Electronics World's renowned news section starts on page 4

ELECTRONICS WORLD

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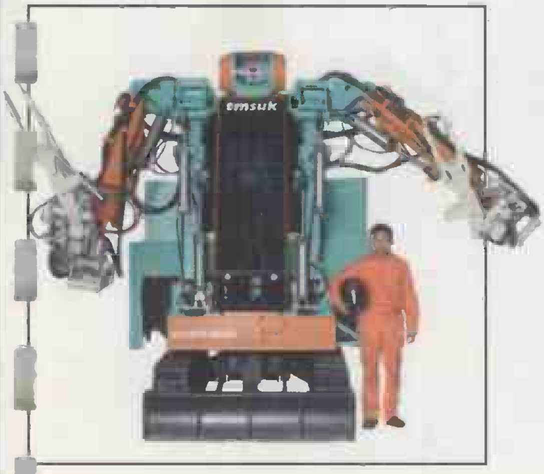
Cellphone access methods

Pseudo-sine wave inverter

USB analogue i/o

The discovery of electron diffraction



Circuit ideas:

- Leakage current jig
- Digital dice
- Analogue phase shifter

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Ghosts

From time to time, ghosts come back to haunt me, arising from articles I have written in the past. For example, the Editor recently forwarded to me an interesting query about "The MOS controlled thyristor", an article which appeared in these pages in the September 1993 issue. Other such ghosts have surfaced from even further back; my first contribution to these pages – a Design Idea entitled "Two for the price of one" – was back in about 1970, a useful circuit although I no longer have a copy of it as published. It's not just from articles either. Occasional queries arrive, triggered by people reading my books, particularly the one titled "Oscilloscopes"†. This was first published in 1981, is now in its fifth edition, and has never been out of print.

These "ghosts" are always interesting, and originate from readers just about anywhere, France, India, Australia, the USA among other places, all come to mind. They often set me thinking even further back over a career in electronics spanning half a century, to days – for example - spent servicing AI10 units. Airborne Interceptor Mk10 was an airborne radar which saw service during the Second World War, still in service with the RAF's Gloster Meteor NF11 night fighters in the mid fifties, although by then hopelessly out of date. The American "doorknob pentodes" in the IF strip were unobtainable by then, explaining the pilots' routine complaints of low sensitivity.

A couple of years later found me at The Central Research Laboratories of The G.E.C., in the days when that company's motto was "Everything Electrical". The labs were much later renamed "The Hirst Research Centre", and have now disappeared off the face of the earth, to be replaced by houses, shops and what-have-you. It was, in its heyday, an extraordinary institution, where Ph.D.s were two a penny, and a carefree university-student atmosphere pervaded the buildings. There, at one stage, I had access to a diffusion furnace, and stayed behind one evening to make myself a silicon rectifier. This was for a mains power supply for my home-made battery portable radio, using DK96 series valves with their 25mA filaments. They were happy days, when petrol cost four shillings (20p) a gallon, and - following WWII – things could only get better. Some of the extraordinary activities and characters at the CRL of the GEC in those days would doubtless be of interest to, and probably even strain the credulity of, a later generation, but space dictates that any such reminiscences must await another occasion.

† ISBN 0 7506 4757 4
Newnes/Butterworth-Heinemann

Ian Hickman

All change

Thanks to Ian for the leader – I thought it time that someone else should have a go!

I'd like to let you know of some staff changes here at *EW*.

Firstly, my sincere thanks to Alan Kerr who has been laying out *EW* for years and has now decided to pursue a freelance career. And so we welcome Jane Massey and wish her all the best in her new job. This issue is her first 'solo' run!

I'd also like to thank Geoff Arnold for all his proofing work over the years; sadly Geoff is retiring from *EW*, even in his retirement! We wish him good luck for the future. And on that note, if anybody thinks that typos in *EW* are too frequent – let me know if you think you could do the (part time) job.

Phil Reed

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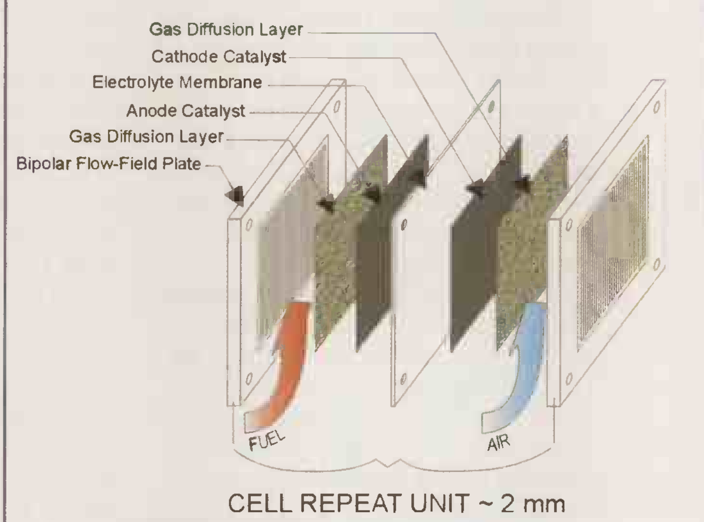
Diverse technologies cut fuel cell drawback

CMR Fuel Cells, a Cambridge-based spin out from Scientific Generics, has a novel fuel cell structure which side-steps cell membrane leakage.

The compact mixed-reactant cell, from which the company gets its name, uses selective electrodes to remove the need for fuel and oxidiser to be separated. In fact, it needs them to be mixed.

Membranes in conventional cells separate fuel and oxidiser and have to be thicker than electrically necessary to cut unwanted fuel leakage into the oxidiser side. "Ours can be much thinner," CMR founder Michael Priestnall told *Electronics World*, "and in principle could be a coating on one catalyst or the other. Just enough to provide electrical insulation."



The CMR design also saves space. In conventional fuel cells, fuel and oxidiser flow across opposite faces of a membrane. This needs flow space, and a baffle to stop the fuel from one cell mixing with the oxidiser from the next. These extra part eat-up volume in cell stacks.

In the CMR cell, a mixture of fuel and oxidant flows through a fully porous anode-electrolyte-cathode assembly, then straight on to the next similar assembly.

