balanced. Or try blowing on the resistor. The display will change immediately. This is due to moisture or the heat of your fingers or the cooling breeze, or some combination.

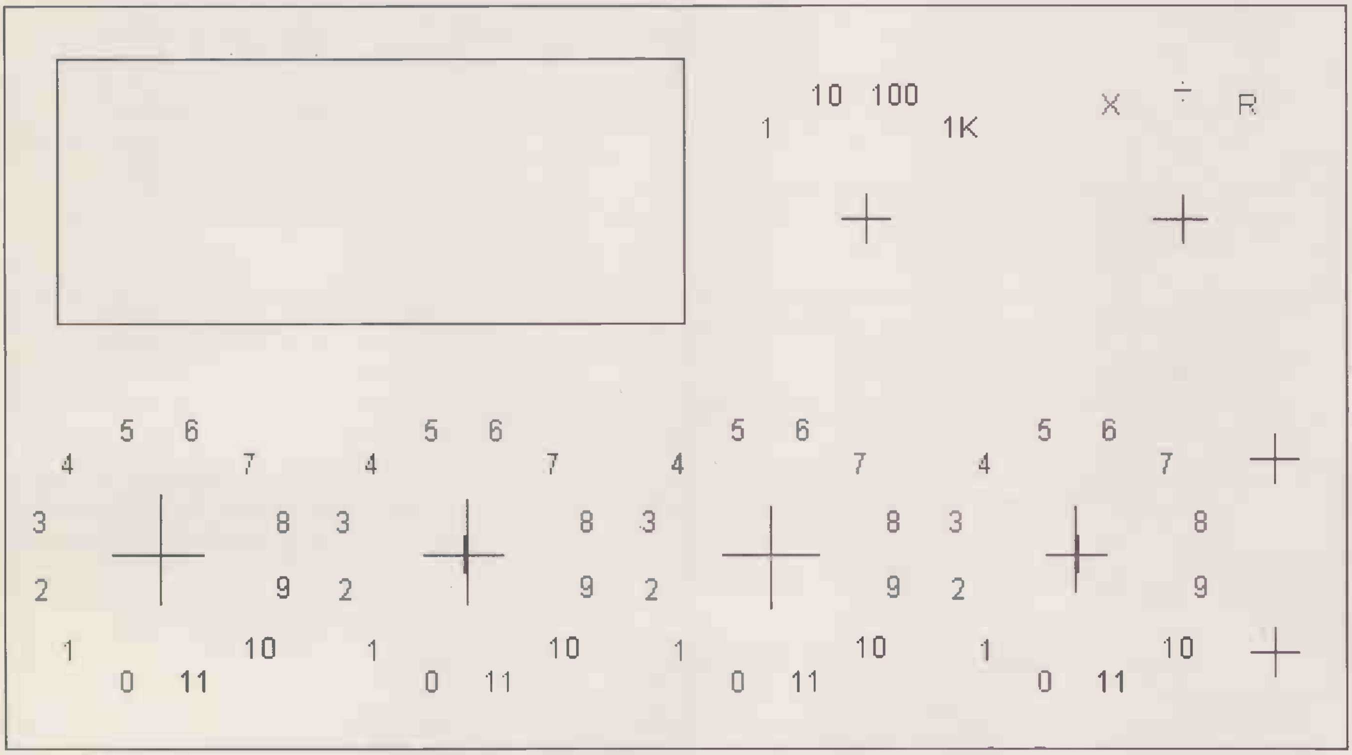
The original Wheatstone bridge with the galvanometer replaced with a DVM. Balance is achieved with a 5.6kΩ resistor.

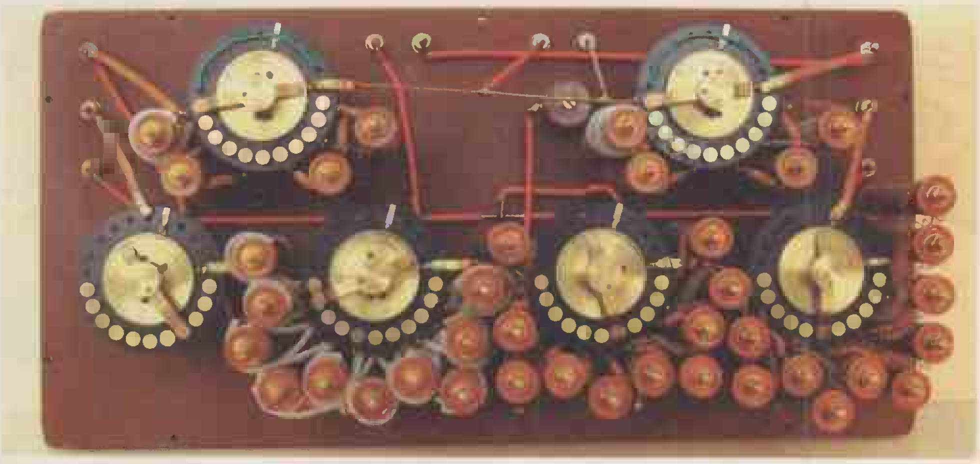
Try balancing the bridge at the end of the day and leave the resistor under test connected while the unit is switched off overnight. The next morning at switch-on the bridge will need considerable re-balancing because the temperature in the room (and hence the resistance of the component being measured) will have changed.

So far, I have considered the accuracy of readings when the ratio of A to B gives the value n=1, i.e. when the component being measured has a value in the range from 1kΩ to about 12kΩ. For this range, a sharp balance will be achievable right down to the 'Units' switch.

As I have shown above, by averaging the 'multiply' and 'divide' results, accuracy will be close to 1 part in 500 000. However, when the ratio 'n' is not equal to 1, the multiply/divide technique cannot be used and both the accuracy and sensitivity of the single reading will

Fig. 8. Positioning and drilling template for the bridge's front panel.





Rear of original Wheatstone bridge, showing wiring and interconnections.

Components

Resistors: all 0.25 watt and 5%, unless marked.

$R_{1,2}$	100, 0.4W, 0.1%
R_3	1k, 0.4W, 0.1%
R_4	10k. 0.4W, 0.1%
R_5	100k, 0.4W, 0.1%
R_{6-16}	1k, 1%
R_{17-27}	100, 1%
R_{28-38}	10, 1%
R_{39-49}	1, 1%
$R_{50,51,53,55}$	1k
R_{52}	470
R_{54}	0.1
R_{56}	27k
P_1	39k
P_2	2k2

Capacitors

C_1	220μ, 25V
C_2	220n
$C_{3,4}$	1μ, tantalum
C_5	330p
C_6	22μ, 16V
C_7	100n
$C_{8,9}$	330n
C_{10}	220μ, 16V

Switches

S_1	3P4W, rotary, PCB
S_2	4P3W, rotary, PCB
$S_{3,4,5,6}$	1P12W, rotary, PCB

Semiconductors

IC_1	L200 volt regulator
IC_2	741 op-amp
IC_3	MAX660 DC-to-DC
IC_4	78L12 volt regulator
IC_5	7555 CMOS timer
$D_{1,2}$	1N4001
$D_{3,4}$	BAT85, Schottky.
ZD_1	5.1 volt, zener

Miscellaneous

Transformer	15-0-15V, 1.5VA
Binding posts	2
DVM module	PM-128

Three 8-pin, DIL IC sockets, case, spacers, 6 switch knobs, etc...

begin to degrade.

With n=10, or 1/10, there is little change from n=1. Across most of both these ranges there will still be a sharp balance point and the 1/10th-ohm position can be estimated. Overall accuracy will be around 1%.

For the other four ranges, n=100, n=1/100, n=1000 and n=1/1000, the balance point gets less sharp but the results are still very usable and will be at least as accurate as those read on a standard multimeter.

When using n=1/1000 and measuring high value resistors – say more than about 5MΩ – the balance may be flat enough so that the 'Units' switch will make little difference to the balance point. In addition, parallel leakage resistance may result in a very slightly smaller value than the unknown should have.

At the other end of the ranges, when n=1000 (12Ω), the figures reached on S_3, S_4 and S_5 will themselves be reliable, while that on S_6 may be out by ±1 digit. The repeatability problem with this range is much more connected with random switch and track resistances, and with unreliable contact made with the binding posts.

However, the accuracy of these very small resistances can be improved on. I balanced the prototype bridge that I built by trying to measure the resistance of a very thick block of solid copper tightly screwed across the binding posts.

A clear balance of 0.028Ω was achieved. This of course should be pretty nearly 0.000 and represents the random resistance of switching contacts, resistor errors and copper tracks. Consequently when I measure small resistances I subtract 0.028 from the reading and get a more reliable value. Of course for resistances above a few ohms, this correction is no longer relevant.

The Bridge is finished by cutting off the unwanted lengths from all the switch spindles and then fitting suitable knobs to the remaining stubs, ensuring that the grub screws tighten against the flat side of each spindle. The whole unit then needs to be enclosed in a suitable – preferably plastic – box, ensuring that the mains supply connections are safely insulated from prying fingers.

I started this article by reporting my purchase of an early Wheatstone bridge. If you enjoy antiquing you may very well find in the local bric-a-brac junk shop or a neighbourhood boot sale an early twentieth century one of your own. They do turn up surprisingly frequently and can provide the basis for a high quality modern bridge.

If your purchase has an integral galvanometer, remove it and replace it with a DVM; if there never was a galvanometer, just connect the digital meter module to the appropriate 'Galvo' terminals where marked. Now provide 'battery' power for both the bridge and DVM using no more than the power supplies' section described in this project.

For experimentation it really does not matter which way round the pair of 'battery' and the pair of 'galvanometer' connections are made. Either way you will have a modern bridge providing very high accuracy in the measurement of resistance. ■

Determining the error

If x is the amount by which either A or B is greater than the other, then their ratio will be either $(100+x)/100$ or $100/(100+x)$. Therefore,

$$P = R\frac{100+x}{100},$$

using 'multiply-by-1';

$$Q = 100\frac{R}{100+x}$$

using 'divide-by-1'. Therefore,

$$\frac{P+Q}{2} = \frac{R}{2}\left(\frac{100+x}{100} + \frac{100}{100+x}\right)$$

$$= \frac{R}{2}\left(\frac{2.100^2 + 200x + x^2}{[100(100+x)]}\right)$$

$$= R\left(\frac{100(100+x)}{100(100\ +\ x)} + \frac{x^2}{200(100\ +\ x)}\right)$$

$$= R\left(1 + \frac{x^2}{200(100+x)}\right)$$

Therefore the percentage error in R is

$$\frac{100x^2}{200(100+x)}\%.$$

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RELAYS

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

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

Prices include base

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

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12V – Order Ref: FR18	48V – Order Ref: FR20

Price £1 each less 10% if ordered in quantities of 10, same or mixed values.
RECHARGEABLE NICAD BATTERIES. AA size, 25p each, which is a real bargain considering many firms charge as much as £2 each. These are in packs of 10, coupled together with an output lead so are a 12V unit but easily divideable into 2 x 6V or 10 x 1·2V. £2.50 per pack, 10 packs for £25 including carriage. Order Ref: 2.5P34.
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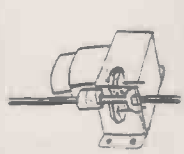

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FIGURE 8 FLEX, figure 8, flat white PVC, flexible with 0·4 sq mm cores. Ideal for speaker extensions and bell circuits. Also adequately insulated for mains lighting, 12m coil. Order Ref: 1014.
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DOLLS HOUSE SWITCH. A very neat white body with red control tag. Pack of 2. Order Ref: 57.
MAINS RELAY. Plugs into octal base, double-pole changeover contacts which look OK for up to 10A. Order Ref: 7TOP14.
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TINY MAINS MOTOR. This is only 2in. square, the shaded pole type with good length of 1/8in. spindle. Order Ref: 7/1R7.
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Batteries included

The appearance and popularity of power-hungry digital cameras has led battery suppliers to meet ever-increasing demands, which has stimulated the sector as a whole.

It is hard not to notice the capacity improvements that have appeared in rechargeable batteries in the last couple of years.

It was not long ago that an AA NiCd would only store 500mAh whereas today US company iPower is selling a 2100mAh (0.2C rate) AA-size NiMH to consumers.

UK customers will have to wait a little longer but GP Batteries is close to launching a 2.1Ah AA in the UK.

The AA size has almost become a battle ground with battery-makers vying for the business of digital camera owners who have found their new toys consume a lot more power than they thought they would.

Aimed at exactly that market, last year a new primary (non-rechargeable) battery chemistry hit the shelves for the first time. Nickel-zinc is the type and both Panasonic and Toshiba have announced AA versions. Both companies claim significant capacity improvements over traditional alkaline cells in camera applications although formal tests are thin on the ground.

Back with nickel metal-hydride, GP Batteries has released an 8.4V PP3-type NiMH in the UK which, at 170mAh, it claims is the most capacious PP3 yet. It also claims the GP17R8H, as it is called, has the highest power discharge and charge characteristics. Charging at 1C and discharged at 3C (0.5A) is possible. A 9.6V version particularly for alarms is will be added to GP's line-up in future.

The largest standard cylindrical cell is the F size (33dia x 91mm) which, it appears, was originally developed to be used in fours inside spring-topped 6V lantern batteries.

Saft has introduced an NiMH F cell with a capacity of 13.5Ah (typical at C/5 load). Called VH F, pulses of up to 100A are available from this cell as is 40A (20°C) continuous delivery. Applications in electric bikes and gardening equipment, are foreseen.

Not all NiMH cells are created equal and the VH F is a case in point. Despite its size, it has not been designed for 1 hour charging. The quickest charge is in 3-4 hour using between 4 and 5A. 5-6h charging is possible at 3-2.5A and the standard charge is 1.35A for 15 hours.

The GP 2.1Ah AA cell

What is lost in fast charge capability in the Saft's VH range is made up with extra capacity. Its D cell offers 8.5Ah (typical) capacity against 7Ah for many other NiMH D-cells. Fastest charge for the VH D is 2-3h. A 9.5Ah version is due out later this year.

For capacity and environmental reasons, NiCd cells exist in the shadow of their younger NiMH cousins, but they still win-out in discharge capability and low-cost.

Well known for its lead-acid batteries, Yuasa is now selling a range of NiCd cells. Ranging from 130mAH to 7.5AH there are currently 24 sizes in the standard range plus three high-temperature NiCds:, sub-C (1.3Ah), C and D (4.4Ah).

Trickle charging for Yuasa's NiCd cells is 48h at 0.05C, standard charge is 14 to 16h charge is at 0.1C and quick at 0.3C in 4h is possible.

One other advantage of NiCd cells over NiMH is trickle charge lifetime. NiCd cells are traditionally made to be able to withstand a 0.1C charge indefinitely whereas NiMH cells seldom are. As a result 0.1C NiMH charging without discharge will eventually finish off most NiMH cells.

Based around the superior discharge capability of NiCd cells, Powerstream Technologies of Utah in the USA has a range of NiCds especially designed for fighting robots. Its half-D cell (33mm dia x 37mm) weighs 81g and is claimed to deliver an astounding 98A. Capacity is 2.5A nominal and repeated charging at 4C is possible.

Lithium cells are increasingly offering the best capacity for a given weight, at a cost premium.

The latest lithium cells, called lithium polymer, use a solid electrolyte and can be made in flat sheets and some can even be bent.

PoLiFlex is a range of lithium polymer cells under development at Varta Microbattery. These are made from stacks of flat sheets and, according to the company, can be

Saft NiMH F cell.

piled up to make a wide variety of sizes and capacities. Two standard sizes are available. a 3.8x35x62mm 650mAh model and 780mAh in 4.2x35x66mm. Palmtops and GPS receivers are predicted markets.

Both the Varta PoLiFlex cells are fitted with electronic safety circuits. These are a feature of all rechargeable lithium-based cells sold to the public as lithium cells can react dangerously when abused.

Supplier All Batteries, for example, only supplies Liion cells as packs including electronics to control charge, discharge and cell balancing.

It distributes Saft's MP range of medium prismatic lithium-ion cells, which are available from 1.0 to 5.0Ah.

Life can be an issue with Liion cells but Saft claims 1,000 cycles "under most conditions". Charge retention, almost always good with Liion cells, is said to be over 95 per cent of initial capacity after 30 days at 20ºC. ■

Capacity in rechargeable cells is frequently declared in Amp-hours (Ah) or milliamphours (1,000mAh = 1Ah).
When charging or discharging is discussed, the term C is frequently used. This is the capacity of the cell. Thus a 1.8Ah cell has C = 1.8Ah.
If the manufacturer describes a C/10 or 0.1C charge, this means charging at 180mA. Similarly, a 0.5C discharge indicates a 900mA is being drawn from the cell.
Slightly confusingly, although a 1C discharge will empty a full cell in 1 hour, a 1C charge will not fill an empty on in an hour.
This is because charging is not 100 per cent efficient. In general 1.4C is required to fill a NiCd cell.
Charging efficiency for some Liion cells approaches 100 per cent.
Although users and misusers get away with some terrible charging practices, some do not. Longest cells life it to be had by following manufacturers charge, discharge and storage instructions.
All Batteries has an excellent technical guide on its website and some interesting snippets on the knotty problem of fast-charge termination can currently be gleaned from the New Products of GP Batteries' website where its PP3-sized cells are described.

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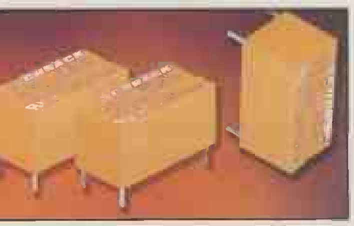
PCB relay switches up to 1,250VA

The Schrack PE series of single-pole, 5A, power PCB relays from Tyco Electronics is available in a one-coil polarised bistable design. Dimensions of 20 x 10mm with a height of 10mm are identical to those of the monostable relay, said the supplier. This power PCB relay offers insulation to IEC 255,



and 4kV coil to contact dielectric strength, for use in industrial electronics, measurement and control, room temperature thermostats and white goods. The maximum breaking capacity is 1,250VA, (5A at 250V AC) with a maximum switching voltage of 440V AC. Constructed with cadmium-free AgNi contacts, the rugged relay has a single C/O contact and operates in the ambient temperature range of –40 to +85°. For reliable operation, it is protected to IP40 (IP67 available on request) and has a mechanical life expectancy of 5 x 10^6 operations. There is a choice of coil voltages ranging from a nominal of 2.2V DC to 24V DC, with a typical power consumption of 360mW.

Tyco Electronics
www.tycoelectronics.com
Tel: +44(0) 20 8954 2356

30W isolated power module

Texas Instruments is offering a series of 30W isolated power modules in an 8mm package. The PT3400 series of 30W DC-DC converters accept input voltages from 36V to 75V and deliver output currents from 7A to 16A depending on output voltage. The range includes a power-up sequencing control pin that simplifies power sequencing when more than one module is used to power ICs with more than one power rail. It is also specified to a six million hour mean time between failure (MTBF) and lead-free construction. PT3400 integrated power modules are available in a surface-mount, vertical through-hole or horizontal through-hole styles (65.5 x 37.08 x 7.9mm).

Texas Instruments
www.ti.com
Tel: +44(0) 049 8161 803311

Ethernet interface for non-PC products

Following its acquisition of Conexant's SocketModem business earlier in the year, Multi-Tech Systems has introduced Ethernet and telephony interface modules to its product line. SocketEthernetIP and SocketSLIC add communications and connectivity capabilities to non-PC products. SocketEthernetIP is a serial-to-Ethernet module with a complete TCP/IP protocol stack. The company sees it connecting legacy devices to an IP network for remote monitoring, control and configuration. SocketSLIC is an isolated and programmable analogue-to-PCM (digital) interface module. It provides standard analogue interfaces including FXS, FXO, and E&M on a single programmable module. Uses include conversion of a telephone to a digital signal for phone systems, central office equipment, channel banks or VoIP gateways. A further shake-up in the range renames the company's ModemModule (and Conexant SocketModem) as SocketModem, and ModemModuleIP as SocketModemIP.

Multi-Tech Systems
Tel: +44(0) 118 959 7774

Scopemeter gets colour wide-screen

The ScopeMeter 190C Series, now available from TTi (Thurlby Thandar Instruments),

features a large, high-resolution, colour screen and a digital persistence mode to give a better view of complex waveforms. The high-performance hand-held, battery-powered oscilloscopes offer specifications usually found on top-end bench instruments, with up to 200MHz bandwidth, 2.5Gsample/s real-time sampling and a deep memory of 27,500 points per input. The digital persistence mode helps to find anomalies and to analyse complex dynamic signals by showing the waveform's amplitude distribution over time using multiple intensity levels and user-selectable decay time. The effect is similar to looking at the display of an analogue real-time oscilloscope. High-speed display update reveals signal changes instantaneously, which is useful for making adjustments to a system under test.