Each time, the mixture first meets a fuel-selective catalyst which splits H^+ ions from the fuel. These are absorbed straight into the membrane which conducts ions, while being electrically insulating - preventing electrons flowing back and shorting the cell out, and porous to the mixture.

When the mixture exits the membrane it meets an oxygen-selective catalyst which combines oxygen and the H^+ ions to make water.

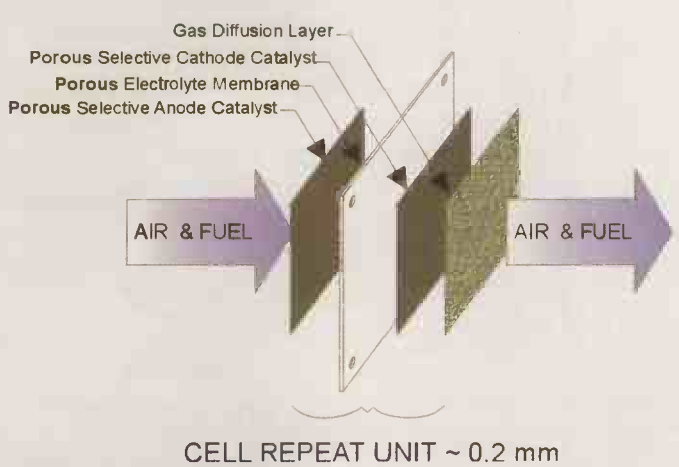
The catalysts are conductive and, as previously mentioned, the membrane is insulating, forcing electrons from the reactions to travel around any external circuit. As it passes each membrane fuel and oxidiser are gradually used up.

By stacking a porous carbon layer between each membrane assembly, the potential from all the cells in a stack can be added for a higher output voltage. Carbon cannot carry H^+ ions and will therefore block any ionic short circuits.

The technology is applicable to most fuel cell chemistries, claims the firm, including the 'direct methanol' types proposed for phones and laptops.

However, it is only applicable to active fuel cells which include oxidiser and fuel pumps, and not passive fuel cells which have a tank of fuel on one side of a membrane and the atmosphere on the other for oxygen – see the box.

Conventional fuel cells (top) have to have sideways flow and therefore need baffles. The flow-through CMR design can be thinner.



Fujitsu Laboratories has developed a material that allows highly concentrated (30 per cent) methanol to be used in passive fuel cells.

"This technology enables much higher power capacities for passive micro fuel cells and realises longer run-times for mobile devices such as notebook PCs, PDAs and mobile phones," said Fujitsu.

Fuel in conventional fuel cells has to be dilute or much of it will leak across the cell membrane and uselessly combines with the oxidiser - for an exception, see the CMR fuel cell article.

Passive systems are simple and lightweight as they have no pumps, but without pumps they cannot self-dilute fuel using waste water, so they have to be fed bulky dilute fuel.

The answer, according to Fujitsu, is a less porous alternative to the standard fluorinated polymer membrane. Its membrane is an aromatic hydrocarbon covered with a high density of platinum-based nano-particle catalyst with methanol blocking properties.

"This reduces the total methanol crossover effect to one-tenth that encountered with typical fluorinated polymers," said the firm.

An industry insider told Electronics World that the Fujitsu development, unlike many proposed alternative membranes which rapidly self-destruct, looks promising, but would be expensive to produce.

The prototype pictured is 15mm thick and delivers 15W.

Japanese to English speech translation

NEC claims to have made a robot capable of bi-directional Japanese-English speech translation.

The translator has been built into the firm's prototype PaPeRo personal robot.

"In order to realise an operable robot capable of conversation with a translation function, small memory and compact translation software are necessary," said NEC. "Through the development of a compact, high-speed speech recognition system NEC succeeded in installing this function in the small robot."

The robot has been programmed with 50,000 Japanese and 25,000 English travel and tourism related words.

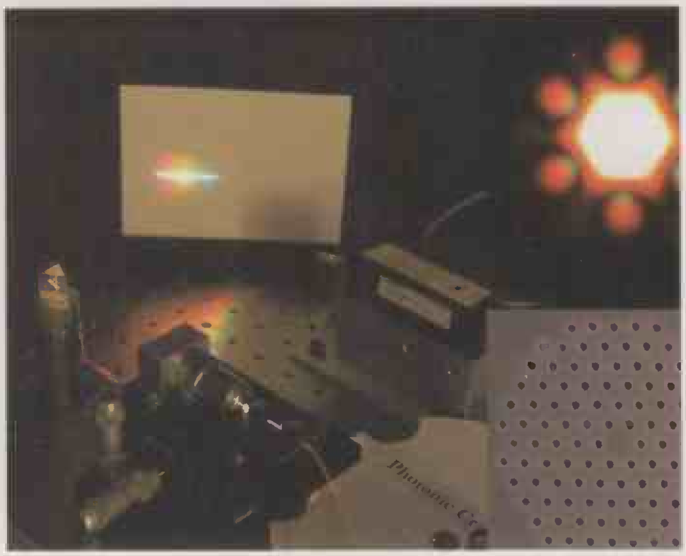
At the moment a microphone is necessary. "NEC will continue to work on this system to enable hands-free [microphone-free] voice input."

PaPeRo is at: www.incx.nec.co.jp /robot/ robotcenter_e.html

Robot to the rescue

Enryu HyperRescueRobot is a 3.45m tall machine from Japanese firm Tmsuk - better known for personal robot 'friends' and mobile security camera platforms. Weighing 5,000kg, Enryu can span 10m with arms outstretched and move at up to 3km/h. The operator sits inside or can work it remotely. Power comes from a built-in diesel engine. See www.enryu.jp for a video.

Light spreader



A UK firm has used a photonic crystal fibre to develop a broadband light emitter called an optical supercontinuum.

BlazePhotonics from Bath said the special fibre optic cable takes narrowband light from a solid state laser and outputs light covering an octave or more.

The input at 1,060nm, typically from a Neodymium laser, is turned into light from 550nm (green) to 1,600nm (infra-red). This light could be very useful in applications such as fibre characterisation and testing, optical coherence tomography, microscopy and chemical sensing.

Existing systems, such as superluminescent LEDs and pumped fibre lasers, are at least twice the price, said the firm.

The converter works due to non-linearity in the fibre and the presence of small sidebands in the input laser. These sidebands are amplified and spread, causing more sidebands which are themselves amplified.

If the fibre is long enough, about 20m, the output is a flat (within about 5dB) spectrum.

A photonic crystal fibre has microscopic air holes throughout the cladding of the fibre. Light can also be guided through a hollow core in some designs.

No-melt laser trims cheese

Xiaochun Li, a University of Wisconsin-Madison professor and laser expert, has adapted 'cold laser machining' to cut cheese. "The fast-food industry wants cheese that is still nicely shaped, but is cut very thin," said Li, "But when you cut cheese thinner it tears or sticks to the blade."

Li tried conventional commercial lasers, but they melted or burned the cheese.

However, ultra-violet lasers which cut by photo-ablation had no problems.

Unfortunately for cheese sculptors, UV lasers are expensive and the computer-driven prototype only cuts at 1mm/s.

Patents get re-invented

The Government has published its Patents Bill, aimed at encouraging innovation with better support for small businesses.

One of the key measures in the bill is the ability for the Patent Office to give an independent opinion on the validity or infringement of patents. This could avoid the need for costly litigation.

"Effective, flexible and up-to-date patent law is essential to help businesses turn bright ideas into successful products and processes," said Lord Sainsbury, Minister for Science and Innovation.

The bill would bring UK patent law into line with the European Patent Convention, making it easier for UK companies to operate across Europe.

It would also deter patent holders from making unreasonable allegations of infringement, said the Patent Office.

Lithium ion battery gets boost

Sanyo Electric is to raise production of its prismatic lithium ion batteries, with an electrode structure said to have better safety than standard Li-ion cells. The prismatic (rectangular) cells use a mixture of lithium cobalt oxide ($LiCoO_2$) and lithium manganese oxide ($LiMn_2O_4$) in the positive electrode.

The firm said reducing the cobalt in favour of manganese is good, as it is cheaper and more stable with heat, making it safer. However, $LiMn_2O_4$ has lower cycle and storage abilities.

Other firms working in this area include PolyStor which bases its cells on lithium nickel cobalt oxide ($LiNiCoO_2$) cathodes. The polymer construction technology is licensed from Motorola's energy systems group.

Sanyo's latest model, the UF553450L, has an 820mAh capacity, measures 50x34x5.5mm and weighs 19grams. Energy densities are 324Wh/l and 160Wh/kg.

Valve goes digital

A digital valve has been developed for medical applications by Camcon Technology.

The firm's design is bi-stable, and hence does not require power to hold its state. aThis low power operation would make it ideal for giving patients mobility while on medication.

"Until now, the medical sector has had to rely on big, energy inefficient and fixed installations," said Wladyslaw Wygnanski, inventor of the valve and MD at Camcon. "We hope that our cell battery operated bi-stable pinch valve will break the ground for medical solutions helping patients to be more comfortable and mobile as long as automatic flow controlling device is needed."

Camcon's design is formed from a magnetised armature held in position by permanent magnets. Coils placed around the ends of the armature can be briefly energised to disrupt the magnetic flux, allowing the valve to swing to its alternate position.

Reaction times of the armature are said to be under 100μs, while each switching action uses around 3mJ of energy. Devices have been tested by the firm running to billions of cycles.

Add a bit of colour to your life

The Vos Pad in London is claimed to be the only flat in the world solely lit by LEDs. Lighting company Vos Solutions fitted it out as a showroom. RGB LEDs fittings provide the light and can give almost any colour. www.thevospad.com

Europe gets behind fuel cells

The European Commission has established a hydrogen and fuel cell group to promote the technology. The EC aims to speed the development of fuel cell technology by coordinating international research efforts, both commercial and academic.

The initiative was described as "a milestone for hydrogen and fuel-cell stakeholders in Europe" by Romano Prodi, president of the European Commission.

"I am sure that it will be highly influential in bringing forward a radically new approach to the way we produce and use energy in Europe - and eventually worldwide," said Prodi.

The European programme will run for some ten years, drawing on ¤2.8bn in public and private money, said the EC.

Unfortunately the UK lags Europe and the US in research and development of fuel cell technology. DTI funding amounts to between £1m to £2m a year.

US spending on fuel cell research dwarfs UK and European efforts. At its height the US put $3bn into research in one year.

Europe already imports over 50 per cent of its oil, a figure set to rise.

"Current trends are clearly unsustainable. We have to act now in order to change them," said Prodi.

Chemicals etch holes in PCBs

Using chemical etching to make vias in printed circuit boards is a tenth of the cost of existing methods, according to CERN, the European particle physics lab.

CERN developed its chemical etching technique for internal use, but is now hoping to license the idea to PCB makers.

Called ChemicalVia, the process can be used to produce blind and buried vias in multi-layer PCBs.

This capability has, until now, been limited to manufacturers with equipment such as laser drills and plasma etching machines.

CERN, through its UK representative PPARC, said its licence fee of £15,000 was one tenth of the cost of existing equipment, while running costs are similarly reduced in price.

ChemicalVia can be used on polyimide boards such as Kapton or FR4. A layer of metal is epoxy bonded to the board, and the board is then patterned using photolithography then etched and cleaned using three chemicals.

A final metallisation process fills the vias in exactly the same way as the conventional process.

CERN's approach can produce vias down to 25μm in diameter, more than sufficient for the electronics industry.

Roll-up, roll-up for flexible displays

Philips Research in the Netherlands has produced a quarter-VGA, 320x240 pixel, monochrome display with a bending radius of 20mm.

The five inch panel is based upon an organic active matrix backplane just 25μm thick and containing 80,000 thin film transistors. On top of the backplane is a 200μm thick layer containing reflective electronic ink from US firm E Ink.

Philips said the shift register formed by the organic TFTs are the largest functional circuits ever made using this process.

The firm is spinning off a firm

called Polymer Vision to develop the roll-up displays. The firm claims it is already producing 5,000 displays of this type a year for research purposes.

Intel claims success with 90nm

Perhaps the first mainstream product manufactured using 90 nanometre (90nm) technology has gone on sale - the latest Pentium 4 processor from Intel.

The microprocessor firm described details of the device, codenamed Prescott, which squeezes 125 million transistors into a 112mm^2 die.