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

Video transceivers for SD and HD rates

Available from DT Electronics are two video transmission and reception chips from Gennum, the GS9060 and GS9062. These devices operate at SD-SDI and DVB-ASI rates and are pin-compatible with the HD-Linx II dual-rate devices the GS1560 and GS1532 respectively. This is intended to allow designers to create board layouts for both SD and HD applications, thus allowing HD development costs to be spread over both HD and SD product ranges, according to the supplier. The GennumGS9060 deserialiser and GS9062 serialiser are SMPTE 259M-C compliant and utilising few other external components they can provide either a transmit or receive for SD-SDI and DVB-ASI. In operation, the GS9062 performs the functions of parallel to serial conversion, scrambling as per SMPTE 259M and NRZ to NRZI conversion. The SMPTE scrambler may optionally be bypassed to support the transmission of other coding schemes. Further, the device includes a range of additional data processing functions such as TRS, line number and CRC insertion, DVB-ASI and EDH support. It is also able to insert TRS signals, Calculate/insert line numbers and CRCs, re-map illegal code words and insert SMPTE 352M payload identifier packets if programmed by the host interface.

DT Electronics
www.dtelectronics.com
Tel: +44(0) 2476 437437

Please quote *Electronics World* when seeking further information

Test probe uses spring-loaded ball

Peak Test Services has introduced the P945-D, a spring-contact test probe, which replaces the conventional contact surface based on a moving head and plunger construction with a spring-loaded ball. The design gives a very low spring travel of 0.4mm which results in a very compact assembly for ease of installation. The probe is ideally suited to applications where lateral stresses are likely to be encountered, including tests on reading heads or slip rings. The total length of the probe, including connector pins, is 11mm, and it can be used in a number of different soldering or PCB mounting configurations. Minimum separation for mounting is 3mm between centres, and spring force is 1.5N at 0.4mm working travel. The P945-D probe is available directly from Peak Test Services in the UK and Eire, and from a network of distributors worldwide.

Peak Test Services
www.thepeakgroup.com
Tel: +44(0) 191 3871923

Voltage-mode PWM for isolated DC-DCs

Semtech is offering a BiCMOS, primary-side, voltage-mode PWM controller designed for building isolated DC/DC and off-line power supplies using a secondary-side external error amplifier. According to the supplier, in a typical telecom application the SC4905 controller would supply the control and drive circuits needed to convert a bus supply rail, typically ranging from 18V to 75V, to 12V or some other low voltage. In addition, the device can be used in industrial, isolated, and point-of-use power supplies. Features include programmable operation up to 1MHz; integrated oscillator and voltage feed-forward compensation; and programmable duty cycle to avoid transformer saturation. There is also line voltage monitoring, external synchronisation that accommodates ripple-reducing bi-phase operation with another controller, a 200mV current limit threshold and less than 100μA of start-up current.

Semtech
www.semtech.com
Tel: +44(0) 1794 527600

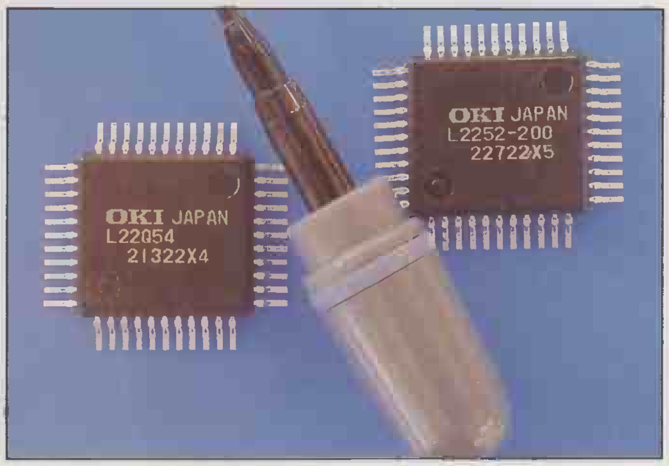
RF connection with a light touch

Huber+Suhner's latest Quick Lock N connector is designed to require a low mating force of about 30N and according to the supplier, can be significantly faster to mate than other N type connectors, as the locking mechanism snaps closed in a single step. Pulling back the decoupling sleeve opens the snap ring of the mating mechanism, allowing for de-mating with a force of 30N. The mated retention force is greater than 450N. The QN connector is presented as an alternative to screw-in N type connectors, to be used in applications such as radio basestations, antenna systems and test.

Huber-Suhner
www.hubersuhner.co.uk
Tel: +44(0) 01869 364229

Multifunction speech synthesiser

OKI Electric has a family of multifunction speech synthesisers, the ML2252/54, ML22Q54 and ML2240, which are respectively on-board mask ROM, flash and external ROM versions with the ML2252/54 and ML22Q54 providing two-channel and the ML2240 four-channel mixing functions. All of the devices have independent channel volume control, a wide range of selectable sampling frequencies, an internal D/A converter and a smoothing filter as well as a large variety of algorithms. The ML2252/54 has 1Mbit/4Mbit of internal mask ROM and a two-channel mixing function, with each channel's volume independently controllable, from –60dB to 0dB in 2dB steps. To save memory space a pause-less loop function is implemented. Interfacing with the system microcontroller is facilitated using the serial or parallel interface. Five algorithms (2/4-bit ADPCM2, 8-bit non-linear PCM and 16-bit PCM) combined with its wide range of sampling frequencies, up to 48kHz, are designed to allow the user to optimise playback time and sound quality. The ML22Q54 with 4Mbit flash is designed for prototyping and allows on-board programming and storage of digital data. The four-channel ML2240 stereo speech synthesiser can accept up to 128Mbit external ROM.



OKI Electric
www.oki.com
Tel: +44(0) 1753 787700

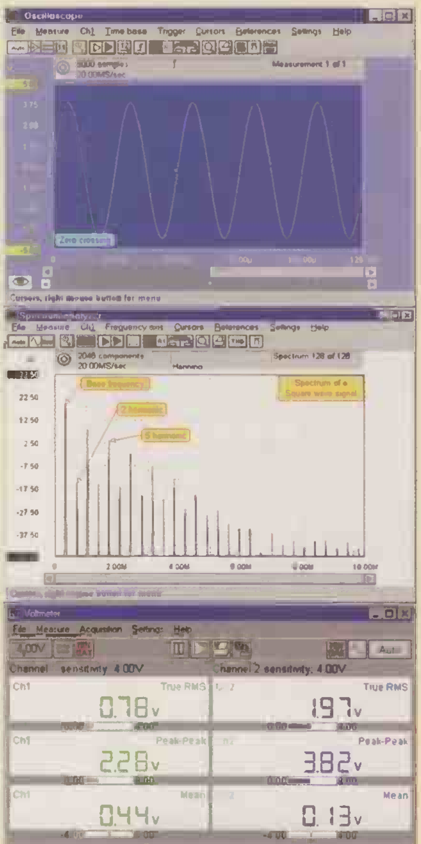
Audio codec with integrated ADC and DACs

Wolfson Microelectronics has introduced WM8722, an audio codec for surround sound applications. This is the company's first codec to integrate both the ADC and a six-channel DAC on-chip and is

OSCILLOSCOPE | FFT ANALYSER | VOLTMETER | RECORDER

The Handyscope 3 is a powerful and versatile two channel measuring instrument with an integrated function generator.

- USB 2.0 connection (USB 1.1 compatible)
- sample speed up to 100 MHz per channel
- 8 to 16 bit resolution (6 μVolt resolution)
- 50 MHz bandwidth
- input sensitivity from 200 mVolt up to 80 Volt
- large memory up to 131060 samples per channel
- four integrated measuring devices
- spectrum analyser with a dynamic range of 95 dB
- fast transient recorder up to 10 kHz
- several trigger features
- auto start/stop triggering
- auto disk function up to 1000 files
- auto setup for amplitude axis and time base
- auto trigger level and hysteresis setting
- cursor measurements with 21 read-outs
- very extensive function generator (AWG) 0-2 MHz , 0-12 Volt



HANDYSCOPE HS3

WWW.TIEPIE.NL

for more information, demo software, software, source code and DLL's visit our internet page: http://www.tiepie.nl

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

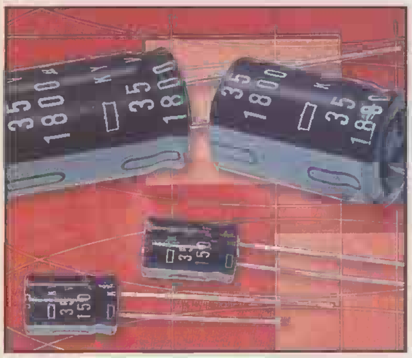
TiePie engineering (UK)
28, Stephenson Road, St. Ives
Cambridgeshire, PE17 3WJ, UK
Tel: 01480-460028
Fax: 01480-460340

Please quote *Electronics World* when seeking further information

aimed at 'lifestyle' mini component applications. In a DVD-RW device, for example. the device allows recording at 48kHz and playback at 44.1kHz using the same device. In a karaoke machine, the ADC digitises the voice and mixes it with the audio being played back. The DACs provide support for Dolby 5.1 audio surround playback. In addition, the chip can configure the ADC to be the master and the DAC the slave or visa versa. The WM8772 integrates the firm's WM8738 stereo ADC and WM8746 six-channel DAC. Available in either a 28-pin SSOP or 32-pin TQFP package, the ADC and DAC must use the same sample rate in the SSOP version, but there is no restriction in the TQFP.
Wolfson Microelectronics
Tel: +44(0) 131 2727000

Aluminium capacitors get life extension

Nippon Chemi-Con's KY series of aluminium electrolytic capacitors, available from Young ECC use a newly developed electrolyte to minimise ESR. Capacitance values available cover 22μF to 18,000μF.



According to the supplier, life has been extended from the earlier 3,000 to 6,000 hours. It spans 4,000 hours at 105°C with rated ripple in a 5 to 6mm diameter can through to 10,000 hours at 105°C with rated ripple in a 5 to 18mm can. At 50V, 20°C, 100kHz, 22μF capacitors exhibit an impedance of 0.70Ω, while 2,700μF capacitors have an impedance value 0.014Ω. Other specifications include 6.3 to 50V rated voltage range, temperature range of –40 to 105°C and ± 20% capacitance tolerance.
Young ECC
www.youngecc.com
Tel: +44(0) 1494 753500

UARTs operate at 2.5 to 5V

Philips has announced a family of 16C UARTs (universal asynchronous receiver transmitters) that operate at 2.5V, 3.3V and 5V. The SC16C devices, as they are called, are pin-to-pin compatible with industry standard 16C UARTs and all are specified at between -45°C and +85°C. At 3.3V, the SC16Cs have baud rates up to 5Mbit/s (16X). The series includes single, dual and quad channel chips that are compatible with Intel and Motorola bus interfaces and come in DIL, PLCC and LQFP packages.
Philips
www.philips.com
Tel: +44(0) 031 40 272 2091

13.5GHz pre-scalar devices

Zarlink Semiconductor is offering three prescaler chips operating at 13.5GHz. The ZL40813/14/18 prescalers convert RF signals operating at up to 13.5GHz to lower

frequencies. The prescalers convert signals operating at between 10.5GHz and 13.5GHz to lower-frequency signals in fixed division ratios. The ZL40813 divides high-frequency signals by eight, the ZL40814 divides them by 16, and the ZL40818 divides them by four. At offset frequencies of 10kHz, the chips phase noise, when processing 12GHz signals is typically better than –140dBc/Hz (decibels relative to carrier power per hertz). They operate on supplies of 5V, drawing 460mW. They are offered in 8-pin SOIC (small outline IC) or EPAD (exposed pad) SOIC packages, and supported by evaluation boards.
Zarlink
www.zarlink.com
Tel: +44(0) 1793 518128

35W sub-quarter-brick DC-DC converter

The S35 series DC-DC converters from BTCPower deliver a power output of 35W from a sub-quarter-brick (1.2x2.0x0.35in.) package. With input voltage range of 18-36V or 36-75V, the series is available in versions with output voltages of 1.5, 1.8, 2.5, 3.3 5 or 12V. All models feature an input filter, input undervoltage lockout, overtemperature protection. An enclosed, encapsulated construction features an aluminium heat-spreader design to improve heat transfer without hot spots, said the supplier. Using a synchronous rectification topology, its patented flat-transformer design concept supports maximum power output with an efficiency of up to 90%. The converters are designed for use over an ambient temperature range of –40° to +85°C, and mean time between failures is 4,5000,000 hours at 50°C
BTCPower
Tel: +44(0) 1628 675911

Burst SRAMs have "no bus latency"

Cypress Semiconductor is sampling its 72Mbit NoBL 'No Bus Latency' burst family of SRAMs - aimed at networks operating at OC-48 speeds (2.5Gbit/s) and above. Co-developed between Cypress and Ramtron subsidiary Enhanced Memory Systems, the memories use a one-transistor cell. The

Aluminium capacitor for lead-free manufacturing

A range of surface mount aluminium electrolytic capacitors from Rubycon are compatible with the new, higher temperature profile required for lead-free soldering processes. They are designed to meet the requirements of European environmental directives. Currently available in full production quantities, the SEV, SGV, SKV, NSEV and NSKV ranges include a 125°C rated capacitor which is suitable for automotive under-bonnet applications such as engine and other control units, and an SKV model release is anticipated in early 2003 to complete the range. The

capacitors feature a specially developed high temperature electrolyte blend, making them suitable for the higher temperatures used in the lead-free soldering process window.
Rubycon
www.rubycon.co.jp
Tel: +44(0) 20 8842 3221

042003

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PCB Production - Processing Equipment

We carry a large range of the photographic & chemical processing equipment for PCB production, a full list with full technical specifications is available in our catalogue or visit our web site.

UV Exposure units

2 x 8W Tubes, 6 min timer
229 x 159mm working area
Model 332-002 £88.78
4 x 15W Tubes, 7½ min timer
330 x 260mm working area
Model 332-004 £194.51

Chemical Processing

Low cost plastic tray £1.50
Process tanks feature electrically operated pumps and/or heaters with thermostat control, suitable for boards upto 320 x 260mm.
Universal Tank with heater
Model 333-007 £161.60
Bubble etch Tank with heater & bubble pump.
Model 333-004 £198.50

Any of these items, carriage £5.50

PCB Production - Laminates

Copper clad - paper

Single sided low cost paper composite board

100 x 160mm Board	£0.44
100 x 220mm Board	£0.62
160 x 233mm Board	£1.02
220 x 233mm Board	£1.40
8" x 12" Board	£1.70

Copper clad - glass fibre

Single & Double 1.6mm 305g/m^2

100 x 160mm Single	£0.85
100 x 220mm Single	£1.18
160 x 233mm Single	£2.29
220 x 233mm Single	£2.88
8" x 12" Single	£3.44
100 x 160mm Double	£0.88
100 x 220mm Double	£1.25
160 x 233mm Double	£2.30
220 x 233mm Double	£2.90
8" x 12" Double	£3.22

Photoresist Coated

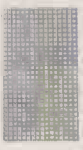
1.6mm 35 micron Pre-coated with a high quality photoresist layer. Available in low cost paper composite or Glass fibre, Single & Double sided. Other sizes also available.

Size	Paper Single	Paper Double	Glass Fibre Single	Glass Fibre Double
4 x 6"	£1.47	£1.82	£1.89	£2.17
6 x 12"	£4.20	£5.04	£5.60	£6.23
9 x 12"	£6.30	£7.70	£8.40	£9.38
10 x 12"	£8.19	£10.01	£10.78	£11.83
12 x 12"	£8.26	£10.08	£10.99	£12.25
100 x 160mm			£2.38	£2.66
203 x 114mm			£3.01	£3.43
220 x 100mm			£3.08	£3.71
233 x 160mm			£4.83	£5.32
233 x 220mm			£6.83	£7.70

PCB Production - Development

0.1" Copper Stripboard

Size	Tracks/Holes	
25 x 64mm	9T / 25H	£0.24
64 x 95mm	24T / 37H	£0.87
95 x 127mm	36T / 50H	£1.41
95 x 432mm	36T / 170H	£4.39
100 x 100mm	39T / 38H	£1.40
100 x 160mm	39T / 63H	£1.80
100 x 500mm	39T / 199H	£6.20
119 x 455mm	46T / 179H	£5.40
Stripboard track cutter		£1.99



Solderless Breadboard

Tie Points & Size	Power Rails	
390 81 x 60mm	2	£2.75
840 175 x 67mm	2	£4.86
740 175 x 55mm	1	£4.03
640 175 x 42mm	0	£3.08

Many other sizes available, also jump wires & matrix board.

PCB Production - Tools

Drill Bits

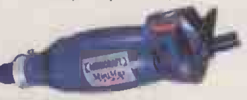
HSS parallel shank bits available in sizes from 0.3mm to 2.0mm

0.3-0.95mm in 0.05mm steps	£0.60ea £4.00/10
1.0-2.0mm in 0.1mm steps	£0.40ea £3.60/10
HSS Reduced shank (2.35mm) bit available in sizes from 0.6mm to 1.7mm in 0.1mm steps	£0.84ea £7.60/10
Reground Tngsten carbide reduced shank (3.2mm) available in sizes from 0.6 to 1.6mm in 0.1mm steps	£1.90

Drilling Machines

Expo reliant 12V drill, 3.8mm capacity, 8400rpm £12.78

Minicraft MX1 230V, 8000 - 21000rpm with chuck & collet.
Model EPE270-390
Normal price £48.51



SPECIAL OFFER PRICE £31.02

PCB Production - Chemicals

100ml	Aerosol Photoresist spray, covers $2m^2$	£4.25
50g	Powder developer, makes 1lt	£1.09
500g	Powder developer, makes 10lt	£7.08
250g	Ferric Chloride Pellets, makes 500ml	£1.68
500g	Ferric Chloride Pellets, makes 1lt	£3.04
2.5kg	Ferric Chloride Pellets, makes 5lt	£9.84
1.1kg	Clear Fine etch crystals, makes 5lt	£17.58
90g	Tin Plating Powder, makes 1lt	£11.58
200ml	Aerosol Flux spray	£3.41
110ml	Aerosol PCB Laquer spray	£3.63

PCB Production - Drafting Materials

A4 Artwork Film (per 10 sheets)

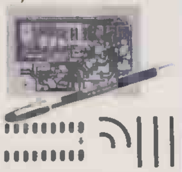
Clear Manual Film	£1.25
Clear Laser Film	£1.75
White HQ Laser Film	£4.62

Etch Resist Pens

"Dalo" Pen	£2.70
"Staedtler" Fine Pen	£0.88

Etch Resist Transfers

Seno mixed DIL pads	£2.24
Seno mixed Rnd pads	£2.24
Alfac mixed pads	£1.84
Alfac mixed lines	£1.84
Transfer Spatular	£1.25



We carry the full range of Seno & Alfac PCB transfers, see our catalogue for full details.

Servisol Products

Aerosols

200ml	Switch Cleaner	£1.96
200ml	Freezer	£3.97
400ml	Foam Cleanser	£2.13
400ml	Cleaner / lubricant	£2.79
75ml	Vide Head Cleaner	£1.94
200ml	Aero Klene	£2.85
200ml	Aero Duster	£4.66
250ml	Cold Clean	£3.14
200ml	Label remover	£3.52
400ml	Isopropyl alcohol	£3.36

Tubes

25g	Heatsink Compound	£2.60
50g	Silicone grease	£2.50

Magnifying Desk Lamp

A high quality scratch resistant magnifying glass fitted to a balanced swivel arm and desk mount. An integral flourescent tube provides illumination.
Magnification: 3x Lens: 120mmØ
Tube: 22W Daylight simulation.

Model: 028-205 £28.80

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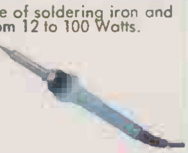
We carry in stock a wide range of soldering iron and soldering accessories. Irons from 12 to 100 Watts.

15W 240V Low cost	£2.80
20W 240V Basic	£3.74
25W 240V Ceramic	£14.05
30W 240V Basic	£4.68

Desolder Pumps

Basic 165 x 18mmØ	£2.85
Antistatic 195mm	£3.92
Antex Mini 198mm	£6.02
Antex Pro 210mm	£10.26



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Side Cutters

130mm Low cost	£1.99
115mm Draper	£2.38
115mm Box Jointed	£4.26
145mm Long reach	£3.40

Wire Strippers

130mm Low cost	£2.30
150mm Draper 5mmØ	£5.86

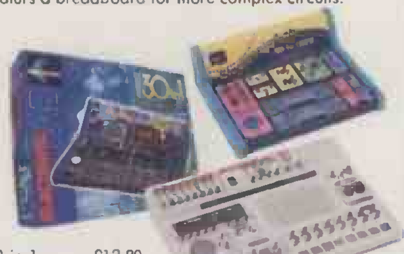
Soldering Station

A 30W adjustable temperature soldering station with a rotary dial, on-off switch, iron holder and tip cleaning sponge. This station features a quick start circuit for rapid heating, adjustable temperature range of 250 - 450°C, Silicone cable and silicone covered handle.
Supply: 240V, Iron: 240V 30W

Model 167-510 £32.18

Educational Kits

These kits are an ideal way to start you interset in electronics. They freature re-useable components which are attached via springs & wires and easy step by step guides to make a range of exciting projects. The 300-in-1 featurs a breadboard for more complex circuits.