However, moving to such as small process as 90nm does not reduce power consumption in the same way as it reduces area. The firm had to reserve the smallest transistors - those with the highest leakage - for the critical paths in the design. This amounted to just one per cent of the total.

The processor also has double the on-chip cache memory at 1Mbyte. With its extra circuitry, memory and leakage, Prescott actually draws more power than its 0.13μm predecessor, with a maximum power of 115W.

At launch, the Prescott versions of Pentium 4 will clock at up to 3.4GHz, only marginally higher than existing devices. However, the smaller process gives it legroom, and Intel expects to reach 4GHz by the end of this year.

The firm also recently described core circuits for a 90nm processor operating at 10GHz, which would suggest Pentium 4 will scale to a clock rate of 5GHz.

LED headlights hit the road.

LEDs have made it into the headlight of a mainstream vehicle for the first time - as a daytime driving lamp.

Each headlight of the 12 cylinder Audi A8 6.0 uses five Luxeon LEDs from California's Lumileds Lighting.

"Our engineers have evaluated prototypes with many different LEDs," said Dr. Wolfgang Huhn, general manager of lighting for Audi. "Luxeon is the LED we believe is capable of performing in all capacities to the levels required."

All headlamp components, "including low and high beams, fog lamps and newer adaptive front lighting systems that contribute additional light while turning", can be made using LEDs claims Lumileds. And beam patterns which automatically

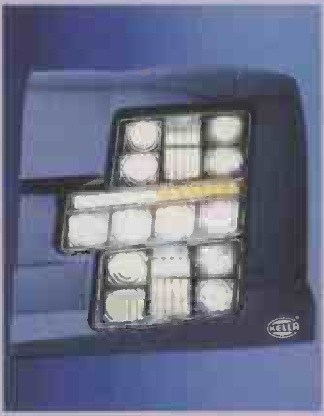
change for motorway, town and twisty will be possible, it said. This feature requires multiple LEDs programmed to angle and change intensity and has been mooted in concept vehicles including the Audi Nuvolari and LeMans, and Ford Model U.

Hella develop the Audi headlight, which also includes discharge lamps in what Hella calls a bi-xenon module.

Hella showed a fully LED headlamp at the IAA 2003 show in Frankfurt.

"The implementation of primary lighting functions in headlamps using LEDs is anticipated by the second half of this decade," said the firm.

In the headlight, dipped beam comes from two five-LED modules split one at the top and one at the bottom. Main beam has four five-LED modules and the daytime running light, which can be dimmed and used as a position light is above, as is the direction indicator.



"An increasing interest is coming from the design departments of automotive manufacturers, now that the light diode offers new potential scope when compared with the conventional headlamp forms and configurations," said Hella. "From a stylistic point of view the LEDs, the preferred and freest of configuration options of many modular lighting systems."

The first LED application in headlamps was in Hella's retrofit LED, xenon and halogen design for the BMW 3 series.

3D photonic crystals from Oxford

Oxford University's physics and chemistry departments have together invented a method of producing 'photonic crystals'.

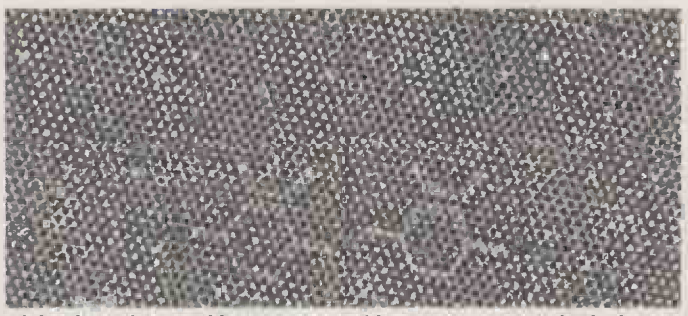
A photonic crystal is a three dimensional lattice structure with a periodicity similar to that of the wavelength of light. This creates filtering and focussing effects for light of certain wavelengths.

Current technologies for the formation of photonic crystals include the stacking of micron sized polymer balls and deep-etching circles on a surface to form round rods.

The Oxford technique interferes four laser beams to produce a custom lattice structure in a block of special plastic. Exposure takes only 6ns.

In an extension to the work, "features typical to those expected in working optical devices" have been added.

Isis Innovation, the intellectual property arm of the university is looking for companies interested in the commercial development of the technology.



Eight photonic crystal layers separated by 0.5μm. Features in the layers relate to four vertical waveguide 'legs' leading to an hexagonal interferometer device where light would pass through and interact with a control signal.

Sharp gets MBE for violet laser

Scientists at Sharp Labs of Europe in Oxford have used molecular beam epitaxy (MBE) to produce a violet laser diode.

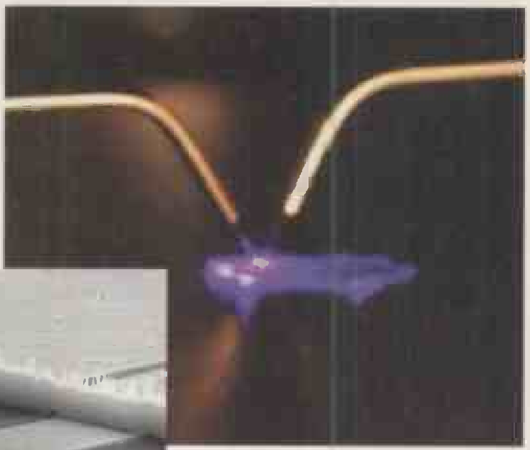
This is said to be the first use of MBE to grow such short wavelength - 405nm - devices. It is significant as MBE is a more efficient process than metal organic chemical vapour deposition (MOCVD), which has been the only way of making these devices.

"There is a significant reduction in the consumption of source materials, which can in turn have implications for laser production costs and in reducing the environmental impact of the production method," said Dr Jon Heffernan, head of the project.

"MBE also has advantages in offering more accurate control of the growth than the traditional MOCVD method. Such an advantage may allow the development of new device structures with significantly improved features."

Sharp's first devices are pulsed, but the firm is confident it can move to continous wave operation, eventually catching up with devices made using MOCVD.

Devices at 405nm are useful as they are specified for Blu-Ray and other standards for high density optical discs. Blue and violet LEDs also form the basis for white LEDs with the addition of a phosphor layer.



Right: Sharp used molecular beam epitaxy to produce 405nm laser diodes.

Left: A photomicrograph showing the violet laser. Light escapes from the dry cleaved face at the end of the laser stripe.

LED internal reflector doubles efficiency

DR-LEDs come in several colours

Omron has introduced an LED package which usefully captures normally-wasted light.

Part of its DR-LED family, the 11mm diameter 2MDR01-11 is aimed at road and rail signaling heads, fixed and variable message signs, large screens in public areas and safety beacons.

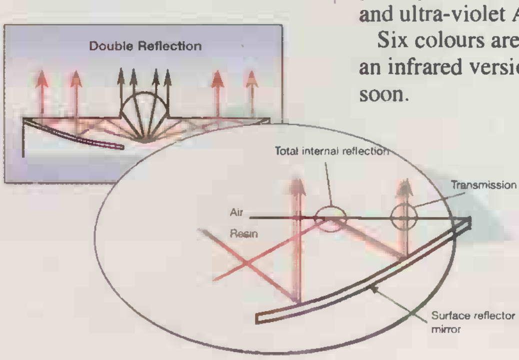
Light spilling sideways from the internal chip is captured by two total internal reflections and directed out in the same direction, and with the same divergence, as the main beam.

"Power dissipation is just 123 - 150mW, with up to 20Cd luminous intensity," said Omron.

As well as the 11mm 9 degree version, there is also an 8.5mm 17 degree type.

Typical service is claimed to be 100,000 hours and the package is resilient to moisture, and ultra-violet A and B.

Six colours are available with an infrared version planned soon.



Omron's LED captures light that would be wasted

£3.2 billion worth of profit lost every year

The latest Plimsoll Portfolio Analysis – Electronics Manufacturers has revealed that a staggering £3.2 billion of profit is being wasted in the UK Electronics Manufacturers industry every year, due to blatant underperformance and a failure by company leaders to focus on the bottom line.

A quick glance in the latest publication from Plimsoll Publishing Ltd reveals:

- Over a third of companies are making a loss.
- 140 companies are losing money for the 2nd year in row.
- 50% of companies make less than a 3% return on investment.

David Pattison, Senior Analyst at Plimsoll Publishing Ltd, said, "These figures show just how competitive the UK Electronics Manufacturers industry has become. The ability to make a profit is becoming the exception, not the norm."

"Although in the minority, 235 companies delivered a 10% return on investment in 2003, proving that success is achievable within the industry. This is the level of profitability required to provide a good return to shareholders, pay for investment and help to ensure company longevity."

The latest edition of the Plimsoll Portfolio Analysis - Electronics Manufacturers has given each of the Top 1000 companies in the industry a "Profit Plan"which identifies how each company needs to focus on its bottom line and make more profit. The analysis shows that a staggering £3.2 billion million in extra profit could be created but is currently being unexploited

To succeed in 2004, managers need to learn from the winners by improving company profitability.

The 1150 page analysis examines the last 4 years' profitability, highlighting the winners and losers in this key area of company performance.

Available in paper or electronic format the Plimsoll Portfolio Analysis is available for £305 from www.plimsoll.co.uk or by calling 01642 626400.

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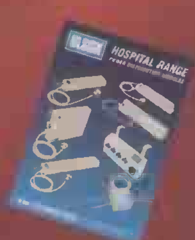

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A pseudo-sine wave inverter

Running ac mains powered electronic equipment from an inverter is not always as straightforward as one might think. Ian Hickman explains why, and presents a demonstrator design which may be developed to suit any application.