30-in-1	£12.80
50-in-1	£16.80
130-in-1	£32.00
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Tools - Ratchet Crimping Pliers

High quality ratchet crimping pliers for various terminals including Automotive, Data, Power and Data connections.

Red / Blue / Yellow	£15.80
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CK® Tools Crimp Pliers

Green/Red/Blue	£24.38
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0.24-2.5mm^2 crimps	£24.35
0.5-6.0mm^2 crimps	£24.35
Non insulated crimps	£24.38

Soldering Station

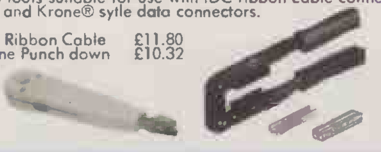
A 48W adjustable temperature soldering station with a rotary dial, LED Temperature metering, on-off switch, iron holder and tip cleaning sponge. This station features accurate heat sensing for instant compensation & stable temperatures. Adjustable temperature range of 150 - 420°C, Low voltage iron with Silicone cable.
Supply: 240V, Iron: 24V 48W

Model 167-540 £44.50

Tools - Insulation Displacement Connectors (IDC)

Two tools suitable for use with IDC ribbon cable connectors and Krone® sytle data connectors.

IDC Ribbon Cable	£11.80
Krone Punch down	£10.32



Panel Meters

High quality anologue panel meters, class 2, zero point correction, mirror scale and prewired for panel illumination. Meter size 46 x 60mm, Cutout size: 38mmØ.

All meters £5.89 each
6V Lamps £1.23 /pair

Range	Int Ω
0-50µA	6k5
0-100µA	1k0
0-500µA	430Ω
0-1mA	200Ω
0-10mA	2Ω6
0-50mA	1Ω2
0-100mA	0Ω65
0-500mA	0Ω12
0-1A	60mΩ
0-3A	20mΩ
0-5A	12mΩ
0-15A	4mΩ
0-10V	10k
0-15V	15k
0-30V	30k
±50µA	1k9

Cable - Ribbon

7/0.127mm Grey ribbon cable on a 0.05" 1.27mm pitch with a red identifying stripe. Supplied by 305mm (1ft) or on full 30.5m (100ft) reels.

Size	per 305mm	per Reel
10 Way	£0.10	£5.36
14 Way	£0.14	£7.50
16 Way	£0.16	£8.58
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CCTV - Black & White Module

A miniature CMOS camera module with a 3.6mm F2 Lens, video output & power via connectors provided.

Specs (660-800)

Power: 12Vdc 50mA
Video System: CCIR
Pixels: 352 x 288
Min Illumination: 0.5Lux
Video Output: 1 Vpp, 75Ω
Dims: 35 x 35 x 28mm 20g **£17.93**

CCTV - Colour Module

A miniature colour CMOS camera module with a 3.6mm F1.2 Lens, video output & power via connectors provided.

Specs (660-842)

Power: 12Vdc 150mA
Video System: PAL
Pixels: 628 x 582
Min Illumination: 3Lux
Video Output: 1 Vpp, 75Ω
Dims: 28 x 28 x 28mm 20g **£36.33**

Tel: 0191 2514363 Fax: 0191 2522296 Email: sales@esr.co.uk http: //www.esr.co.uk

Please quote *Electronics World* when seeking further information

NoBL feature eliminates dead cycles, or wait states, found in conventional synchronous burst SRAM when switching from write to read. The 72Mbit device is organised as 2Mbit x 36, operates at up to 166MHz clock speed and delivers 100 per cent bus use during four-word read/write/read transactions.
Cypress Semiconductor
www.cypress.com

Sector antenna counter interference in 2.4GHz band

Two 2.4GHz band basestation sector antennas from Smiths Interconnect - Radio Waves are designed to provide an alternative to omnidirectional antennas. The two models for the SEC series offer 180° beamwidth for the unlicensed ISM band at 2.4 to 2.5GHz. According to the supplier, the move from an omni antenna to a sector at the basestation will be interesting to designers as the unlicensed band at 2.4GHz is becoming more prone to overcrowding interference issues. In addition to the higher gain offered by both sector antennas, the front-to-back ratio of 20dB is also important.
Radio Waves
www.radiowavesinc.com
Tel: +44(0) 1592 266671

2.8kW switching rectifier for power play

HiTek Power has introduced a 2.8kW, 30V output switch-mode rectifier intended for applications such as telecoms and for use in laser RF generators for powering CO_2 lasers, as used in laser marking systems. The HTR20006-030 offers power factor correction to 0.99, and output current limit and overvoltage protection. Remote sense is provided as standard to allow for compensation of up to 500mV total voltage drop in the

power leads. Units may be operated with outputs connected in parallel without limitation. A current sharing facility is provided as standard, allowing up to five units to share the total load current to within 10 per cent of the full-load current of one rectifier. The unit measures 127x203x330mm.
HiTek Power
www.hitekp.com
Tel: +44(0) 1243 841888

Radar scan converter in PCI slot

Primagraphics has launched an integrated radar scan converter and PC graphics card in a single slot PCI form factor. The commercial-off-the-shelf (COTS) card is designed for applications including command and control consoles, vessel traffic display systems and radar head monitors. Called Advantage+ scan, it converts the radar data and combines the output with that from its onboard Silicon Motion Lynx 3DM+ graphics controller, which supports display resolutions up to 1280x1024 at 60Hz. Support for both analogue RGB and digital DVI displays is included as standard. Scan conversion is performed mainly in software running on the Motorola ColdFire processor. The coordinate transform uses Primagraphics' White-Powell algorithm, which combines both forward and reverse scan conversion to ensure that there are no holes in the displayed image, even when zooming at long range. The new card can simultaneously scan convert radar data from three independent sources, each being displayed in up to eight windows. Advantage+ can also be configured to handle a wide variety of radar sources and to display the resulting images in a range of formats.
Primagraphics
www.primagraphics.net
Tel: +44(0) 1763 852222

Hot swap power management

Xicor has introduced a range of smart power management products designed to integrate power supply sequencing, system management, and hot swap functions to support power distribution from a 48V backplane. The X80010 family have hot swap features that facilitate insertion and extraction of line cards, network interface cards and other peripherals while –48V power is present on the backplane. System management provides a monitor for the CPU host components to inform the system of power status. With four independent built-in delay circuits for DC-DC sequencing, the devices can sequence and control up to five independent DC-DC converters in parallel or relay modes. The X80010 family offers selectable overvoltage and undervoltage detection and protection and has a battery or auxiliary voltage backup mode with undervoltage detection down to –20V. The devices are available in 32-lead QFN packages.
Xicor
www.xicor.com
Tel: +44(0) 1993 700544

Solid-state relay handles 200mA

Clare has a solid-state form A relay which offers 200mA (AC/DC mode) of load current capability along with an output current limit feature. The PAA140L is intended as a replacement for electromechanical relays in applications that require a high blocking voltage and which can benefit from the reliable bounce-free switching performance available from solid state relays, said the company. The addition of output current limiting and the low input drive current allow

DC-DC converter cuts component count

A series of high output current DC-DC converters from ROHM are designed to reduce the component count in applications such as industrial and multimedia systems. With a specified power conversion efficiency of up to 93 per cent and operating without a heatsink, the BP523xxxA stepdown converters will require only an I/O smoothing capacitor for full operation, according to the supplier. The module comprises four standalone DC-DC converters. Output current options are 2A, 3A and 4A.
Rohm
www.rohm.co.uk
Tel: +44(0) 1908 282666

Please quote *Electronics World* when seeking further information

designers to drive the relay directly from logic level signals without the external components necessary when using electromechanical relays. The relay's load voltage rating of 400V and maximum on-resistance of 13Ω make it suitable for process control equipment, telecommunications and data communications equipment.
Clare
www.clare.com
Tel: +44(0) 1823 352541

PC Card controller is power managed

Texas Instruments has a power management chip for dual-slot PC Card controller designs. According to the supplier, all discrete power Mosfets, a logic section, current limiting and thermal protection for PC Card control are combined into the device. The TPS2206A PC CardBus power-interface switch allows the controlled distribution of 3.3V, 5V and 12V to each PC card socket. The current-limiting feature and thermal-protection features can eliminate the need for fuses, said the company.
Texas Instruments
www.ti.com
Tel: 0049 8161 80 3311

OTP microcontroller gets a facelift

Toshiba has expanded its family of TLCS-870/C 8-bit microcontrollers with a one-time programmable (OTP) device. The 20-pin TMP86P202 is available in DIP20 and SOP20 package. The device operates at frequencies up to 8MHz and features powerful instruction sets using 731 basic instructions.

Supply voltage for the microcontroller is rated at 4.5 to 5.5V, while one STOP and two IDLE modes are designed to minimise power consumption. It offers 16 I/O pins. two of which are for high current outputs of typically 20mA. On-board memory comprises 2k x 8 bits of ROM and 128 x 8 of RAM.The two on-board 8-bit timers provide a PPG or PWM output, event counter input and can be configured for 16-bit timer operation.
Toshiba
www.toshiba-europe.com
Tel: +44 (0) 49 211 5296 254

FPGA roadmap aims to cut costs

Xilinx has unveiled its roadmap for Virtex-II Pro EasyPath, an extension to its Virtex-II Pro FPGA family. The devices are standard Virtex-II Pro FPGA circuits. They create a set of configuration patterns and test vectors specific to that design and combine them into a custom test program. The result is an application specific device that functions and performs identically to a Virtex-II Pro FPGA for the specific application.
Xilinx
www.xilinx.com
Tel: +44 (0) 1932 349401

Radial blower for tight spaces

A radial blower from Papst measures 75.7 x 75.7 x 27mm and offers an air performance of 16.6CFM (28m^3/h) and will operate against back-pressures of up to 190Pa (0.7in. H20) at a nominal speed of 4400min-1. The unit operates from a 12VDC, supply, with a voltage range of 10.8 to 13.2V. The RL48-19/12/2 consumes 5.3W with an operating current

requirement of 44mA. Offering versatility, the RL 48-19/12/2 includes a tachometer output for fan speed control, and reverse polarity protection for reliability.
Papst
www.papstplc.com
Tel: 44 (0) 1264 333388

TCP/IP Wizard for 8-bit micros

A Windows-based configuration wizard which eases the setting up of TCP/IP parameters for use with 8 and 16-bit microprocessors is now available from Computer Solutions. The interface allows the multiple options of TCP/IP configuration to be easily set and the necessary initialisation code created. CMX-MicroNet will work with virtually all 8 and 16-bit processors. The stack executes directly on the micro-controller, where support is available for dial-up or direct serial connection as well as Ethernet links. No proprietary protocols, intermediate gateways or special hardware are required to use it. The system can operate in stand-alone mode or in conjunction with an RTOS. It provides support for multiple sockets, UDP, TCP, SLIP, modem and IP. Options are available to support PPP, BOOTP, SMTP, (post), DHCP (client), TFTP and FTP servers and HTTP web server.
Computer Solutions
www.computer-solutions.co.uk
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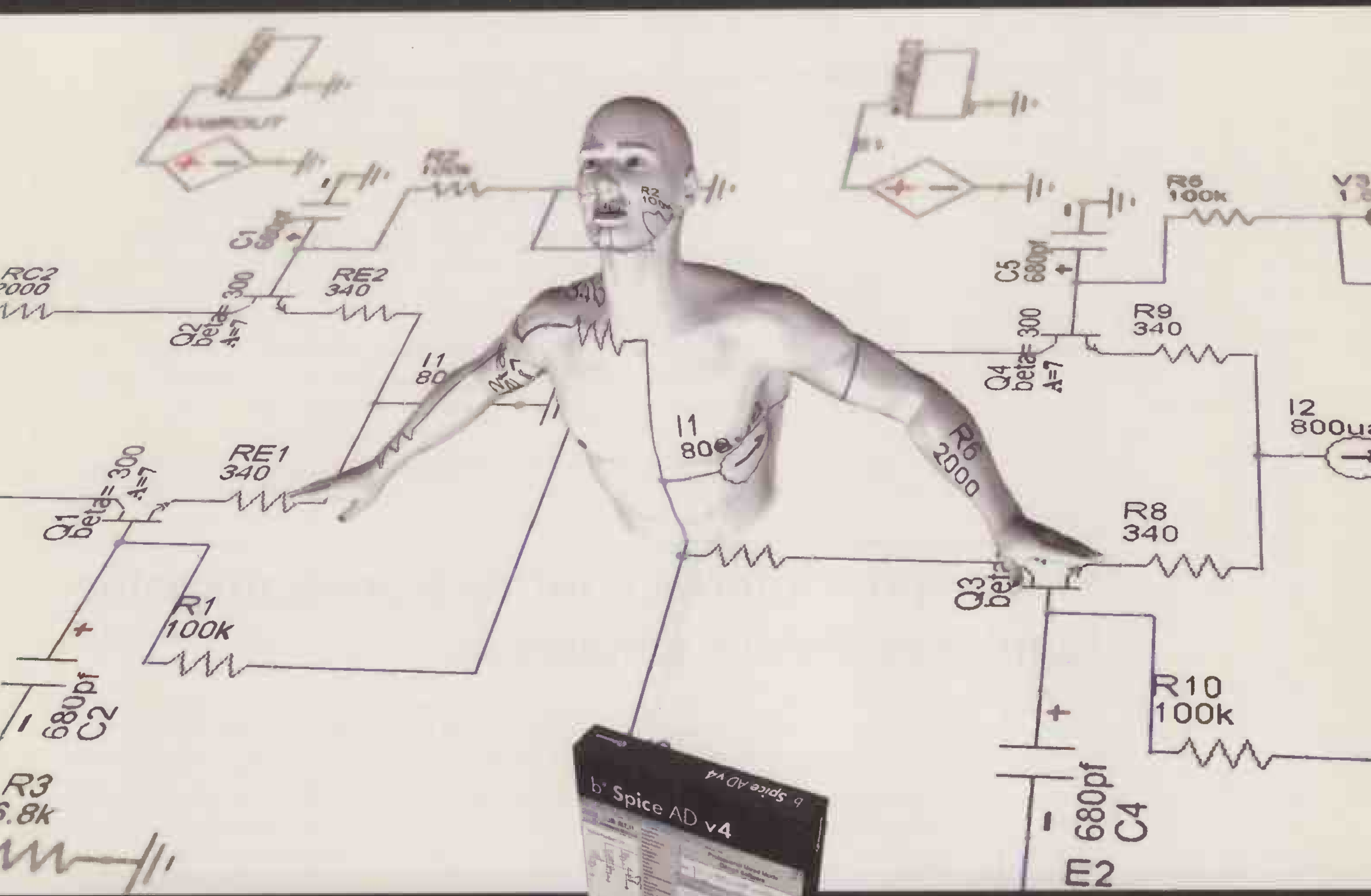

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The best circuit ideas are ones that save time or money, or stimulate the thought process. This includes the odd solution looking for a problem – provided it has a degree of ingenuity.

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*

Printer-port interface forms a programmable bipolar reference generator

Using this small and low cost circuit together with simple control software **List 1**, you can extend the usefulness of your PC's printer port. The software and hardware shown here represent a versatile programmable bipolar reference generator.

Built using a few readily-available and low-cost components, the circuit occupies little space and is easily attached to your PC's printer port. You can use this effective programmable generator as a stable reference source for testing your circuits without going for a big, mains powered general purpose reference generator or PC add on cards.

Further, with this design, you don't need to turn potentiometers or set thumb wheel switches for setting or changing the reference output to any desired value. All you need to do is just enter the desired voltage and the PC does the rest.

The circuit uses a low-power, programmable 13-bit D-to-A converter. This is IC_1, a MAX5130. It also uses a programmable inverting amplifier, IC_2, and a polarity control switch, IC_3.

Depending on the reference output required by the user, the PC controls the D-to-A converter using a three wire serial interface. Thus the data lines D_0 to D_2 of the data port ($0x378_{16}$) of printer interface are used by the PC for sending the chip-select (/CS), data (DATA) and clock (CLK) signals to the D-to-A converter.

In response to the data sent by the PC, the D-to-A converter produces a voltage output in the range of 0-4.0955V in 8192 steps with a step resolution of 0.5mV. Thus a data of $0x4000_{16}$ to the D-to-A converter produces the D-to-A converter output of 0.00 volts while the data of $0x5FFF_{16}$ results in the D-to-A converter output of 4.0955V.

Using the 2.5V internal reference available in the D-to-A converter itself, the output of the D-to-A converter and the data input are related as per the following:

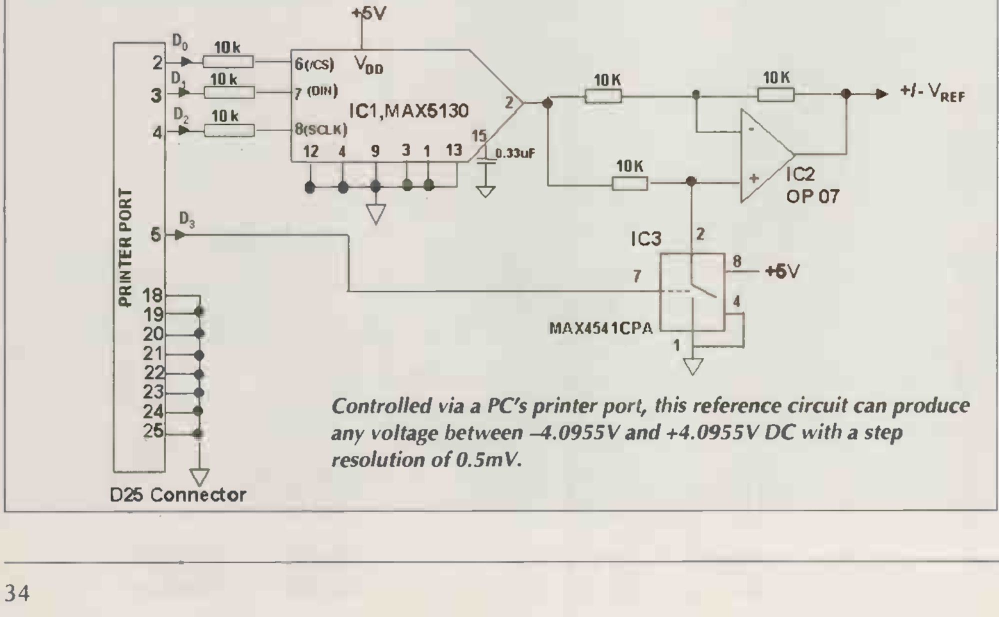
$$V_{out} = \pm\left(2.5 \times \frac{DATA}{8192}\right) \times GAIN$$

Here, *DATA* is the decimal equivalent of binary data sent to the D-to-A converter and *GAIN* is the gain of the D-to-A converter's internal amplifier – usually set to 1.634.

Normally, the D-to-A converter output is unipolar (positive) only. It is also possible to operate the D-to-A converter in bipolar mode with an additional op-amp as specified in the device data sheet. But here the range of the output is limited to –2.499V to +2.499V (for MAX5130).

However, the design presented here enables you to overcome this and get an extended range of reference of –4.0955V to +4.0955V with a step resolution of 0.5mV.

As shown in the diagram, this extended bipolar output is achieved by using the programmable inverting amplifier IC_2 in combination with polarity control switch, IC_3.



Controlled via a PC's printer port, this reference circuit can produce any voltage between –4.0955V and +4.0955V DC with a step resolution of 0.5mV.