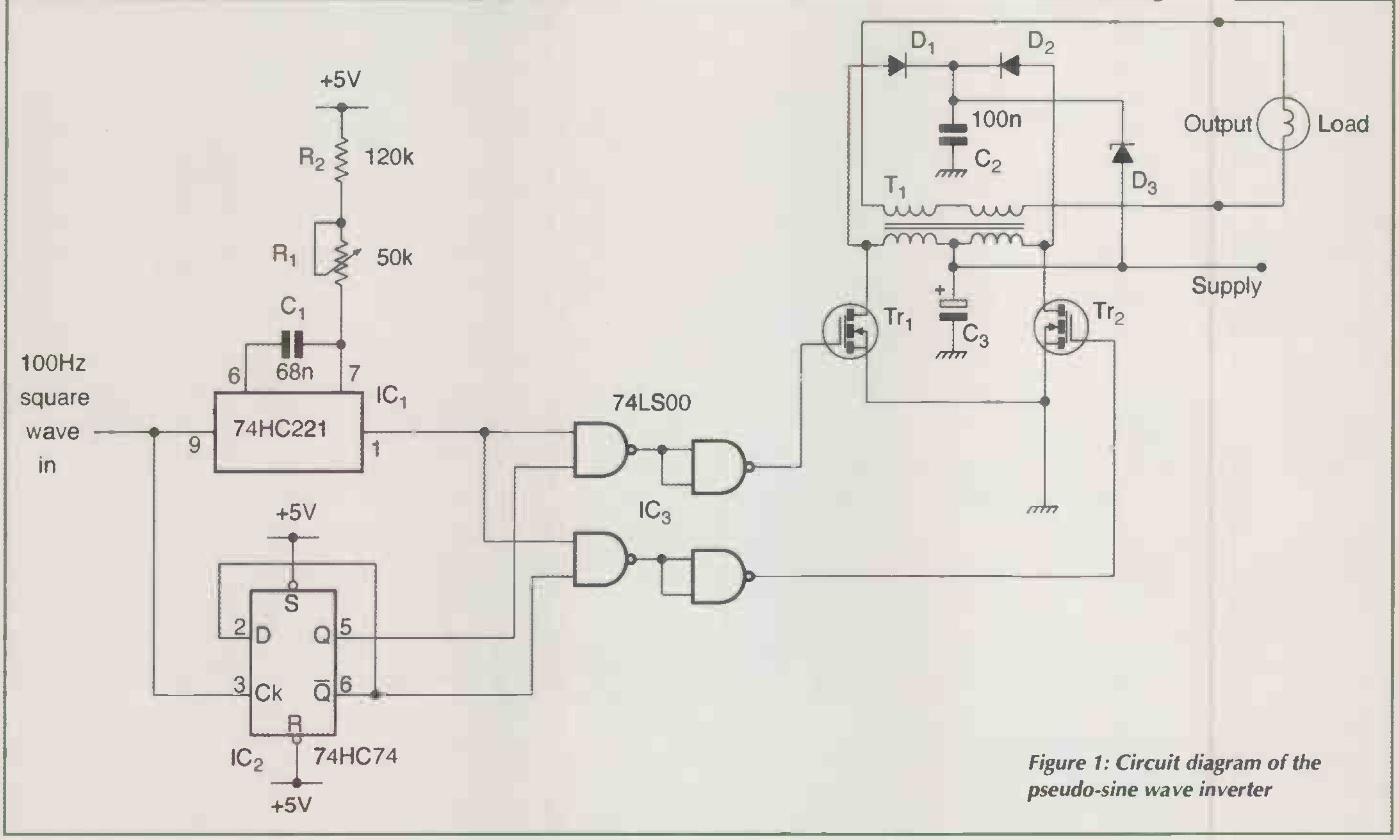


Figure 1: Circuit diagram of the pseudo-sine wave inverter

Back in the 1980s I was conducting some MOD contract tests on direction finding antennas in the middle of Thorney Island, a Class 1 antenna test site on the south coast of England. At one end of the test link, equipment was powered by a small portable diesel generator which seemed to hammer away all day on next to no fuel. At the other end, the equipment was powered by an inverter, run from the battery of the test wagon, or at least that was the plan. Unfortunately, the test signal generator, a Marconi TF2018, kept falling over, with its software tied up in knots. On investigation, this turned out to be due to the '240V ac' output of the Racal inverter. The output certainly read 240V or thereabouts on the ac range of an AVO and it was only on viewing the inverter output with an oscilloscope that the problem became apparent. The inverter's output waveform was a ±240V peak square wave, with just a very modest amount of filtering to file down the sharp edges slightly. With a modern piece of kit, designed to run from any ac voltage in the range 95V to 260V, there would have been no problem. But the signal generator used a conventional mains transformer, rectifiers, smoothing and regulators. It expected to see a 240V rms sinusoidal mains waveform, with a peak voltage of $\sqrt{2} \times 240 = 339$V peak. Fed with a 240V square wave, the raw voltage to the regulators, from the rectifier and smoothing capacitor, was inadequate, and the regulator outputs consequently unregulated.

It is an unfortunate fact of life, that for a 240V rms square wave, the peak voltage is ±240V, not ±339V; since for a square wave, the rms voltage simply equals the peak voltage. It is therefore unsuitable for powering the older generation of equipment fitted with a conventional mains transformer and regulated power supplies.

I do not possess a TF2018, but have various other signal generators, oscilloscopes and spectrum analysers of that generation, all perfectly functional. There are plenty of such items advertised in these pages, all at very advantageous prices. However, should you want to operate them away from ac mains, an inverter with a square wave output is unsuitable. It is not practical to design such an inverter with a higher peak output voltage, as a mains transformer run from it might be damaged, for reasons explained in the box. But it is possible to design a 'pseudo sine wave' inverter, along much the same lines as a square wave output inverter, and such an experimental design is described below.

Whilst being quite a low power design, it is readily modified to use other transformers of higher rating.

Pseudo sine waves

As the details in the box show, a square wave is not a very suitable output waveform for an inverter - indeed it could hardly be less like a sine wave. Whilst a stepped approximation, such as the output from a direct digital synthesiser, can come as close as one likes to a sine wave, for an economical design of inverter, a very crude approximation suffices. This is just what the circuit of **Figure 1** provides. It is driven from a 100Hz square wave input, which is fed both to a monostable multivibrator, and to a D type flip-flop connected as a divide-by-two circuit. For each of the input pulses, the monostable provides an output pulse whose width is adjustable by means of preset potentiometer R1, connected as a variable resistor. These output pulses are applied to two NAND gates, which are enabled on alternate half cycles by the Q and /Q outputs of the divide-by-two circuit. Thus Tr_1 and Tr_2 are turned on, on alternate half cycles, energising the low voltage windings of transformer T_1. The transformer used is a 30VA rated toroidal mains transformer with two 120V primary sections and two 15V secondary sections. In this application it is used 'back to front', to provide a 240Vac output from a low voltage dc supply. The rated peak secondary voltage is of course $15 \times \sqrt{2} = 21.2V$, and allowing for a small volt drop in the MOSFETS, I fed the circuit with a 22V dc supply - apart from the logic, which was run from +5V dc. A 15W 240V bayonet cap lamp was used as a convenient load.

Circuit details

During the period when one of the MOSFETs is ON, the magnetising current in the corresponding low voltage section will increase linearly, at a rate proportional to the supply voltage. When the MOSFET is turned off, the resultant stored energy must go somewhere, and D_1 and D_2 are used as 'snubbers', to prevent enormous and potentially damaging peak drain voltages. The positive voltage excursion is limited by a snubber diode, which diverts the 'flyback' energy into the capacitor C_2. This capacitor discharges via the 22V Zener diode D3, back into the supply (which is decoupled by 1000µF capacitor C3), so that half of the flyback energy is recovered and reused.

Figure 2 shows the drain waveform of one of the MOSFETs (upper trace), and the corresponding gate drive waveform. The latter is less than +5V, being LSTTL derived, with limited drive capability, and thus not ideal. Consequently, the drain voltage does not fall immediately to the MOSFET's saturation voltage, an effect clearly visible in the upper trace. The oscilloscope brightness has been deliberately advanced, so that the switch-off spike is clearly visible at 5ms per division, even though it is only around a microsecond wide.

The TEK475A used is an old instrument, but still exhibits a high 'writing speed'.

Figure 3, at a higher timebase speed of 2µs per division, shows (upper trace) the turn-off spike, caught at about +50V by the snubber diode. In this case, the diodes D_1 and D_2 were 1N4148s; these are fast small signal diodes, exhibiting a substantial forward volt drop at the current involved.