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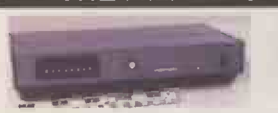

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TELEBOX ST for composite video input type monitors	£36.95
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For overseas PAL versions state 5.5 or 6 mHz sound specification.
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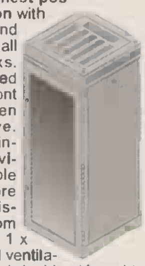

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IBM 8230 Type 1, Token ring base unit driver	£760
Wayne Kerr RA200 Audio frequency response analyser	£2500
INFODEC 1U, 24 port, RJ45 network patchpanels. #TH93	£49
3COM 16670 12 Port Ethernet hub - RJ45 connectors #LD97	£69
3COM 16671 24 Port Ethernet hub - RJ45 connectors	£89
3COM 16700 8 Port Ethernet hub - RJ45 connectors NEW	£39
IBM 53F5501 Token Ring ICS 20 port lobe modules	£POA
IBM MAU Token ring distribution panel 8228-23-5050N	£45
AIM 501 Low distortion Oscillator 9Hz to 330Khz, IEEE I/O	£550
ALLGON 8360.11805-1880 MHz hybrid power combiners	£250
Trend DSA 274 Data Analyser with G703(2M) 64 i/o	£POA
Marconi 6310 Programmable 2 to 22 GHz sweep generator	£4500
Marconi 2022C 10KHz-1GHz RF signal generator	£1550
HP1650B Logic Analyser	£3750
HP3781A Pattern generator & HP3782A Error Detector	£POA
HP6621A Dual Programmable GPIB PSU 0-7 V 160 watts	£1800
HP6264 Rack mount variable 0-20V @ 20A metered PSU	£475
HP54121A DC to 22 GHz four channel test set	£POA
HP8130A opt 020 300 MHz pulse generator, GPIB etc	£7900
HP A1, A0 8 pen HPGL high speed drum plotters - from	£550
HP DRAFTMASTER 1 8 pen high speed plotter	£750
EG+G Brookdeal 95035C Precision lock in amp	£1800
Keithley 590 CV capacitor / voltage analyser	£POA
Racal ICR40 dual 40 channel voice recorder system	£3750
Fiskers 45KVA 3 ph On Line UPS - New batteries	£4500
Emerson AP130 2.5KVA industrial spec.UPS	£1499
Mann Tally MT645 High speed line printer	£2200
Intel SBC 486/133SE Multibus 486 system. 8Mb Ram	£945
HP6030A 0-200V DC @ 17 Amps bench power supply	£1950
Intel SBC 486/125C08 Enhanced Multibus (MSA) New	£1150
Nikon HFX-11 (Ephiphot) exposure control unit	£1450
PHILIPS PM5518 pro. TV signal generator	£1250
Motorola VME Bus Boards & Components List. SAE / CALL	£POA
Trio 0-18 vdc linear, metered 30 amp bench PSU. New	£550
Fujitsu M3041R 600 LPM high speed band printer	£1950
Fujitsu M3041D 600 LPM printer with network interface	£1250
Siemens K4400 64Kb to 140Mb demux analyser	£2950
Perkin Elmer 299B Infrared spectrophotometer	£500
Perkin Elmer 597 Infrared spectrophotometer	£3500
VG Electronics 1035 TELETEXT Decoding Margin Meter	£3250
LightBand 60 output high spec 2u rack mount Video VDA's	£495
Sekonic SD 150H 18 channel digital Hybrid chart recorder	£1995
B&K 2633 Microphone pre amp	£300
Taylor Hobson Tallysurf amplifier / recorder	£750
ADC SS200 Carbon dioxide gas detector / monitor	£1450
BBC AM20/3 PPM Meter (Ernest Turner) + drive electronics	£75
ANRITSU 9654A Optical DC-2.5G/b waveform monitor	£5650
ANRITSU ML93A optical power meter	£990
ANRITSU Fibre optic characteristic test set	£POA
R&S FTDZ Dual sound unit	£650
R&S SBUF-E1 Vision modulator	£775
WILTRON 6630B 12.4 / 20GHz RF sweep generator	£5750
TEK 2445 150 MHz 4 trace oscilloscope	£1250
TEK 2465 300 Mhz 300 MHz oscilloscope rack mount	£1955
TEK TDS380 400Mhz digital realtime + disk drive, FFT etc	£2900
TEK TDS524A 500Mhz digital realtime + colour display etc	£5100
HP3585A Opt 907 20Hz to 40 Mhz spectrum analyser	£3950
PHILIPS PW1730/10 60KV XRAY generator & accessories	£POA
VARIACS - Large range from stock - call or see our website	
CLAUDE LYONS 12A 240V single phase auto. volt. regs	£325
CLAUDE LYONS 100A 240/415V 3 phase auto. volt. regs	£2900

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Depending on the control signal output at pin 5 (D_3 of data port 0x378), the polarity control switch is either closed, with D_3 at logic 1, or open, when D_3 is at logic 0. This causes the IC_2 to function either as a unity gain inverting amplifier or as a unity-gain buffer.

If a positive reference output is required, the switch is opened by sending 0V (<0.8V, logic 0) to D_3, making IC_2 work as a unity gain buffer. Then the D-to-A converter positive output is buffered by IC_2 before becoming available at the output as $+V_{REF}$.

When a negative reference output is needed, the switch is closed by sending +5V (logic 1) to D_3 and the positive D-to-A converter output is amplified by IC_2 with a gain of –1. The desired $-V_{REF}$ is now available at the output.

Thus by controlling the 16-bit data sent to the D-to-A converter and the polarity control switch, the programmable reference generator can be made to produce any desired output between ±5V.

The control software for this bipolar reference generator written in Turbo C is given in the listing. It obtains the desired V_{REF} from the user then checks that the set value lies within the range of –4.0955V to +4.0955V. If the value lies within the range, the program proceeds. If it lies outside the allowed range, an error message warns the user about the over range and asks the user to input correct V_{REF}.

When the desired V_{REF} lies within the permissible range, the program first sets the polarity of the desired V_{REF} by sending the appropriate logic signal to pin 5 of the printer port and then calculates ACTUALDATA to be sent to the D-to-A converter.

The d2b routine converts 'ACTUALDATA' into-16 bit binary data. The program then enables the D-to-A converter (/CS low) and serially clocks the binary equivalent of ACTUALDATA, starting with the most-significant bit to the data pin of the D-to-A converter.

With the least-significant bit set at the data pin, the low-to-high transition of the clock latches the ACTUALDATA completely into the D-to-A converter. Now the user-set V_{REF} is available at the output.

K. Suresh
Indira Gandhi Centre for Atomic Research
Tamil Nadu India.

Listing. Turbo C program for Printer port implements a programmable bipolar reference generator.

```
#include<stdio.h>
#include<conio.h>
#include<math.h>
#include<bios.h>
#include<dos.h>

#define CLK1 0x04           /* Clock Pulse High*/
#define CLK0 0xfb           /* Clock Pulse Low*/
#define CS1  0x01           /* Chip Select high to
deactivate DAC*/
#define CS0 0xfe            /* Chip Select low to
activate DAC*/
#define DATA1 0x02          /* Data Pulse High*/
#define DATA0 0xfd          /* Data Pulse low*/
#define PLUSVREF 0x00       /*Vref =positive*/
#define MINUSVREF 0x08      /*Vref=negative*/

int c[16],dport,ACTUALDATA,out,k;     / * G l o b a l
Declarations*/
float Vref ;                          / * D e s i r e d
Reference output*/
void d2b(unsigned int x, int*c)       /*Routine  for
Decimal to Binary Conversion*/
{
int i;
for(i=0;i<=15;i++)
*(c++)=(x>>i) & 0x1;
}
float SETREF(void)   /*Routine for getting required
reference o/p from user*/
{
int Vin;
printf("\n Enter desired ref. o/p Vref( -4.0955V to
4.0955V):");
scanf("%f",&Vin);
while((Vin<-4.0955)|| (Vin>4.0955))
     {
       printf("\n ERROR!!! Vref Out of Range(-4.0955
V to 4.0955V)!");
       printf("\n Press any key to continue");
       getch();
      printf("\n Enter the desired reference output
Vref( -4.0955 V to 4.0955V):");
      scanf("%f",&Vin);
    }
Vref=Vin;
printf("\n Your Desired Reference is  =%f\n",Vref);
return Vref;
}

void SETPOLARITY( float Vref ) /* Routine for setting
the Vref Polarity*/
{
if (Vref<0.0)
{
    out|=MINUSVREF;
   outportb(dport,out); /* Set the Vref polarity as
negative*/
 }
else
{
    out|=PLUSVREF;
    outportb(dport,out); /* Set the Vref polarity as
positive*/
 }
}

void CLOCK_DAC(void)/*Routine for clocking the DAC*/
{
out|=CLK1;
outportb(dport,out);/*Setting the clock high*/
delay(1);
out&=CLK0;
outportb(dport,out);/*Setting the clock low*/
delay(1);
}

void LOAD_DACDATA(int*c)/*Routine for loading actual
data into the DAC*/
{
out|=CS1;
outportb(dport,out);/*Chip Select high to disable
DAC*/
delay(1);
out&=CS0;
outportb(dport,out);/*Chip Select low to enable DAC*/
delay(1);
printf("\nDATA loaded into the DAC=");
for(k=15;k>=0;k—)
{
out|=c[k];
outportb(dport,out);
printf("%d",(c[k]<<1));
delay(1);
```

```
CLOCK_DAC();
}
out|=CS1;
outportb(dport,out);
delay(1);
}
main()
{
int v,inc;
float y;
unsigned  int x;
double fraction, integer, number;
clrscr();
printf("\tPrinter Port as a Programmable Frequency
Generator");
printf("\n\t\t\t by\n");
printf("\tK.Suresh,MSD,IGCAR,Kalpakkam,TamilNadu-
603102,India");
dport= peek(0x40,8);/*Check up for availability of
Printer Port*/
if (dport==0)
{
printf("\n\n LPT NOT AVIAILABLE! EXITING........");
exit(1);
}
printf("\n\nAddress of the printer port found
=0x%X",dport);
SETREF();
out=0x00;
SETPOLARITY(Vref);
y=(Vref*8192)/(2.5*1.6384);
v=y/1;
number=y;
fraction = modf(number, &integer);
if (fraction<0.44)
inc=0;
else inc=1;
ACTUALDATA=16384+v+inc; /*Actual data including the
Control Word for DAC*/
d2b(ACTUALDATA,c);
LOAD_DACDATA(c);
return 0;
}
```

Improved switch debouncing circuit

Switch debouncing circuits are used to mask the noise that occurs when a mechanical switch changes state. A typical switch debouncing circuit is depicted in **Fig. 1a)**.

Together with other components such as the inverter, capacitance and resistance, the first D-type flip-flop forms a monostable circuit. The second D-type flip-flop acts as a frequency-divider. As long as the monostable time delay interval is longer than that of the contact noise, the output of U_{out} is noise-free.

Figure 1b) indicates that when both positive and negative going edges of the input U_{in} have contact noise, the circuit works well.

Due to the randomness of a mechanical switch though, it is possible that bounce only exists in the positive-going edge of U_{in}. In this case, the output of the switch debouncing circuit will remain at logic 1.

In the modified circuit of **Fig. 2a)**, NOR gate NOR_1 is used instead of the inverter. One input of the second NOR gate, NOR_2, is U_{in} while the other input is the output of the second D-type flip-flop.

Output from NOR_2 triggers the monostable resulting in two output pulses. In this case, regardless of whether the bounce exists in the positive and negative-going edges of U_{in}, U_{out} is noise-free, as shown in **Fig. 2b)**.

Deng Yong
Shanghai Jiaotong University
Shanghai
China

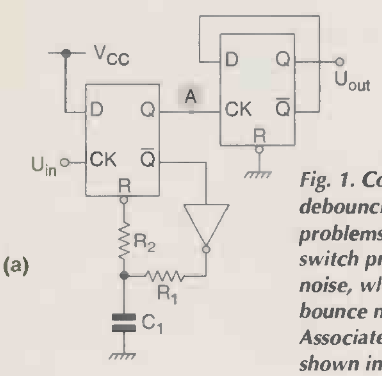

Fig. 1. Conventional switch debouncing circuit a) has problems if the mechanical switch produces polarised noise, which it can as bounce noise is random. Associated waveforms are shown in b).

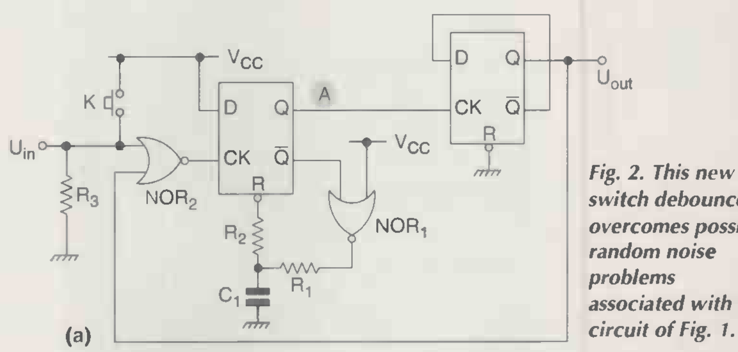

Fig. 2. This new switch debouncer overcomes possible random noise problems associated with the circuit of Fig. 1.

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'.

DAB: The BBC replies

Here is the full text of a reply I have just received from the BBC about the declining quality of DAB. I think it speaks for itself:

Dear Sir,
Thank you for your enquiry.

Let us explain the general policy under which we operate the DAB multiplex.

Given the fixed overall capacity available to us, our policy is to allocate capacity to each service based on its content, balanced across all our digital radio services. As a public service broadcaster, the BBC attempts to provide services, which meet a wide range of tastes and interests. Connecting with the UK's increasingly diverse audiences is a major objective for the Corporation.

We have taken considerable care over the technical arrangements needed to allocate suitable capacity for the digital radio services. This does mean the capacity individually allocated to some services has had to be reduced at certain times in order to bring Five Live Sports Extra to listeners. Radio 3 has broadcast at 160kbps from time to time. This will continue to be the case on occasions when we consider the balance across our digital radio services demands it. We firmly believe that reducing the bit rate on certain services does NOT hinder the sound quality of DAB digital radio. The BBC is deeply committed to ensure that digital radio represents an extremely attractive medium to all its listeners when judged by the rich diversity of stations it offers, its robustness of reception, and the overall technical quality it is able to provide.

In relation to the German situation - DAB is still in a relatively early stage of development currently (like the UK some years back). It is generally accepted in Germany and most territories around the world, that as DAB matures into a full market proposition indeed compromises will also need to be made in relation to bitrate levels.

Simply simulcasting FM stations on DAB would result in the medium remaining a specialist 'niche' proposition. Radio needs to maintain momentum along with all other forms of communication as they turn digital. Maximising the appeal to the general public (via new digital only services) is a vital tool in moving DAB from the niche position it has occupied for the last 7 years to it becoming the radio transmission standard of the future.

Thank you again for taking the time to write.

With best wishes,
BBC DIGITAL RADIO
Don Pearce
UK

Improved hybrid power amplifier

Shouldn't the power supply have 0.1μf decoupling capacitors across the windings, and across the electrolytics (which should have a working voltage about 2x the DC voltage)? The input switching would benefit from double pole switches, or no switch at all. Q8 would surely benefit from some decoupling.

Is a μA741 really the best component for this position? It has very restricted performance of power supply noise rejection, bandwidth, slew-rate, noise etc. Also could or should the EL34 heaters have (separate) DC supplies? Should R15 be replaced with a low noise fixed resistor?

The transformer is the usual stumbling block with in valve output stages; are any substitutes available? Is a 15Ω version available for high-fidelity enthusiasts? Have magnetic coupling effects been considered?

Are gold plated (or solid) wires/leads recommended (or required)? A steel, mumetal or aluminium chassis? Is a ventilation fan (low noise obviously) recommended?

And finally, and possibly most importantly, should a star earth (or ground) point be used?

What a minefield hi-fi electronics has become! It is nice to see pentodes in the house though.
J Gray
London UK

DAB and CD quality bit rate.

I am puzzled by Roger Thomas' figure of 256 kbps as the bit rate required by DAB to produce CD audio quality. (*Electronics World* February issue 2003. P 14). The figure should be 16 x 44.1k x 2 = 1.4112 Mbps for stereo. This is what I expect Digital Audio Broadcasting to deliver from the studio to my living room error free.

Perhaps DAB is offering us a quantum leap backwards in terms of quality broadcasting.
Tony Erwood
Shetland, UK.

If you think that's bad – try 270Mb/s compressed to about 3Mb/s! That's what digital TV is all about. Do see however, the letter concerning the BBC's answer as to how DAB works. – Ed.

FM Stereo and Class A Amplifier

I am ashamed to write back so late to thank you about the letters you sent explaining the subjects of FM Stereo and Class A Amplifier by Mr. John Linsley Hood.

I should have made the acknowledgements earlier, but the birth of my first child (a lovely baby girl named Anne-Sophie), has prevented me from doing so, as most of my time after a working day was dedicated to her during the early months. Now that Anne-Sophie is seven months old and the pressure to provide her with the strictest care has been reduced, I am able to find some time in the evening to experiment with electronics. This said, I want to testify in favour of the NE5532 IC, which in one of your issues of 2001, sparked an argument between a reader and Mr. Douglas Self over the use of this IC in his precision preamplifier.

I used the NE5532 in the preamp Section of A Pioneer A202 amplifier and the results are absolutely remarkable. The sound is so different from that of the amp with its original Japanese IC in place. The frequency response has been considerably improved such that I can now use the source direct channel to listen to my CDs or tapes without having to tilt the tone controls to adjust to my taste every now and then.

Listening through headphones is a mere pleasure, revealing details that were concealed before. It is as if the sound stage has been brought forward and the sound is more natural. I am very much happy with my system at present and can listen for hours to my favourite songs.

Another modification that may interest you is that made to the Class A Amplifier. I built my prototype on Veroboard and I am still experiencing problems getting it to sound right, but a great improvement to its performance was obtained when I switched from PNP Silicon transistors to Germanium Japanese made ones with 25B prefixes (173, 175). Hum has been reduced to much lower level, though as I do not use a stabilised power supply, I found by bolting all transistors on a heatsink with the necessary insulators further added breadth to the beauty of the music.

I want to have your comments on the above if possible in your esteemed magazine, which, although I am not a regular subscriber, I never fail to buy.

Eric Lamarque
Port-Louis, Mauritius

When you read this, Eric, please note that both the editor and the magazine's location have changed! But thanks anyway. – Ed.

John Linsley Hood

As a quite long standing reader of this magazine (since 1963), I must agree with D. Lucas' opinion (Letters, *EW* Jan '03).

The quality of JLH articles (without any lesser honour to other respected authors of articles published in *EW/WW*...) are, to my opinion, something to be made accessible, in a similar way as the book 'Self on Audio' by Douglas Self.

Would it be too much of an effort to the editor of *EW* to gather JLH's articles, the corresponding correcting hints and perhaps the letters connected to them and make them available? I am pretty sure that there should be enough a public showing interest in this 'hand made' electronics articles on audio applications/circuits.

Christoph Keutmann
St. Augustin, Germany

It would be a huge effort – especially as JLH's articles are from our 'non-electronic' era. However, I'll give it some thought. Does anybody know when the first article appeared? I remember building the 10W class A in the early 70's – but I assume he was around before then. – Ed.

Mobile Phones in Filling Stations

You were enquiring in Jan 2003 Electronics World about the safety of mobile phone antennae located in filling station advertising towers whilst the use of handsets in filling stations is prohibited.

According to a HSE bulletin last year, Shell have reported at least three instances of mobile phones igniting fuel fumes at filling stations causing significant fires and injury. The phones in question were either resting on the vehicle, or in the hand or pocket at the time. The fires occurred when phones either rang or were answered, and are believed to be due to energy release causing an ignition spark in the phones when the display lights up, as it does on some modern phones. There is no blame attached to the RF radiation from the phone and therefore this risk does not apply to base station masts. In any event the RF power level, as measured at the pumps, from an antenna in the top of an advertising sign is likely to be very much lower than from a mobile handset that could be actually within an area of explosive vapour adjacent to the vehicle filler.

A simple calculation can be performed to compare the power level at a distance of 0.1 metres from a handset with that from a mast antenna 10 metres away. RF radiation reduces as the square of the distance, so the transmitter power for the mast, being at 100 times the distance and assuming an isotropic antenna, would need to be 10,000 times stronger than that in the handset to give the same incident power. A 1kW mast would therefore equal a 100mW handset. Local mast transmitters do not approach this power. In reality the mast antenna will have a flat beam, not isotropic, and the pumps will be below the main beam further reducing the incident power from the mast. This shows that RF power levels from local masts are lower than from handsets.

The above instances should highlight the need for mobile phones to be switched off before entering filling stations or other areas prone to

Modern Impedance Measurement

In Alan Bate's 'Modern Impedance Measurement Techniques III' (*EW* Feb 2003), he says that "The FFT calculation is carried out twice for Es and ET".

Is this necessary? Could you calculate the FFT's of the two functions simultaneously, as described in section 12.3 page 515 of "Numerical Recipies in C++" by Press", et al, Cambridge University Press 2002?

Alan J Munday
Southampton, UK

Catt comments

I was very interested to read the article concerning air traffic control and the kernel machine ideas produced by Ivor Catt. The article reminded me of work I had done some years ago that concerns information processing without using a von Neumann computer. I had an article called "Dumb Intelligence" published in *EWW* as *EW* was once known. The title was not of my choosing but it was appropriate. I think that it appeared in March 1987.

I have refined my ideas a little since then but the underlying principles apply. It is possible to produce a totally automatic ATCC system that does not use von Neumann processing.

I do not have the resources to produce a basic prototype or the money to finance a proper patent application. I have no wish to amass vast sums through patent licences but I would like my design to be protected for the benefit of Britain.

My design combines all the features needed for an ultra reliable system while costing much less than any other system to implement. I am sure that it would provide a very cheap competitive alternative to Ivor Catt's system and thereby reduce the value of his excellent work.

Wilf James
Herts, UK

Wilf actually enclosed a draft article with his letter. Expect to hear some more from this gentleman. – Ed.

explosive vapours, the passive act of not making or answering calls in not sufficient.

Mr. J.W.Attwood
Bushey, Herts

Who on earth wrote the HSE report? I cannot see how powering up a few LEDs in the phone could cause fuel to ignite. More likely, I would think, that the energy produced by the phone when ringing (ever had one go off next to audio equipment?) would be sufficient to induce some voltage in the pump handle which could then spark to the car (at the fuel filler orifice) igniting the fuel vapour. But I do take your point on the transmitters. – Ed.

Capacitor power ratings

As both a user and provider of capacitor 'S' parameters and power ratings I would like to expand on the Tuck Choy letter. For many years I was tasked to respond on both issues on behalf of my employer.

Since 1986 I have found capacitor 'S' parameters invaluable especially when designing for higher frequencies using simulators, however measuring 'S' parameters would not have revealed the distortion mechanisms. I have also written a number of dedicated circuit simulator programs and have a good variety of commercial simulators permanently installed in my computer. My oldest simulator, 'Analyser' from No1 Systems does accept 'S' parameters, my newest Microcap 6 does not.

Excepting Saber, simulators come essentially in two varieties, those that calculate basically in the 'time' domain (oscilloscope presentation) others in the 'frequency' domain (bode plot.)

Some 90% of all simulators in common use for circuit designs are based on the public domain 'Spice 2' software, developed in 1975 by Lawrence Nagel at Berkeley for his doctoral thesis, funded by Motorola. While able to provide frequency domain results, it is optimised for time domain use. Consequently it provides well for voltage dependant component non-linearities, but poorly for frequency dependencies so does not accept 'S' parameters.

When designing for higher frequencies, component frequency dependant anomalies are more important so most RF targeted simulators do accept components' 'S' parameters but are restricted as to voltage dependencies. Such simulators calculate by frequency then use convolution to provide 'time' domain outputs. Because commercial test jigs dedicated to particular semiconductor sizes are available, given a jig and vector network analyser, semiconductor 'S' parameters are easily produced.

Apart from small surface mounted chip capacitors, such jigs do not exist, so must be specially fabricated and calibration data deduced. Not easy. I designed some easily fabricated capacitor 'S' parameter measurement jigs many years ago; it required several weeks measurement and calculation to provide the calibration standards to be used with these jigs.

The main cost in developing a simulator, especially for RF, resides in measuring components then generating the component models it provides, so all worthwhile simulators are expensive. A few do provide evaluation or student versions, perhaps the best and most comprehensive of these 'Aplac' was developed at Helsinki Uni and funded in part by Nokia. A usable but circuit size restricted version can be downloaded from the Aplac site.

Shortly after becoming freelance I was contracted to provide 'S' parameters and other frequency data from 1 MHz to 3 GHz by a large capacitor maker, for his capacitors. Consequently most makers of capacitors targeted to high frequency use do supply 'S' parameters so perhaps Tuck Choy should enquire further at say AVX, BC Components, etc.

One inexpensive simulator which uses 'S' parameters can be obtained from the ARRL in US. This is a cut down version of Super-Compact, a well regarded RF simulator and includes a library of 'S' parameters. Interested readers may also look on the internet for the now old free RF simulator which used to be available from HP, called 'Appcad'. This also includes a small library.

To illustrate a capacitor 'S' parameter file I append just the first two of two hundred frequency data sets for a 47pF ceramic chip data file, which was supplied to me from one of the largest makers, in 1992. Similarly over many years I have also provided capacitor power ratings. Most capacitor makers now provide this data, but often only by request. In the case of electrolytics, current ratings not power are provided. These ratings invariably result from practical measurements of temperature rise on 'known' capacitors stressed using a sine wave, to facilitate measurements and calculations.

However capacitor ESR is strongly frequency dependant so calculating the power imposed on a capacitor with real-life non-sinusoidal waveforms can become difficult. For this reason many capacitor makers prefer to deliberate themselves for each application rather than publish ratings.

However, with the more ideal capacitors some makers do provide power ratings and even downloadable software to perform the calculations in your own computer. I have in mind the excellent software provided by Evox-Rifa for certain of their capacitors.

Surface mounted chip capacitors introduce an extra complication. Much of their self-heating is dissipated into the circuit board and copper tracks. Consequently the quantity of glue used to 'stick' the capacitor into position for soldering and also the width of copper track used can significantly affect heat dissipation and hence survivable power. Most engineers happily under-run surface mount resistors but capacitors are frequently unwittingly overstressed. The problem only being clarified following a number of capacitor failures.

Readers interested in exploring capacitor power further might wish to look up EW April 1995 also September 2000.

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These ratings invariably result from practical measurements of temperature rise on 'known' capacitors stressed using a sinewave, to facilitate measurements and calculations.

However capacitor ESR is strongly

Wireless idea

I'm glad to hear that *Electronics World* is not going to get any smaller.

One feature that might be of interest to those of us who signed up to *Wireless World* would be something on DIY wireless Internet access. There was a BBC feature on this not long ago.

I also find it fairly pathetic that ADSL at 256K is regarded as fast when we should be looking at 10Mbps/100Mbps or better.

Keep up the good work. I've just worked out that I've got over 30 years of copies of *WW* and *EW* in the basement. That's scary.

Crispin Horsfield
Bristol, UK

As I'm just about to do the same thing myself at home – is anybody out there up to the task? – Ed.

frequency dependant so calculating the power imposed on a capacitor with real-life non-sinusoidal waveforms can become difficult. For this reason many capacitor makers prefer to deliberate themselves for each application rather than publish ratings.

However with the more ideal capacitors some makers do provide power ratings even downloadable software to perform the calculations in your own computer. I have in mind the excellent software provided by Evox-Rifa for certain of their capacitors.

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Readers interested in exploring capacitor power further might wish to look up EW April 1995 also September 2000.