Figure 4 shows the same thing but with D_1 and D_2 now type 1N4006. The spike is now limited to +48V due to the lower diode forward volt drop, but the subsequent history of the spike is quite different, presumably due to the longer storage time of the slower diode. The ideal component for the snubber diode would be a fast low forward volt drop type, but the demonstrator circuit was implemented entirely with devices from stock, and a more suitable diode type was not to hand. The same comment applies to the MOSFETs Tr_1 and Tr_2, which were type BUZ10, with a Vdss drain voltage rating of only +50V!

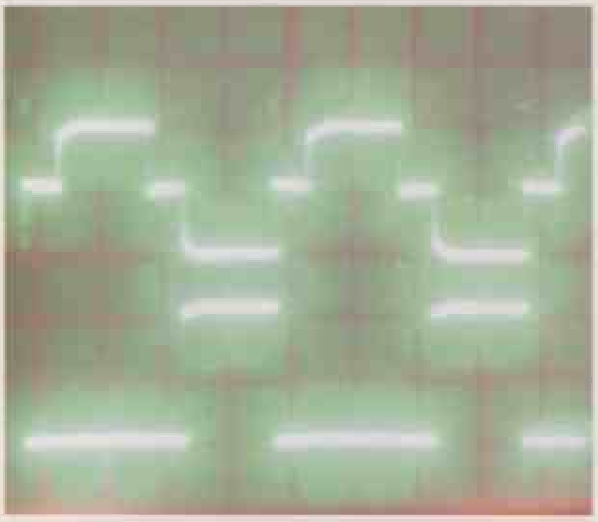


Figure 2 Tr1 drain waveform (upper trace), 20V/div; Tr1 gate waveform (lower trace), 2V/div, both at 5ms/div.

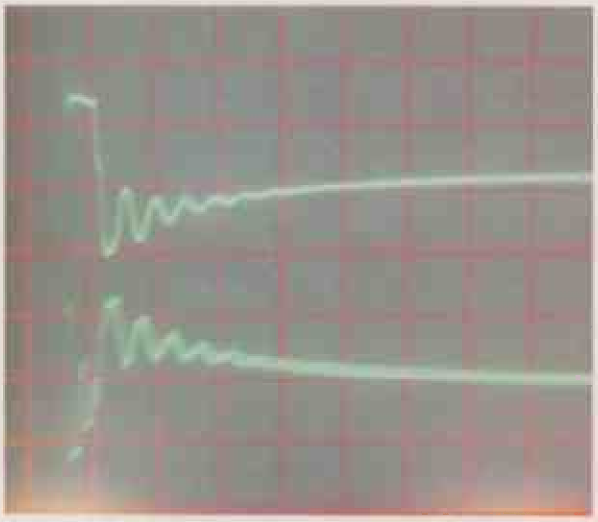


Figure 3: As Figure 2 but 2ms/div. Snubber diodes 1N4148

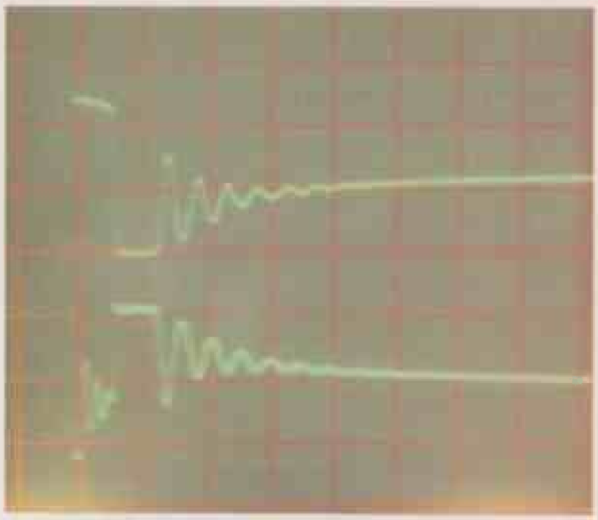


Figure 4 (below) As Figure 2 but 2ms/div. Snubber diodes 1N4006

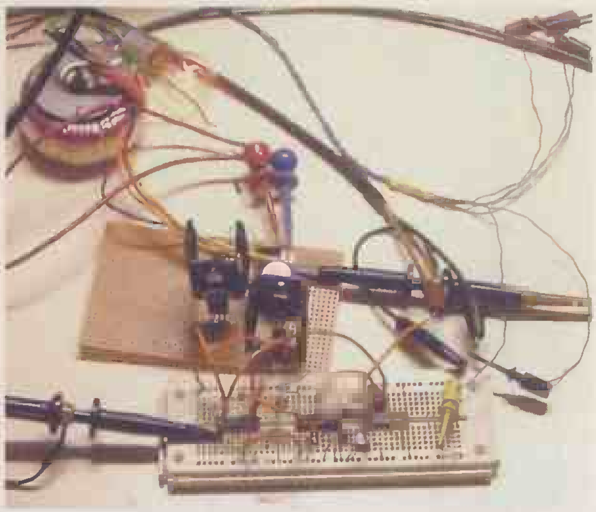


Figure 5: Experimental set-up of the demonstrator circuit.

As a temporary project, most of the circuitry of the demonstrator was put together using plugboard (Experimentor 300™), with just the MOSFETs, snubber diodes, C_2 and the 1000µF C_3 supply decoupling capacitor mounted on 0.1 inch matrix copper strip board, as shown in **Figure 5**.

The lit lamp shows the circuit is running, but the supply voltage was wound down for the photograph, to prevent the lamp "blinding" the camera. In the event, with just a 15W load, the twisted-vane heatsinks on the MOSFETs could have been dispensed with as they showed a negligible temperature rise.

Conclusions

The demonstrator circuit shows that an inverter circuit providing the same peak and rms voltage as 240V ac mains can be built using a very simple design. To a close approximation, the level of losses in a transformer used 'back to front' like this, can be expected to be the same as if it were used the usual way round. The additional losses, due to the MOSFETs and snubbers, are small, in view of their high speed switching and the low frequency of operation. Since 22V dc is not a very convenient supply voltage, a custom wound transformer will normally be preferred. MOSFETs with a V_{dd} margin suitable for the particular supply voltage will need to be selected, and a type fully enhanced at +5V V_{gs} will be convenient.