Abbreviated 'S' parameter file 47P.S2P

```
!Dataset Name:
/lib0805cap_cor/NP0/cap47p
  !Modified: 29-Sep-92 14:51:26
  !Data Table: spana.SP
  !Stimulus Table: IVARDATA1
  !Stimulus Variable: freq
  !FILEFORMAT: MDS
  !TITLE: netlist
  !DATE: Tue Sep 29 14:51:21 1992

  # Hz S RI R 50

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0.591611792048176
0.761970999196389
0.594414840145648
0.20955514843624 -
0.544922008335474
  119775000 0.0336691787446464 -
0.244170803091028
0.968172719171654
0.232889600482893
0.967139014654969
0.236459384127851
0.0373159209603486 -
0.24321299456287
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Cyril Bateman
Acle Norfolk UK

Editor corrected

In your editorial "a change of focus" you mentioned that "the 2B1Q algorithm used to send fast digital signals down a pair of copper wires cannot punch its way through the "bridge taps" where local lines are spliced." This is unfortunately some misinformation.I work in the field, so I felt compelled to set the record straight. First, "bridge taps" are not just points where local lines are spliced together; they are not-used lines that are spliced to lines that are in use, thereby causing horrific mismatches and signal reflections in these lines. According to the operators themselves, bridge taps are almost non-existent in Europe, except in Italy. Bridge taps seem to be a serious problem in the USA however.

Second, 2B1Q and TC-PAM are different line codes but they really are only different flavours of the same thing, namely Pulse Amplitude Modulation. For each transmitter clock cycle, 2B1Q transmits one out of four voltage levels, equivalent to two data bits. TC-PAM on the other hand, transmits one of sixteen voltage levels, thereby representing four bits: three data bits and one extra Trellis Coding bit for error correction at the receiver. So to achieve the same data rate, TC-PAM can transmit a little slower then 2B1Q, hence it needs a little less bandwidth. The drawback of using more voltage levels is however that they must become closer together for the same transmit power, hence it is more difficult to detect the correct levels at the receiver, but the error correction through Trellis coding makes up for that. So fundamentally, as far as bridge taps are concerned, there is no difference at all between 2B1Q and TC-PAM at all. The effects of bridge taps are a linear distortion (a convolution) that can be reversed by adaptive equalizers for the received signal and adaptive echo cancellers for the reflected signal. The performance of these is not at all affected by the choice of line code; it is affected only by their topology, updating algorithms and design parameters such as order and resolution. Both 2B1Q and TC-PAM receivers use these adaptive filter techniques. As defined in current xDSL standards, TC-PAM (SDSL) does have a bigger noise immunity then 2B1Q (HDSL), but that is only because TC-PAM has performance enhancing techniques such as Trellis Coding error correction, spectrum shaping and Tomlinson pre-coding. It has nothing fundamentally to do with the ability of handling bridge tap effects.

Luc Heylen
Westerlo
Belgium

Shot in the foot

Imagine my horror upon opening the February issue of *EW* to find that I might be accused by a reader, more familiar with ancient Greek than myself, of a horrible gaffe. This concerns what appeared in my letter printed therein as 'Hoi su technon' when it should have been 'Kai su....'.

However, since upper case 'K' and 'H' are so similar in script, as are 'a' and 'o' in lower case, errors are so easily made. I must learn to type or use a word processor! Then, perhaps, 'worked' would not be rendered 'washed'.

A C Bloomfield
Gloucester, UK

I hope we printed this one OK! In fact we were unsure whether you meant 'worked' as it looked like something a lot ruder. – Ed.

Spectrum Pricing

With reference to Robin Clark's letter on Spectrum Pricing (*EW* January 2003), that and other subjects he mentioned rang a resonant bell with me. Subscribers of long standing (of whom I'm sure you still have many) would

More nonsense but no conspiracy – honest!

Wayne Hu's suggestion (in an article in January's *New Scientist*) that particles of cold dark matter have a mass of 10^{-22} eV, which equates to ~ 10^{-58} kg, leads support to the values of 1.375 x 10^{-50} and 9.8 x 10^{-51} kg for λ given in the January issue of *EW*, and models (holomovement – implicate/explicate ordering) than some of the nonsense currently under consideration: 'Crumbly', 'exploding', hot and cold CDM coming out of some pretty good schools; Einstein was at *Princeton*! Hu is at MIT where Earle Williams had been researching Schumann Resonance for yonks: 4 x 1.87 = 7.48Hz (second period-doubling on F_1/F_2!!) which is mid range of the values (7.06 in August to c. 7.83 February's) measured at Much Hadham since 1990 using an ELF counter.

I was very fortunate to get this model (Wisher 308) by way of an advertisement in *EW*; Some ELF counters don't respond to SR, OR 1.87, like Dom di Mario's. In fact, a second 308 I got from the same source, via *EW*, responds in the range 15.5 to 16.5Hz! Why? Is this Larmor resonance around the Earth?

***A G Callegari** BSc., MPHIL. (Lond)*
Much Hadham
Hertfordshire
UK

appreciate those sorts of articles. As he said, valves are fun, and apart from people like Morgan Jones, who else deals with them nowadays?

This brings me to a rather sore point. He mentioned that he built a hot audio power amp in March 1995. Would he perhaps be referring to Jeff Macauley's article in the October 1995 issue on hot audio power? I built this particular amp after having bought the valves from a London firm, and the transformer set from Antrim, on a visit to England in 1996 (Antrim were in Canterbury at that stage). The other parts were as specified, apart from T1 and T2, which I couldn't get here (Japanese high voltage), so I substituted. I was lucky to get a maximum of 20 watts midband out of it into 8Ω and was not at all impressed with the response, either high or low, the LF response at 100Hz showing the start of a kink, which became absolutely horrible at 50Hz. This applied to both output transformers.

I wrote to Jeff Macauley via *EW* at the time, but never had a response and my letter was never published. I gave up in disgust even after experimenting considerably and have not been inspired since to try again, bearing the present cost of different output transformers in mind. Perhaps either Robin Clark or Jeff Macauley would be prepared to comment?

Finally, how about considering a reduced subscription for senior citizens, such as I have been enjoying for the past few years from the RSGB? It all helps, particularly with the abysmal rate of exchange we have put up with at the bottom end of the African continent.

Frank Van Vloten
Gillitts,
KZN
South Africa

Your subscription idea is good, but would be difficult to police in practice. May I suggest that you come up with a circuit idea or even an article, payment for which would offset your subscription? Ed.

Alternative power source

The story of Cornell University's nuclear powered battery (*EW*, Jan 03, p. 5) suggests using electrons emitted by radioactive nickel-63 as a source of electricity. Getting 1 amp involves 1 coulomb/second or 6.25 x 10^{18} electrons per second, which is simply equal to the amount of beta radioactivity in becquerels, decays per second (assuming 100% efficiency). In traditional radiation units, this translates to 169 Megacuries, similar to 169 tons of radium.

The legally accepted limit of radioactivity in British consumer products (e.g. smoke detectors) is only 0.99 microcurie, equivalent to under a microgram of radium. So a lot of red tape stands in the way of progress. Since the beta particles are stopped completely by aluminium foil, excessive safety demands reflect our nanny state politics, not the actual danger. Because the genetic code DNA is passed on to each descendant, every single piece of DNA in every single living organism on the planet has been subject to mutations from background radiation, about 2 millisieverts/year, since life began. My DNA over the last million years (since the discovery of fire) has received 2000 sieverts.

The lethal dose for a brief exposure to a single person is only 10 sieverts. Therefore DNA, continuously being copied along with its errors and passed on, withstands surprisingly huge accumulated doses from background radiation. How? Protein P53 is continuously repairing the breaks which are made in the DNA. Inhaling or ingesting emitters of alpha and high energy beta radiation are the only ways to get cancer or genetic damage risks at low doses. These radiations can both be stopped by thin plastic or tin foil. There is overwhelming evidence that the more penetrating radiation, gamma, is too weakly ionising along its path through tissue (low linear energy transfer) to induce the number of multiple strand breaks in DNA needed to overcome the P53 repair mechanism at low dose rates. Experimental evidence with large groups exposed to gamma radiation fields a few times the average background radiation level indicate a reduction in normal cancer rates.

Gamma radiation at low intensities probably stimulates P53 activity to a greater extent than it causes breaks. It is pseudoscience to claim that all radiation is dangerous, unless you have a valid scientific basis for that assertion. Extrapolation down from the definite cancer effects known at high doses is nonsense in biology because of changes in mechanism, e.g., vitamin D is vital to life in small amounts, but is a rapid lethal poison in large amounts.

Mathematical nonsense abounds when people in science present simple linear dose response equations as "laws of nature", when in fact they should be admitting ignorance of the causes and mechanisms underlying the phenomena, and deserving further investigation. We know that a linear response curve for cancer induction does exist in animals, including mammals closely related to humans. But humans have a much better DNA repair mechanism than in lab monkeys. (This explains the old puzzle of why monkeys looked after well in zoos never live to half the average human lifespan.) Radioactive waste should probably be used constructively to manufacture long life high power batteries, not dumped for political reasons.

Nigel Cook
Colchester
Essex
UK

Quality Reduction between TV and VCR

Can anyone tell me why it is that, although reception of Sky and BBC Digital is excellent here, VCR timed recordings do not work and PDC does not appear on the screen?

Analogue is ok as always. Have I missed something?

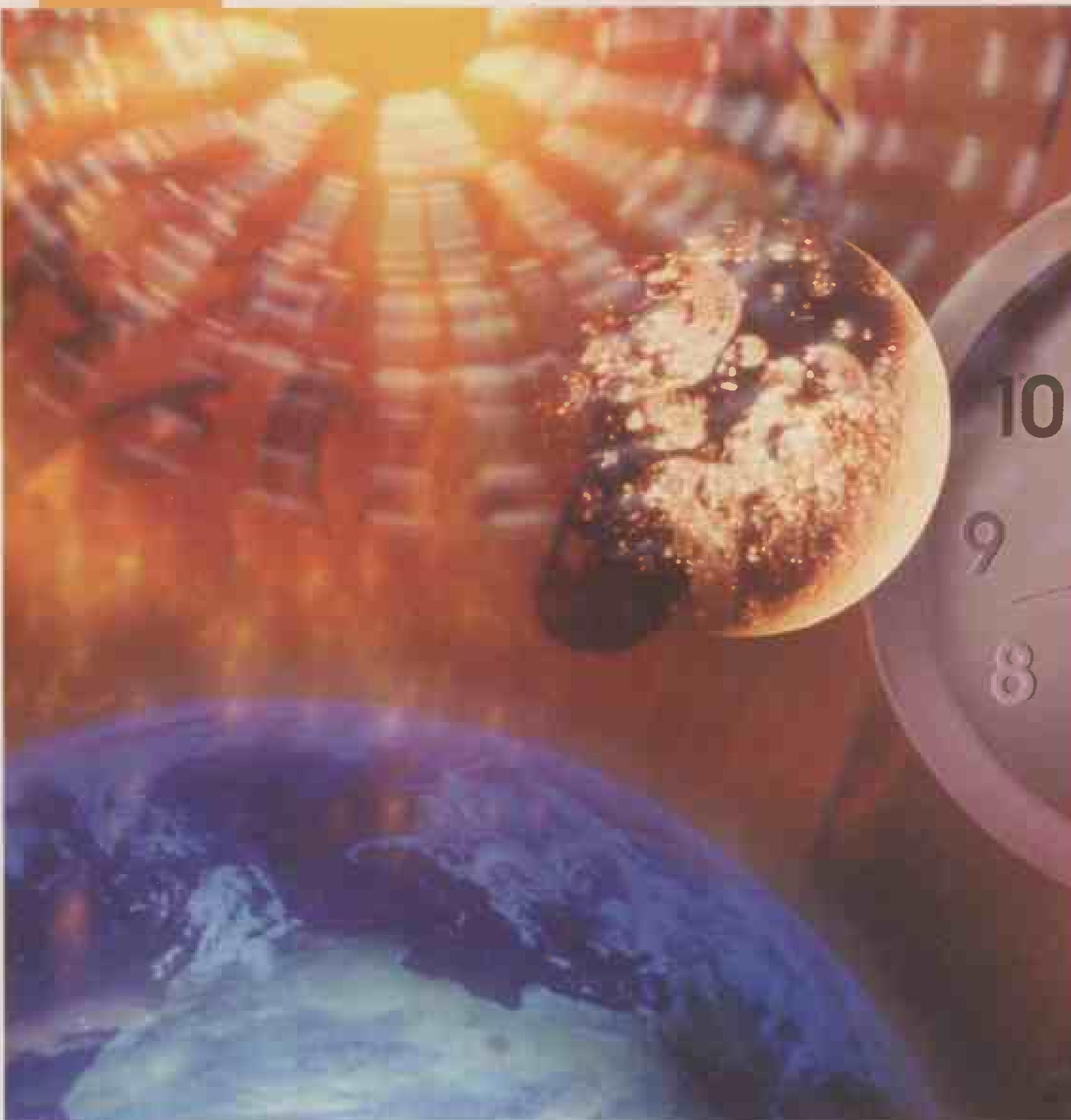
A Cox
Bexhill on Sea
East Sussex
UK

Have a look at the uk.tech.broadcast Internet newsgroup, where this subject comes up a lot. As far as I can see, nobody is actually policing the broadcasters when it comes to these 'peripheral' services. Some carry them, some do not. And it varies between regions. And of course does your digital box 'talk' to your VCR? To say that standards are all over the place is an understatement. I personally am thinking of building my own hard disk recorder/time shifter, like a home-grown 'Tivo'. Any budding authors with similar thoughts? Ed.

Regulator

Just some words to confirm A.C. Bloomfield (letters to the Editor, Feb 2003) that the ripple regulator using a 7805 is a well used form featured in Circuit Ideas from May 1976 (see on page 80, the title being 'Adjustable Voltage Switching Regulator). ■

Jean-Marc Brassart
Saint-Laurent-du-Var
France



Part 2: The Electronic Big Bang. Nigel Cook continues to question some established theories in this occasional series. Interested readers can find Part 1 in the August 2002 issue of *Electronics World*.

An Electronic Universe

The single velocity universe was proved some time ago by Ivor Catt. The speed of electric energy entering a pair of wires, and leaving them, is that of light in the medium between the wires. The speed of electric energy is identical to light. The phenomena of transmission lines, capacitors, inductors, tuned circuits, and static electricity have been experimentally and theoretically proven to be entirely the result of 300,000km/s electromagnetic waves. This work was accomplished by Ivor Catt, Malcolm Davidson, David S. Walton, and Mike S. Gibson. As their research rigorously proved, we live in a 'single velocity universe.' At first glance this seems absurd.

Catt's work indicates (see Part 1, *Electronics World*, August 2002) that a charged particle is a standing wave (circular motion) of transverse electromagnetic (TEM) energy, always having electric field E, magnetic field B, and speed c at right angles to one another. This TEM wave, trapped by its own gravity, has a 'spin', which produces a spherically symmetrical electric field and a magnetic dipole, explaining the 'wave packet' in 'particle' physics. The 'particle' is a trapped transverse electromagnetic wave.

If a 'particle' propagates in a direction along its spin axis, it can spin either clockwise or anticlockwise around that axis relative to the direction of propagation. This gives rise to the two forms of charge, positive (positrons, upquarks, etc.) and negative (electrons, downquarks, etc.). The orbital directions of the electrons can be in such a direction as to either add or cancel out the magnetic fields resulting from the spin, which gives rise to the pairing of adjacent electrons in the Pauli exclusion principle.

Everything seems to be either static or in motion at relatively slow speeds. The idea that *everything* is always in *constant* 300,000km/s motion, together with the statement that there is no significant energy transfer by an electric drift current, sounds ridiculous. But we 'see' using such motion all the time, in the sense that sight itself necessitates 300,000km/s electromagnetic energy entering the eyes. The origin of the constant speed of light lies in

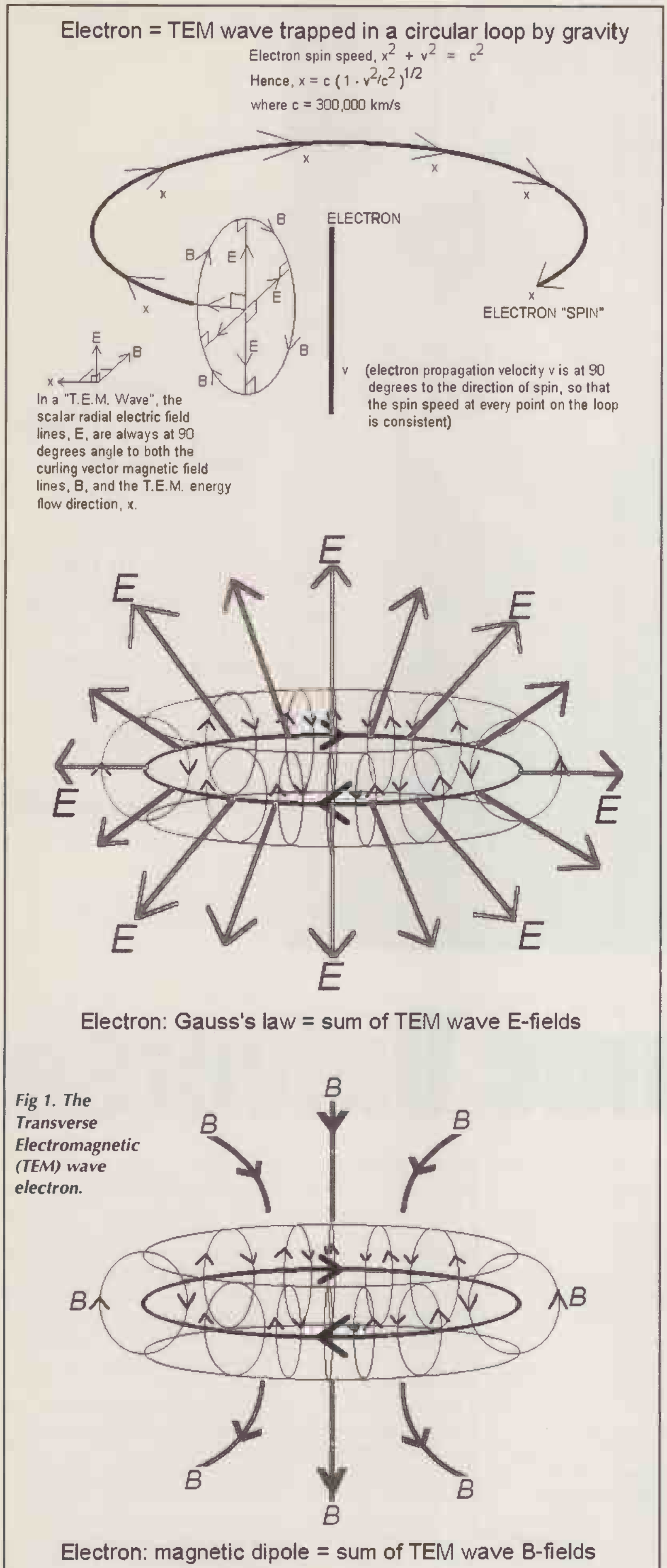


Fig 1. The Transverse Electromagnetic (TEM) wave electron.

the matter which physically emits the light, and this offers an obvious and simple mechanical explanation to account for the phenomena of relativity.

Unification of quantum mechanics and relativity

When drifting along at right angles to their plane of spin, the consistent circular spin speed of 300,000 km/s at each point on the ring electron will be reduced, because part of the spin speed is then diverted into drift motion. Pythagoras' theorem gives us: $x^2 + v^2 = c^2$, where x is the speed of spin of the electron, v is the drift speed, and c is the velocity of light. If an electron moves at a speed approaching the velocity of light, the equation above, rearranged, shows the measure of time for the electron (the relative spin speed), is: $x/c = (1 - v^2/c^2)^{1/2}$.

This formula, derived from Ivor Catt's proof of the single velocity universe, is identical to the time-dilation formula predicted in an abstract mathematical manner a century ago by Einstein. Further, it follows from Catt's work that if time is dilated, then distance must be contracted by the same factor, in order that the velocity of light (ratio of distance to time) remains constant. Therefore, Catt's work implies not only the correct time-dilation but also the distance-contraction formula previously postulated to explain the inability of the Michelson-Morley experiment to detect our motion through the dielectric of the vacuum (an effect of the contraction of the measuring instrument by precisely the same factor as the change in the velocity of light).

The equation $E = mc^2$ is far better derived by Ivor Catt's single-velocity universe (see part one) than by Einstein's postulates. Dr Arnold Lynch suggested to the writer that where observed fields apparently 'cancel out' energy still needs to be accounted for. Since electrons pair up with opposite spins, the magnetic fields are cancelled out at long distances, but the magnetic field energy is still there. Since half of the TEM wave energy is magnetic, we see the reason behind the factor of _ in the familiar equation for kinetic energy, which is absent from Einstein's relation.

The reader interested in this aspect can consult the official U.S. Atomic Energy Commission compilation, edited by Dr Glasstone, *Sourcebook on Atomic Energy* (Van Nostrand, London, 1967, pp. 88-9). This provides two derivations of $E = mc^2$. One derivation uses the binomial theorem and the other uses calculus: neither contains any physical explanation of how the speed of light is related to matter. Catt's theory dispenses with Einstein's mathematical postulates of relativity, by providing a physical mechanism. The big bang universe has an absolute age and hence absolute chronology and size, which is incompatible with special relativity which assumed the steady-state, infinite, eternal universe, which was the acceptable theory back in 1905.

The four fundamental forces in the universe

"In many interesting situations... the source of the gravitational field can be taken to be a perfect fluid.... A fluid is a continuum that 'flows'... A perfect fluid is defined as one in which all antislipping forces are zero, and the only force between neighboring fluid elements is pressure." – Bernard Schutz, *General Relativity*, Cambridge University Press, 1986, pp. 89-90.

Fig. 2 gives the mathematical derivation of gravity using the dielectric of electronics, based by the writer on Ivor Catt's analysis of the physical properties of the 377 ohm dielectric or continuum of the vacuum. The dielectric is a continuous medium imbedded with atoms of matter. The continuity of dielectric with matter means that there is no continuous dissipation of energy due to particle collisions as occurs in material fluids, and therefore only resistance to acceleration (thus providing the explanation of the inertia). If we accept that the stars are receding as modern astronomy shows, we must accept that the electronic dielectric of the vacuum moves in the opposite direction (towards us), maintaining continuity of volume. If you walk down a corridor, your volume of matter V will move in one direction, and will be continuously balanced by a volume of air, also V, moving in the opposite direction at the same time; this is why you do not leave a vacuum in your wake. (Without the opposite motion of an equal volume of the surrounding motion, flowing around you as a wave in space, motion would be impossible.) Since distance is proportional to time (the sun being 8 light-minutes away, and the next star 4.3 light years, etc), the statement of the Hubble constant as velocity divided by observed distance is misleading (the stars will recede by a further amount during the interval that the light is travelling to us), but a true 'constant' for the speed of recession is proportional to the time taken for light to reach us (which is also the time past when the light was actually emitted). Correcting Hubble's error thus gives us a constant which has the units of acceleration, which leads directly to gravity. This shows G to vary depending on the place in the universe, analogous for our purposes to a 10^{55} megatons nuclear explosion in

Fig.2. The 16 step proof of gravity's cause and detailed mechanism.

Equating Hubble's expansion rate of the universe with the differential definition of velocity we find: $v = rH = dr/dt$. Hence: $dt = dr/(rH)$. Thus, acceleration, $a = dv/dt = d(rH)/[dr/(rH)] = rH^2$.

The step-by-step mathematical analysis for the mechanism proves that $a = (3/4)H^2M/(\pi r^2\rho) = GM/r^2$ (gravity), with $G = (3/4)H^2/(\pi\rho)$, an effect of Hubble expansion.

Step by step proof of the mechanism for gravity

1. Distance of mass M from observer = r

2. Spherical surface area, $A_r = 4\pi r^2$

3. By definition of pressure, $P_{dielectric} = F_{dielectric} / A_r$

4. By definition of force, $F_{dielectric} = m_z a_H$

5. Equation of continuity: [Constant volume or mass of continuum (or mass-energy by $E=mc^2$)] = [Mass of nuclei, etc.] + [Effective mass of dielectric, m_z]

6. From this continuity equation we see that a reduction in the mass within a volume due to the big bang leads to an equal and opposite motion of the continuous fabric of space (the 377 ohm dielectric of the vacuum) so: m_z = [Equivalent mass of *inward moving dielectric* surrounding r] = [Mass of *outward moving mass* surrounding r] = [Volume of universe surrounding radius r].[Density, ρ] = $(4/3)\pi(R^3 - r^3)\rho$

7. Radius of universe (near which the speed of motion and total amount of moving mass is so large that it contributes the majority of the dielectric pressure where we are located) = R

8. Hubble expansion rate, $v = RH$, where H is the Hubble constant. Note that since we are looking back in time with increasing distances, due to the travel time of light emitted by stars ($t = R/c$), the velocity is really varying as a direct function of time past, i.e., *velocity is proportional to time* so there is *acceleration*, as the galaxies will *no longer be at the distances they appear* when the light reaches us. So Hubble's effect is *acceleration into the past*.

9. Correcting this simple error in Hubble's expansion rate, we discover the actual acceleration: $a_H = v/t = RH/t = cH$, where for distances near the radius of the universe where the greatest speeds occur, c is approximately R/t or v, so: $a_H = cH = vH = (RH)H = RH^2$. (The negative sign in acceleration which is due to the *slowing down* in velocity with increasing time after the big bang is cancelled out by the negative sign due to the fact that as we look to larger distances we see the earlier universe so time after the big bang *decreases*, rather than increases.)

10. Due to optical-type geometric divergence with distance (gravity effects travel at the speed of light), the cross-sectional area (producing the inward dielectric pressure) of the equivalent mass of dielectric (m_z) near universe radius R is much bigger than it appears to be (m) for effects at radius r, by the ratio of the spherical areas, hence: $m_z = m(A_R/A_r)$, so that the effective equivalent dielectric mass for pressure effects at radius r is: $m = m_z(A_r/A_R)$

11. Spherical surface area, $A_R = 4\pi R^2$

12. The asymmetry, created by a mass at distance r shielding the observer, produces a net pressure directly proportional to the cross-sectional area ($A_r/4$) that is shielded: $P_{net} = P_{dielectric}(4A_{shielding}/A_r)$

13. [Mass needed for complete shield of dielectric pressure (by elastic recoil analogy)] = [Equivalent mass of all moving dielectric] = [Actual mass of expanding universe (assumed to be of uniform density as a first approximation)] = $M_{universe} = (4/3)\pi R^3\rho$. By analogy to nuclear radiation shielding by mass, the effective shielding cross-sectional area at radius r from mass M is directly proportional to that mass: $A_{shielding} = (A_r/4)(M/M_{universe})$

14. By definition of net pressure, $P_{net} = F_{net} / (A_r/4)$ Hence: $F_{net} = P_{net}(A_r/4)$

15. By definition of net force, $F_{net} = ma = P_{net}(A_r/4)$

16. Hence: gravity acceleration, $a = P_{net}(A_r/4)/m = (3/4)H^2M/(\pi r^2\rho) = GM/r^2$ (the gravity equation), with $G = (3/4)H^2/(\pi\rho)$, where Laplace's symbol for the universal gravitational constant is G.

outer space (like a scaled-up version of the 9 July 1962 Starfish Prime 1.4 megaton test at 400 km altitude).

There are four fundamental forces:

strong nuclear force,
electromagnetic force,
weak nuclear force, and
gravitational force.

The short-ranged STRONG NUCLEAR FORCE holds the nuclei of atoms together against the immense coulomb-repulsion of many positive, closely-confined protons, and this strong attraction is explained by the vacuum flux of 'virtual' particles being exchanged between nucleons (neutrons and protons). At short ranges (adjacent nucleons), the strong nuclear force is 137 times stronger than electromagnetism, because that is the difference between the force given by Heisenberg's uncertainty equation (in its energy and hence momentum exchange version), and Coulomb's law of electric force, for unit charges. (Since the nucleon's shield one another, the force within the nucleus drops exponentially with distance, in addition to the inverse square law.)

We can prove this. Werner Heisenberg's uncertainty relation for energy is simply: $Et = h/(2\pi)$, where E is the uncertainty in the energy, and t is the uncertainty in the time. This can be rewritten in the form of E/t by rearranging to give $2\pi/h = 1/(Et)$ and then multiplying both sides by E^2, which yields $E/t = 2\pi E^2/h$.

Force is given by:
$F = ma = dp/dt = d(mc)/dt = c.(dm/dt) = (1/c).(dE/dt)$.
Substituting the uncertainty principle (in the form $E/t = dE/dt = 2\pi E^2/h$), together with the definition of work

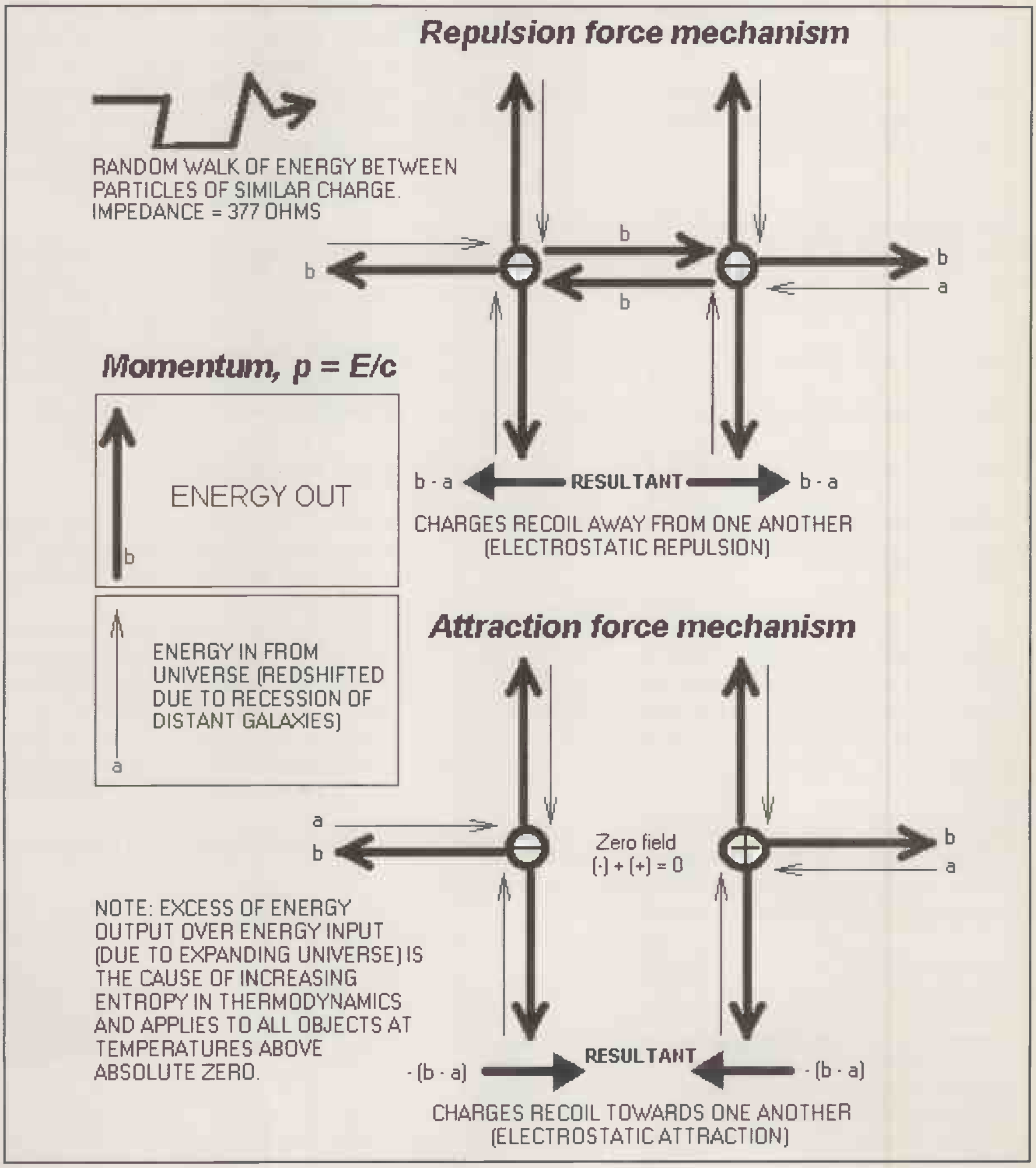


Fig. 3. The mechanisms of electromagnetic forces.

energy as force multiplied by distance moved in the direction of the force ($E = Fd$) into this result gives us:
$F = (1/c).(dE/dt) = 2\pi E^2/(hc) = 2\pi(Fd)^2/(hc)$.

Because this result contains F on both sides, we must cancel terms and rearrange, which gives us the strength of the strong nuclear force at short distances:

$F = hc/(2\pi d^2)$.

This result is weaker than stronger than Coulomb's law of electromagnetism by the ratio $2hc\varepsilon/e^2$, which equals about 137.036. Therefore, we have the explanation for the traditionally mysterious constant of physics, 137.

The weak nuclear force consists basically of Coulomb's force law of electromagnetism, with a 10^{-10} multiplication factor for the beta radioactivity of free neutrons. This factor is given by $\pi^2hM^4/(Tc^2m^5)$, where h is Planck's constant from Planck's energy equation $E = hf$, M is the mass of the proton, T is the effective energy release 'life' of the radioactive decay (i.e. the familiar half-life multiplied by $1/\ln 2 = 1.44$), c is velocity of light, and m is the mass of an electron. In beta radioactivity, neutrons decay into protons by releasing an electron (beta particle) and an anti-neutrino. The fact that the controlling force is smaller than the Coulomb force gives the name of the 'weak' force. It is still very much stronger than gravity.

Electromagnetic forces are caused by a continuous (non-quantum) electromagnetic energy emission and reception at the speed of light. Electric attraction is caused by opposite charges blocking the reception of energy from each other's direction, and so recoil towards one another, due to receiving energy from every other direction. Repulsion is caused by similar charges which exchange more energy than they receive from the expanding universe around them, so they recoil apart (the momentum, p, delivered by electromagnetic energy is: $p = mv = mc = E/c$, from $E = mc^2$).

A continuous electromagnetic energy transfer in theoretically static situations would lead to equilibrium, with no net gain or loss of energy, but the big bang universe is expanding. The energy input from distant receding charge is red-shifted. This energy exchange process is distinct from the quantum theory of radiation which explains thermodynamics. In 1792 Prevost had first introduced the modern thermodynamic idea that all objects at constant temperatures are in a thermal equilibrium, receiving just as much energy as they radiate to the surroundings. The expansion of the universe disturbs the thermal equilibrium between galaxies by red-shifting energy, which is why less energy is received than is radiated into space, providing a useful heat sink.

Fig 3, using the principle that energy exchange transmits momentum, proves the mechanism behind electrostatic attraction and repulsion, and proves that the magnitude of the attractive force is equal in magnitude to that of the repulsion force. The impedance of the fabric of space in the vacuum is 377 ohms, not ohms/metre. So there is no attenuation with distance. Hence, the force of electromagnetism is numerically the same as the gravity mechanism already explained, multiplied up by the statistical vector summation, a random-walk (mathematically similar to molecular diffusion) of energy between all of the surrounding charges.

In the universe there are N particles distributed randomly in spherical symmetry around us, so the contribution from each particle in the universe must be added together. The distance of greatest contribution is near the outer edge of the universe where both the recession speed and number of particles is greatest and also most symmetrical around us. The contribution from nearby objects is insignificant. Hence, the forces of electromagnetism are equal to the attractive force of gravity for each particle, multiplied up by a factor which allows for the number of particles in the surrounding universe.

Since opposite charges block each other (by cancelling each other's field), we find that there can be no straight-line addition because the continuous mode TEM wave in a straight line will encounter equal numbers of positive and negative charges in the universe, which will block each other, statistically cancelling out.

Instead, the continuous mode TEM wave has an effective power due only to travel along a 'random walk' between particles of similar charge in the universe. This situation must therefore be analysed by random walk statistics, which for N particles contributing equally and distributed in space in perpendicular directions x, y, and z, predicts a vector sum by Pythagoras' theorem (assigning the 50% of energy contributions towards us a positive sign in the expansions of the brackets, and the 50% which are away from us are assigned a negative sign, which means that the 3 given by the expansion for each original term in brackets cancels down to just 1 term per particle):
$[X/(\text{gravitational acceleration})]^2 = (1_{x1} + 1_{x2} + \ldots)^2 + (1_{y1} + 1_{y2} + \ldots)^2 + (1_{z1} + 1_{z2} + \ldots)^2 = N$. Hence, $X = (\text{gravitational acceleration}).N^{1/2}$.

N can be calculated from the know density of matter (average mass of a star, multiplied by the number in a galaxy, divided by the average volume of space which each galaxy has to itself; which gives density, and this is multiplied by the volume of a sphere with a radius equal to the distance travelled by light during the age of the universe; which roughly gives the entire mass of the universe, and this in turn is divided by the mass of a hydrogen atom to give the number of particles of either charge because about 90% of the mass of the universe is hydrogen; the final result is 10^{80} particles, so $N^{1/2}$ is about 10^{40}, which is indeed the factor we need).

The ratio of electromagnetic to gravitational force is thereby proven to be $N^{1/2}$, where N is the number of like charges in the universe. Calculation proves that this rigorous theory is correct, giving us unified electromagnetism and gravity. The electric charges which participate in electric attraction and repulsion are those on the outside surfaces of conductors, since the electromagnetic radiation which produces the forces by delivering momentum cannot penetrate conductors. This is the reason why gravitation, being due to the dielectric pressure, affects all the subatomic particles in the entire internal volume of an object composed of atoms, whereas Coulomb's law is found to only apply to the outer 'charged' surface layer of atoms.

Deriving the basic equations of electromagnetism

'From a long view of the history of mankind – seen from, say, ten thousand years from now – there can be little doubt that the most significant event of the 19th century will be judged as Maxwell's discovery of the laws of electrodynamics. The American Civil War will pale into provincial insignificance in comparison with this important scientific event of the same decade.' – R.P. Feynman, R.B. Leighton, and M. Sands, *Feynman Lectures on Physics,* vol. 2, Addison-Wesley, London, 1964, c. 1, p. 11.

James Maxwell translated Faraday's empirical law of induction into the mathematical form, $\text{curl}.E = - dB/dt$. Here, E is electric field, B is the magnetic field, t is time, and 'curl.E' is a simple mathematical operator: it is the difference between the gradients (variations with distance) of E in two perpendicular directions. It is evident that curl.E can be constant only if the electric field line has a constant curvature, a *circular* shaped field line, from whence the vector operator's name 'curl.' This is why electric generators work on the principle of varying magnetic fields in coils of wire.

Maxwell then sought to correct Ampere's incorrect law of electricity, which states the strength of the magnetic field curling around a wire is simply proportional to the current, I: curl.B = μI, where μ is the magnetic constant (permeability). He realised that a vacuum-dielectric capacitor, while either charging or discharging, constitutes a physical break in the electric circuit.

He tried to explain this by studying capacitors with a liquid dielectric. Particles of the liquid, charged ions, drift towards oppositely charged capacitor plates, creating a 'displacement current' in the liquid. Maxwell naturally assumed that the fabric of space permits a similar phenomenon, with virtual charges forming a displacement current in a vacuum. He therefore decided to add a term for displacement current of his own invention to the current I in Ampere's law to correct it: curl.B = μ(I + ε.dE/dt). So Maxwell's equation for displacement current is the rate of change of electric field (dE/dt) times the electric constant (permittivity). Before I start applauding Maxwell for either physical or mathematical insight, it is worth considering historian A.F. Chalmers' article, 'Maxwell and the Displacement Current' (*Physics Education*, vol. 10, 1975, pp. 45-9).

Chalmers states that Orwell's novel *1984* helps to illustrate how the tale was fabricated: "history was constantly rewritten in such a way that it invariably appeared consistent with the reigning ideology."

Maxwell tried to fix his original calculation deliberately in order to obtain the anticipated value for the speed of light, proven by Part 3 of his paper, On Physical Lines of Force (January 1862), as Chalmers explains: 'Maxwell's derivation contains an error, due to a faulty application of elasticity theory. If this error is corrected, we find that Maxwell's model in fact yields a velocity of propagation in the electromagnetic medium which is a factor of $2^{1/2}$ smaller than the velocity of light.' It took three years for Maxwell to finally force-fit his 'displacement current' theory to take the form which allows it to give the already-known speed of light without the 41% error. Chalmers noted: 'the change was not explicitly acknowledged by Maxwell.'

Maxwell never summarised the four so-called 'Maxwell equations.' He produced chaos with hundreds, and it took the mathematician Oliver Heaviside to identify them. Here they are (the divergence operator is just the sum of the gradients of the field for each perpendicular direction of space):

curl.B = μ(I + ε.dE/dt) (A combination of Ampere's and Maxwell's equations)
curl.E = - dB/dt (Faraday's law of induction)
divergence.B = 0 (Magnets' opposite poles have equal and opposite fields, cancelling one another)
divergence.E = ρ/ε (Gauss' law which is just the electric field version of Coulomb's force law, ρ is the charge density).

The crucial two curl equations have never been explained or derived before. This can be done this using Catt's discovery that the fundamental entity of the universe is the eternally c-speed transverse electromagnetic (TEM) wave, which has the simple property: E = cB. I emailed my derivation to Catt's co-author Dr David Walton, who agreed with the mathematics. Start by taking the curls of both sides of E = cB and its equivalent, B = (1/c).E, giving:

curl.E = c.curl.B
curl.B = (1/c).curl.E

Now, because any field gradient or difference between gradients (curl) is related to the rate of change of the field by the speed of motion of the field (eg, dB/dt = –c dB/dr, where t is time and r is distance), we can replace a curl by the product of the reciprocal of –c and the rate of field change:

curl.E = c [–(1/c)dB/dt] = –dB/dt (Faraday's law of induction)
curl.B = (1/c) [–(1/c) dE/dt] = –(1/c^2) dE/dt

We can therefore see how the universe is controlled by the c speed TEM wave, eternally in motion, and eternally having both magnetic field B and electric field E related by E = cB. From this fundamental building block of the universe, springs electricity and the law of electromagnetic induction.

We also see that the speed c is actually the speed of electricity. What Maxwell thought of as being the exception to the rule (displacement current in a vacuum) is actually the rule: the normal mechanism of energy transfer in electricity, since a capacitor is a transmission line. Less than well informed teachers (see Feynman quotation above) like Nobel laureate Feynman, who never discovered the mechanisms for the forces of nature, have done useful mathematical work. However, Feynman is popularly quoted as saying that, because something has not yet been done, it will therefore always be impossible to do it: 'nobody understands quantum mechanics.'

This is most frequently quoted by the establishment researchers who squander tax-payers money on efforts to promote the mistaken results of their obfuscating mathematical trivia. Instead of using remarks like Feynman's to hold back progress, we should read them as being proof of the ignorance and apathy behind the equations. Readers of this magazine will know that I have for long been developing the force mechanisms based on Catt's nature of space (EW June 1999 and Jan 2001). It started out as an idea proven by the nature of physical space and its reaction to the big bang. A rigorous mathematical proof was then formulated. The first version was publicised through the letters column of EW in 1996, predicting specifically that the far reaches of the universe will not be slowed down by gravity, a year before Saul Perlmutter experimentally proved from supernovae red-shifts that this is indeed a fact. ■

Turnips and 1/f noise

Consider an agricultural scenario. Farmer Brown has a wheelbarrow, with some turnips in it. He passes the barrow once per hour. Every time he passes and according to random whim, he either removes a turnip from the barrow or adds one from an adjacent pile. Clearly, the total number of turnips in the barrow fluctuates; but what is the frequency spectrum of the fluctuation, and what is the best estimate of the number of turnips that will be in the barrow on Friday, today being Monday? Robert Craig discusses the deep-rooted problem

This doesn't sound much like a suitable subject for *Electronics World*. But it is an analogy of a very general situation, where the characteristic under examination is an accumulation of events, rather than a rate at which something happens. For instance, a leaky electrolytic capacitor might have a conductivity which depended on the total number of ions or sites available for conduction, that number coming and going with time. A reverse-biased diode might have a leakage dependent on the accumulation of electrons on crystal defects crossing the junction.

Returning to the farmer's barrow, **Figure 1** shows one possible behaviour for the farmer. The graph is up (positive) when he adds a turnip, and down (negative) when he takes one out.

Figure 2 shows the resulting accumulated number of turnips. [My farmer's allowed to have negative numbers of turnips.] The graph in Figure 2 is not unlike many an oscilloscope trace I've seen when things aren't as they should be. The next figure, **Figure 3**, shows the frequency spectrum (generated by Fourier transform) of the graph in Figure 2. You will see that this follows a 1/f rule quite closely. The lowest and highest frequencies which are meaningful are one cycle in the complete length of the Figure 2, and one cycle per two steps of the same figure. Figure 2 is based on one turnip per hour. One might envisage a faster rate of one turnip per microsecond; given 10,000 samples that corresponds to 100Hz to 500kHz.

The simulation can be extended to allow fractional numbers of turnips, rather than just one or minus one, to be added. **Figure 4** shows a set of Gaussian numbers of turnips, with mean 0 and standard deviation 1, and **Figure 5** shows the corresponding accumulation. Figure 4 now looks like - and is - white noise. Figure 5 looks very similar to the previous case, and has the same 1/f spectrum. Almost any process which depends on accumulation behaves similarly. A well-known example is a "drunkard's walk". The usual example allows the drunkard to move in two dimensions, but a simpler case is where he is confined to a corridor. He takes steps

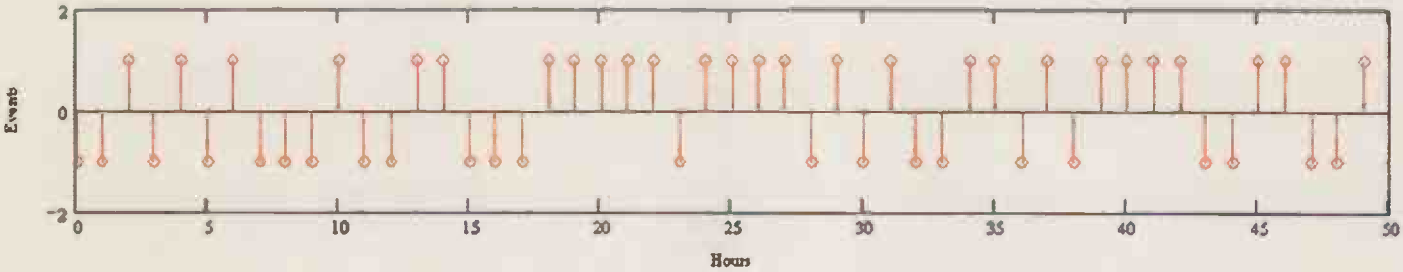


Fig. 1. Binary incidents.

randomly forward or backwards, his distance from the starting point looking like Figure 2. In the 2D random walk case, if we consider say the x-component of his position, we get something like Figure 4. In both cases, the frequency spectrum of a graph of distance versus time is 1/f.

Realising the link between 1/f noise and random walks leads to some useful though depressing conclusions. In most situations where noise is involved, we can reduce the noise by averaging over a number of samples to arrive at a truer value of the signal than that derived from

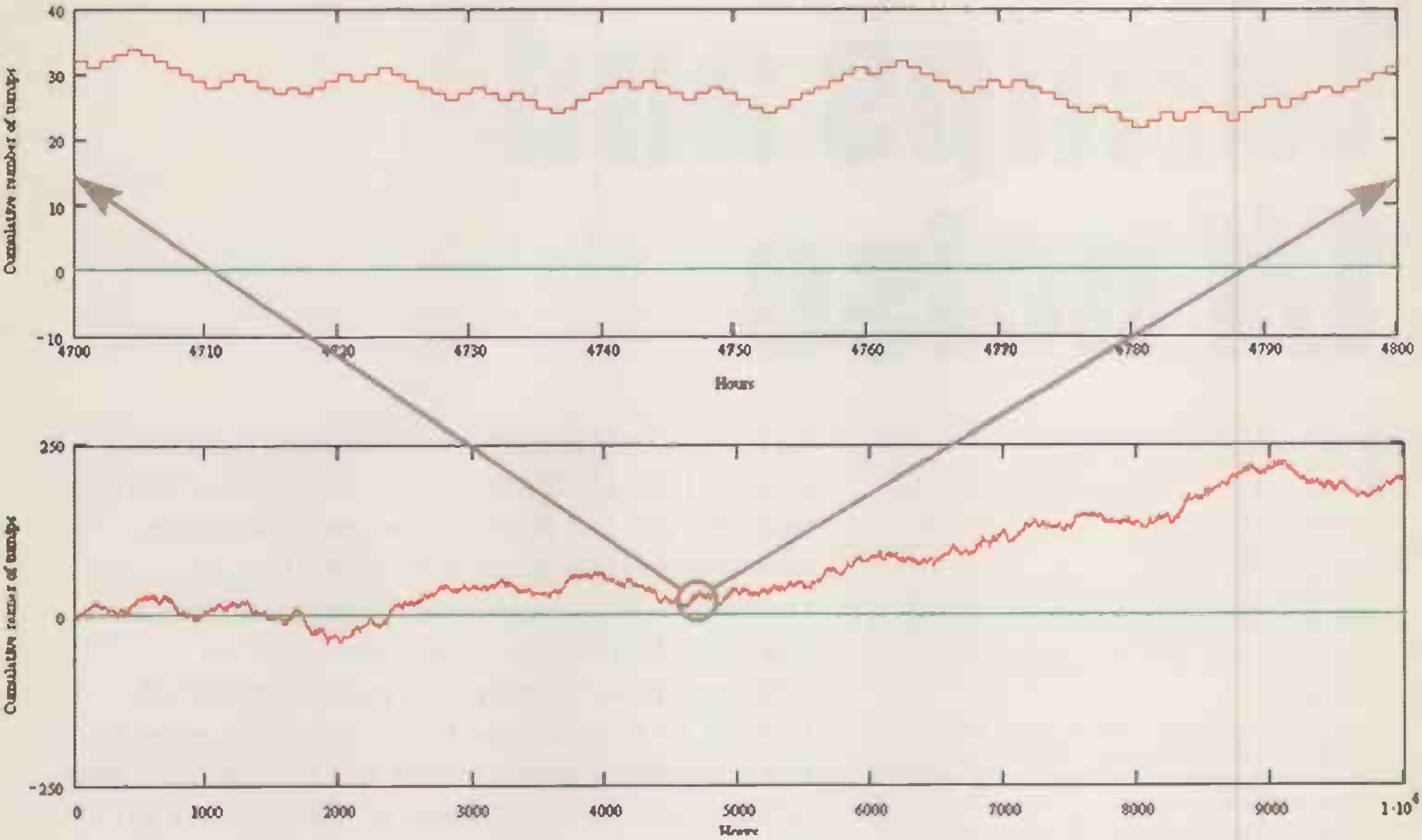


Fig. 2.

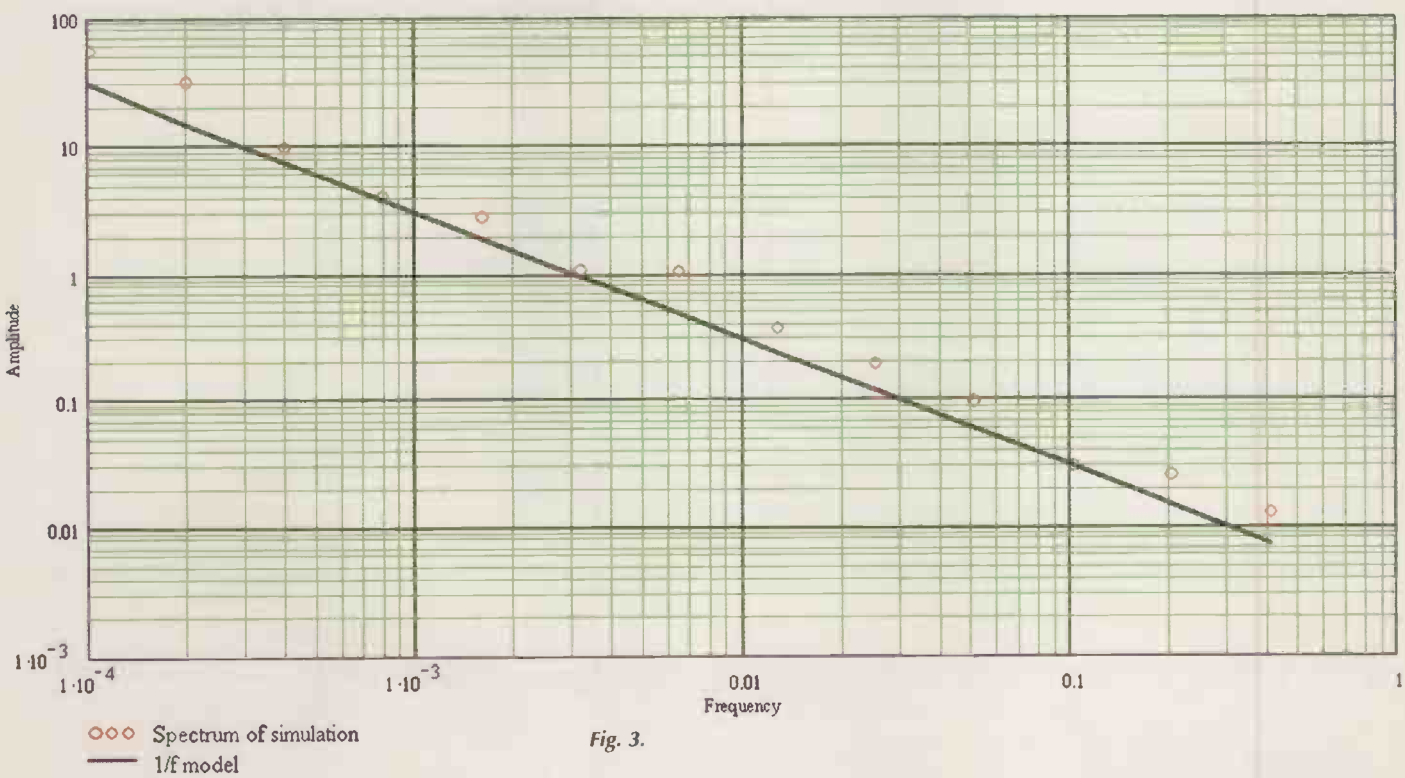


Fig. 3.

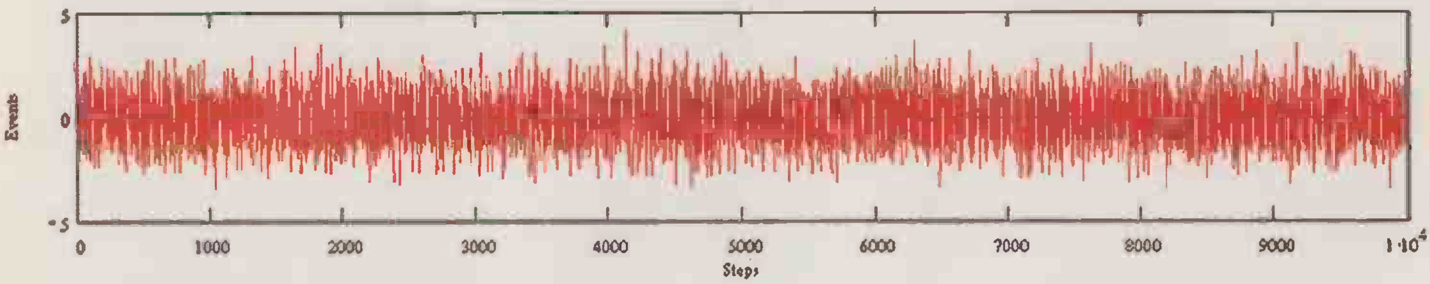


Fig. 4. Gaussian incidents.

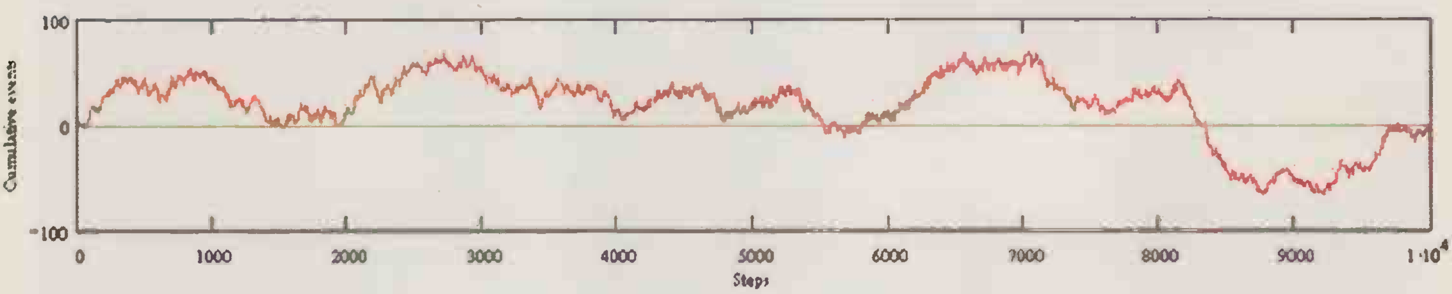


Fig. 5. Cumulation of Figure 4's gaussian incidents.

one sample. But 1/f noise is an indication of a random walk. If we're trying to estimate the number of turnips in the barrow on Friday, knowing the number of turnips now, information about how many there were yesterday, or an hour ago, is valueless. The best guess about Friday's situation is the current number. The only way of obtaining a better estimate is to wait until nearer Friday.

It is however possible to make an estimate of how wrong our guess is likely to be, and how the estimate will improve with time. **Figure 6** shows half-a-dozen random walks starting at the same point. It is obvious that the spread of outcomes increases with time. This is investigated further in **Figure 7**, which shows how the RMS spread of a particular set of 1000 walks increased with time. It will be seen that this increase goes as √time. In general, the RMS spread is the mean step size times the square root of the number of steps. So if there at 200 turnips in the barrow today, and 36 working hours until Friday, the best guess as to Friday's turnips is 200 ±6.

Leaving the analogy and returning to electronics, the lesson is that where 1/f noise is around, one should always work at the highest possible frequency. That is, one should depend on the characteristics of the components for the shortest possible time. In my own field of thermal imaging, there are serious problems with 1/f noise from the detectors used. The low frequency noise is hidden from the user by clamping or DC restoring the signal as frequently as possible, preferably after every scan line. The same technique is used on analogue TV systems.

Readers should be aware that the description above of the link between a particular random process and a corresponding 1/f noise covers only one possible (and very simple) scenario. This scenario of a drunkard's walk (otherwise known as Brownian motion) corresponds to an "infinite memory" process, contrasted with a white-noise or "zero-memory" process. Brownian motion gives a 1/f amplitude or $1/f^2$ power spectrum, whereas white noise gives a flat spectrum. Real-life situations are often intermediate, and traditionally, "1/f noise" refers to a spectrum which is 1/f in terms of power. The subject is treated more rigorously and in more depth in, for instance, *M. J. Buckinham, Noise in Electrical Devices and Systems, Ellis Horwood 1983*. I haven't been able to track down a more recent textbook. More recent papers are *Kaulakys, Physics Letters A, 257 (1999) 37* or *Wolf, Proceedings of the Fifth International Conference on Noise, Bad Nauheim (1978) 122*. The latter has a good list of historical references. ■

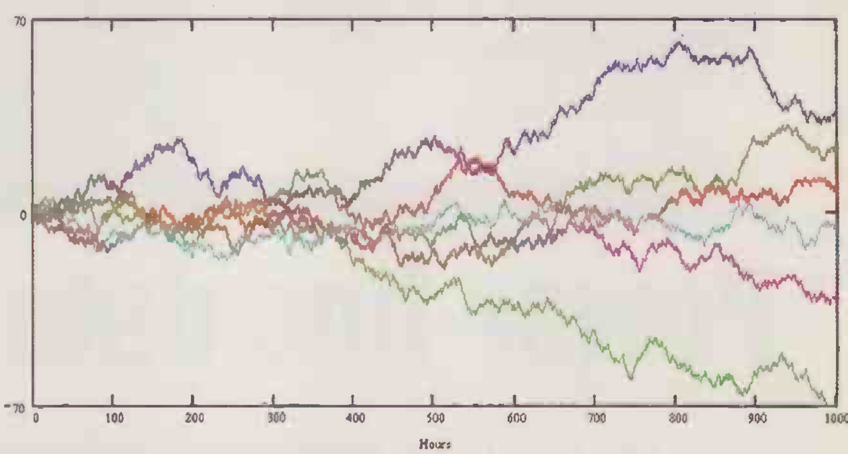


Fig. 6. Random walks diverging with time.

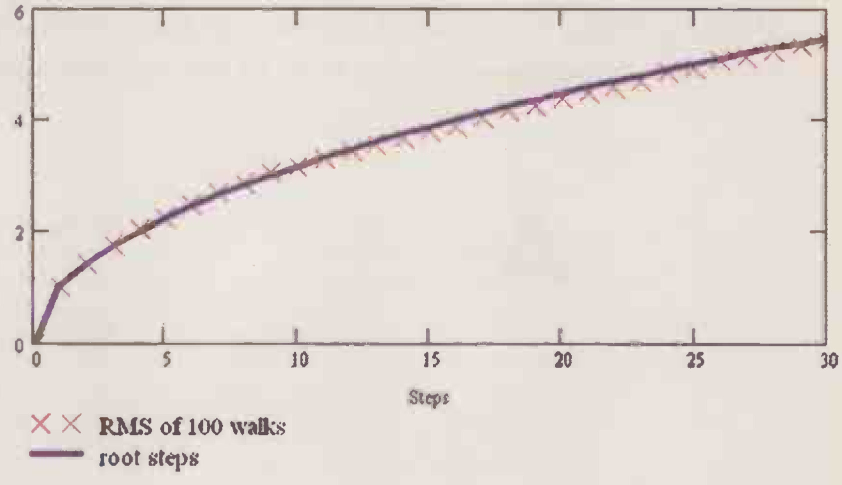


Fig. 7. Spread of many random walks √time.

Power-line data distribution

For the past fifteen years the telecommunications and electricity supply industries have been collaborating on ways of transmitting broadband signals via the mains distribution network. J. LeJeune takes a look at the current state of the art

Attempts to use the mains electricity supply for communications purposes have been made since the early Twenties, when a radio programme was distributed as base-band audio over the DC supply in a small town near Plymouth, Devon. Large chokes at each dwelling prevented domestic appliances being affected by the audio, and the audio signal being shunted away by electric cookers, bowl fires and the domestic lighting. The transition to AC made this scheme impossible, and systems using a carrier were tried as an alternative.

Carrier systems

Sending a carrier signal via the mains supply is problematical because of the high level of electrical noise present, the uncertain and varying impedance of the cables and high signal attenuation, particularly with older installations. Partially successful schemes have been used for years within the shell of a building – these are purely local systems. Many use FM, because of the high electrical noise levels that would affect AM transmission. Place an AM radio receiver close to electrical wiring to sample the kind of impulse noise that's present on the mains supply.

Items such as baby alarms, telephone extensions and remote-control extenders that use the mains wiring in a building are available. FM is suitable for small point-to-point services. The bandwidth required is very small, and the power output need not be excessive – and must conform to the prevailing regulations. Moreover FM circuitry is easy to implement, operate and repair.

Broadband distribution

For the past fifteen years the telecommunications and electricity supply industries have been collaborating on ways of distributing broadband signals via the National Grid, medium-voltage and low-voltage lines. Numerous companies are involved, and of late the results have been encouraging.

The main efforts towards achieving effective broadband communication via the mains supply have been carried out in the US, but research in

Europe has also been making progress. A successful system is up and running in Switzerland, providing customers of the Freiburgischen Elektrizitatswerken with internet access. Much of the information available is hazy, probably to preserve a measure of security. If the technology succeeds in achieving reliable transmission over the grid system, the power companies will have an enormous network at their disposal.

The Swiss company Ascom is involved in some eighty projects around Europe. Its manufacturing facility turns out in excess of 6,000 adapters and 2,000 items of network hardware a week. Norweb has conducted a trial via medium- and low-voltage lines in the UK. The results of the Norweb experiment indicated a problem with radiation from street lighting standards! Work on the project seems to be divided into two, with some companies focusing on the medium- and low-voltage lines while others concentrate on long-haul communication via the National Grid.

Advanced technology

Media Fusion in the US has patented a system based on quantum physics. It could provide multiple paths for data communication, with maser amplification and inductive power-line coupling, operating at frequencies between 30-24,000GHz. The technology is based on the premise that in a magnetic field there are numerous quantum wells by which signals can be transmitted. Supercomputers sited at strategic points in the network would supervise the alignment of the power grid's field. Negative elements in the quantum well are aligned by the computer so that they push positive protons into collision with one another, thus propagating signals along the lines over thousands of kilometres.

Work is proceeding to find a satisfactory method of inductive coupling to the power cables and, at this early stage, computer-aided magnetic alignment is only a theory waiting to be proved. The control of such a network, signal routeing and level adjustment remain unanswered questions. The signals also require processing to convert them into usable ones such as 10baseT Ethernet. Data identification and error-correction techniques remain to be studied. Processing via a "reduced Coulomb energy network" is proposed. The signals bypass transformers, and could be sent over great distances with low attenuation. Maser amplification (the m stands for microwave, the rest being as in laser) would provide very low-noise signal boosting.

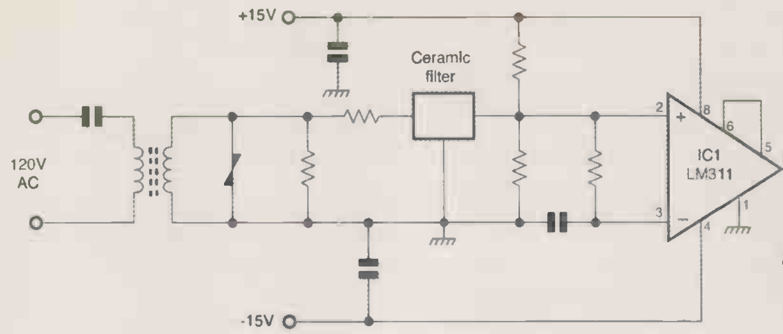


Fig. 1: A suggested power-line communications receiver front-end.

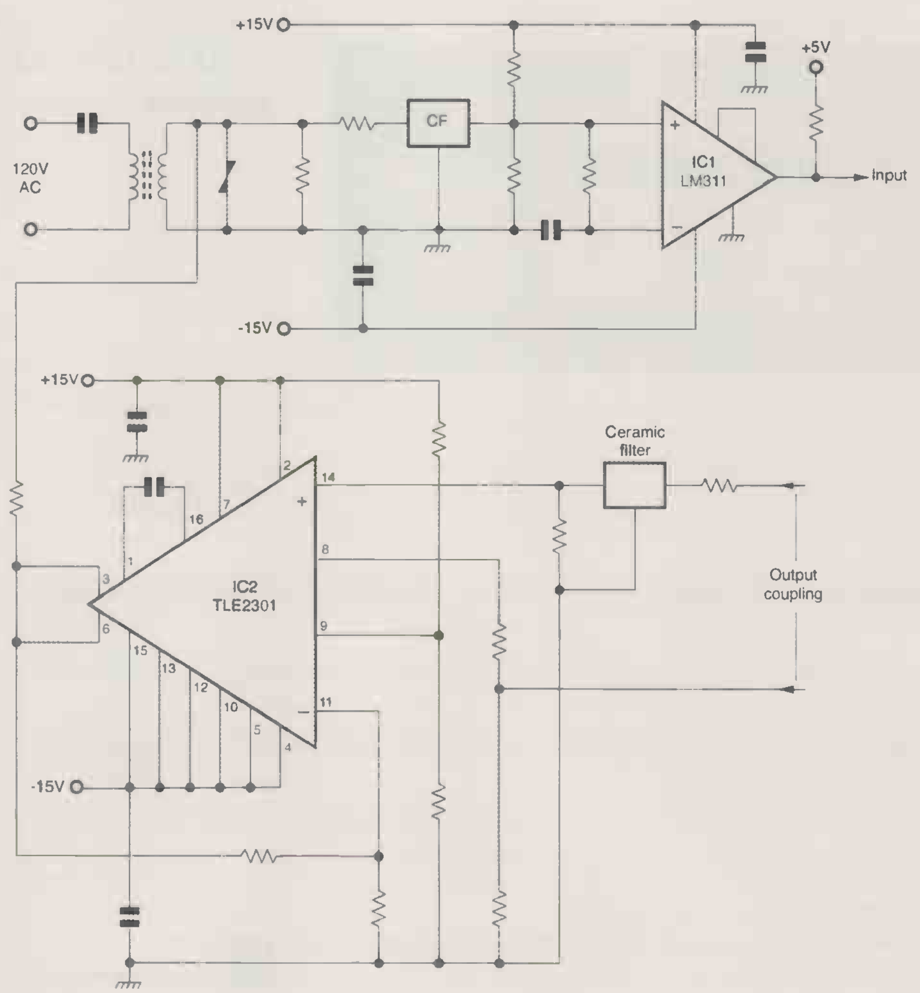
Users of this type of technology would retrieve signals from the power grid via filters composed of shaped polymer electromagnetically-coupled material. The cost of such filters is likely to be very high initially, but mass production would bring the price down to a few dollars each.

One could be forgiven forthinking that this is largely science fiction, but those working on the project seem to be very optimistic. Ambient Corporation of Massachusetts also has its own technology, and claims that it is ready for use when the market climate improves. This company is also coy about its system, but it is known to involve capacitive coupling to the cables by means of a clamping arrangement. Ambient claims to be able to provide an "end-to-end" solution, from the electricity sub-station to the subscriber's premises.

Local lines

Local lines are already being used for communication at speeds up to 1Mbits/sec in each direction. Coupling to the mains at the customer's end is made at the supply side of the meter, using 10baseT Ethernet to communicate with base

Fig. 2: A suggested power-line communications transceiver front-end.



stations. These forward the data over an ATM (Asynchronous Transfer Mode) network to main stations. The customer's computer is coupled via its USB port to a Nortel DPL1000 communications module, which is rather like a cable TV modem and is used to couple RF signals to the power lines.

The base station combines data from a number of communications modules and sends it over a link, either wireless, coaxial or fibreoptical cable. Work is in progress on video streaming, videophones, internet access, pay TV and high-speed data transmission. A rate of 4·5Mbits/sec is now becoming possible. It should be increased to 20Mbits/sec in the near future.

Noise

The principal problem with power-line communications is noise. There are four main forms:

(1) Impulse noise synchronised to the mains frequency.

(2) Non-synchronous noise with a broad spectrum, e.g. hash from commutator motors.

(3) Random single-event impulses from thermostats and manually-switched loads.

(4) Non-synchronous but periodic noise, e.g. from switch-mode power supplies, electronic lamps etc.

Noise that originates close to a communications module is particularly troublesome. The incoming data signal may be heavily attenuated by the intervening cabling but the noise, from close by, is not. It's easy for the signal-to-noise ratio to fall below the capabilities of the receiver, disrupting the service.

Signal coding is the obvious way of overcoming the problem. Of several types of coding available a form of forward error correction, which will familiar to those who have read up about MPEG-2, seems to be the most promising. Adaptive coding, in which an intelligent transmitter changes the type of coding in accordance with conditions, would also be useful but has been ruled out for the present because of the erratic nature of changes in conditions.

Circuitry

Hardware details of the systems proposed are very difficult to find. However suggested circuits for a power-line communications receiver and transceiver have become available, see Figs. 1 and 2. Both circuits are for the front-end only. Decoding and data-processing circuitry can vary markedly from one manufacturer to another.

In conclusion

Power-line communication is very much a developing technology, though the use of the mains supply for such purposes is far from new. Signals are present on the national grid: power control and switching data is transmitted over it – the signals can be picked up by a long-wave receiver close to some lines.

Once the technology is right, a whole new chapter in telecommunications will open up. ■

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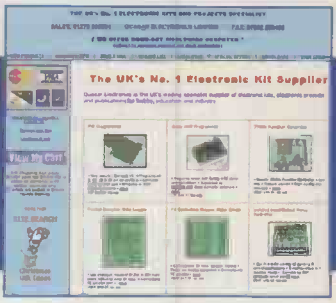

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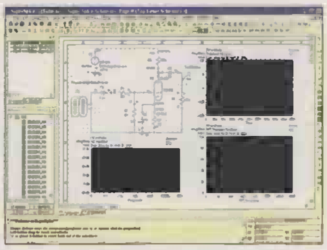

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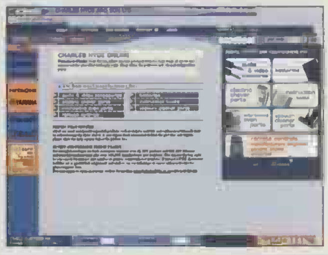

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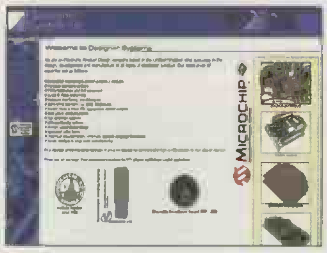

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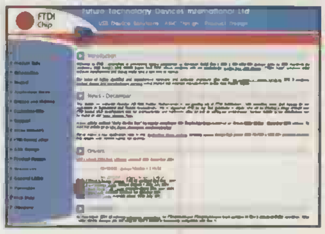

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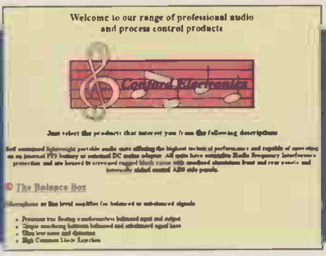

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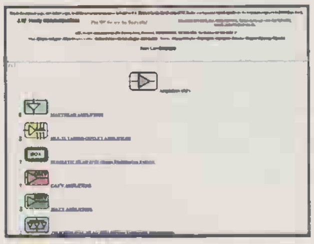

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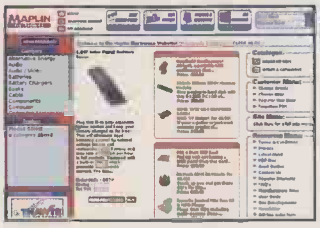

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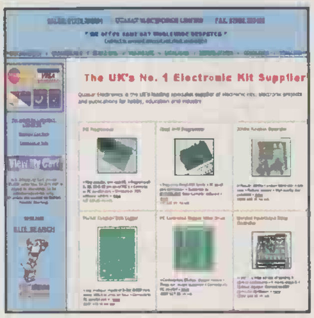

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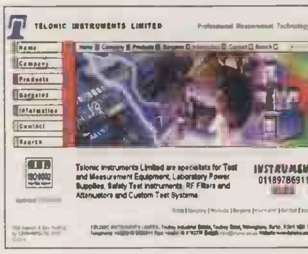

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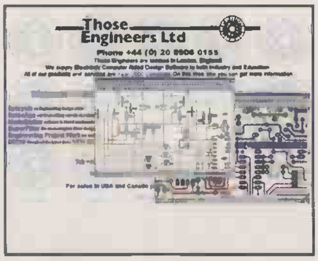

Working evaluations of SpiceAge mixed-mode simulator, Spicycle PCB design tools and Superfilter demo (synthesises passive, active, digital filters). Tech support, sales links and price list.

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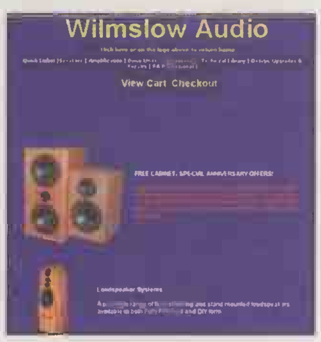

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Megger RM215/ L/2 Breakdown Leakage Tester	1250	39
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HP 1660AS 500MHz Timing/100MHz State 136Ch Logic Ana	4950	179
HP 1661E 500MHz Timing/100MHz State 102Ch Logic Ana	4950	149
HP 1662A 500MHz Timing/100MHz State 68Ch Logic Ana	2900	105
HP 1662AS As above 68Ch Logic Ana c/w DSO	4500	135
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Schlumberger 7150+ 6.5 Digit Precision Multimeter	395	29
Thandar 1604 4.75 Digit Digital Multimeter	395	29
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HP 8719D/010/085/089 13GHz Vector Net Ana c/w S Param	23000	828
HP 8753A/010 3GHz Vector Network Analyser	3950	119
HP 8753B/006 6GHz Vector Network Analyser	6500	195
HP 8753ES 3GHz Vector Network Analyser c/w S Param	16950	508
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Various Active probes from	650	28
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HP 54645D/101 2 Channel 100MHz 200MS/s + 16 Ch LA	2950	107
Kikusui COM7201 4 Channel 200MHz Digitising Oscilloscope	2350	70
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HP 8131A 500MHz High-speed Pulse Generator	6500	234
HP 8133A 33-3000MHz Pulse Generator	16500	594
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Advantest R9211A 100KHz Dual Channel FFT Analyser	2950	99
Anritsu MS2602A/01/04 100Hz-8.5GHz Spectrum Analyser	8950	269
Anritsu MS2711A/05 3GHz Portable Spec Ana c/w Pwr Meas	4250	128
Anritsu MS610B 2GHz Spectrum Analyser	2650	85
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