The 100Hz drive waveform can simply be a 555 oscillator circuit, running at 200Hz and driving the other half of the 74HC74 flip flop. The pulse width for a 339V peak 240V rms output has been shown to be 5.01ms.

This is so close to 5.00ms that the 74HC221 multivibrator can be omitted and the gate drives produced simply by gating the 100Hz square wave. ●

Mains Transformer

A mains transformer draws a 'magnetising current', which is out of phase with the applied primary voltage, lagging it by 90° or a quarter of a cycle. Consequently, over a half cycle, as the mains voltage E increases from zero to a positive maximum and then falls again to zero, the magnetising current I_m rises from its negative peak value $-I_m$, through zero, to its positive peak value $+I_m$. This is illustrated in **Figure A**, where the blue trace represents both the magnetising current, and the flux. Both are in quadrature with the applied primary voltage, but note that even off load, the total primary current will not be exactly in phase with the flux. This is because there is also a component in phase with the voltage, representing a resistive component, due almost entirely to the core loss.

The flux Φ is in phase with I_m and consequently increases from -Φm through zero to +Φm. Thus to support half a cycle of a 50Hz sine wave of 339V peak (10ms duration), a flux *change* of 2Φm is necessary. The mains transformer designer will have designed the transformer so that, off load, at minimum mains frequency and maximum mains voltage tolerance, Φm is still safely below saturation of the transformer's core.

If the mains voltage were twice as much, Φm would need to double, or if the frequency were 25Hz rather than 50Hz, then again, Φm would need to double. In other words, Φm is proportional to the voltage times the half-period, or the 'E × t product'. This is the case, whatever the waveform. In the case of a sine wave, the E×t product is represented by the coloured area in **Figure B**. A handy result to remember is that the area under half a cycle of a sine wave is 2/π times the surrounding rectangle. So from **Figure B**, the E×t product for 240V 50Hz mains is (339 × 10) × 2/π = 2158V.ms or 2.158 volt.seconds.

Figure B also shows half a cycle of a waveform (red trace) with the same peak voltage and the same E×t product as 240V ac mains. For this simple flat top pulse waveform, given the peak voltage is 339V, the pulse duration must be (2158/339)ms = 6.37ms. An inverter with this waveform could safely power an instrument such as the TF2018, providing adequate rectified supply voltage without exceeding the permitted E×t product of the mains transformer. However, for general use, a rather small pulse width should be used. This is because for general use, a pseudo sine wave inverter should have not only the same peak voltage as ac mains, but also the same rms value. With 6.37ms pulses, the mean square value $339^2 \times 6.37/10 = 732047$ V^2 so the root mean square voltage is √73205 = 270.6V, or rather excessive! For a peak voltage of 339V, a pulse width of 5.01ms gives an rms value of 240V. Such a waveform has an E×t product of only 1.70 volt.seconds, within what a 240V 50Hz transformer can stand, by a large margin. On the other hand, an inverter providing a ±240V square wave output will subject a mains transformer to an E×t product of 2.4 volt.seconds. This is 11% greater than the figure for which the primary winding of a 240Vac transformer is designed.

Figure A Positive half cycle of 240Vac mains (red, scale -340V to +340V); corresponding magnetising current and flux (blue, scales not shown).

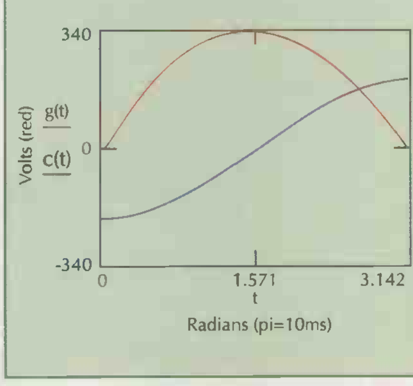
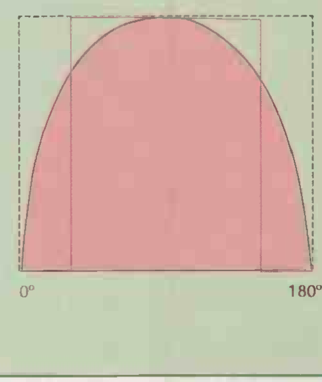


Figure B Indicating the volt.second product of half a cycle of 240Vac mains, and a pulse waveform with the same volt.second product.

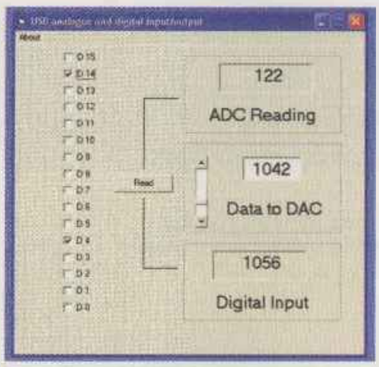


Analogue and digital i/o via the USB port

Following on from Colin Attenborough's Wide digital i/o from the USB port in EW November 2002, this article adds analogue input and output to the basic design

This article shows how to get 16 bit digital i/o and 12 bit analogue i/o through a computer's USB port. It's an extension of my article printed in the November 2002 edition of Electronics World, which showed how to get digital signals in and out of a PC via the USB port. The complexities of USB were hidden from the user by using a Gigatechnology module which accepts USB signals and provides parallel input/output data. As before, I've provided Visual Basic software to control the hardware (see the picture of the user interface above; this software is available from Electronics World as an email and will be included on the EW 2004 archive disc when released, both as source code so that those with Visual Basic can tinker, and as a compiled version so that those without Visual Basic can still use the hardware. Also as before, I've clocked data in and out of the USB module serially, sacrificing speed for simplicity compared to a parallel design.

Sticking with the serial architecture, I've used the LTC1286 ADC and LTC1451 DAC devices (see Electronics World December 1997). One problem is that while the digital input devices can be clocked at as high a rate as the USB module can handle, the LTC1286 has a maximum clock rate of 200kHz. If I'm to use the same clock source for the digital and analogue input, the clock rate must be reduced. (Yes, it would be possible to use different clock rates for the analogue and digital inputs, but only at the expense of increased complexity.)



The USB module

The Future Technology Devices International company (http://www.ftdichip.com) produces a range of integrated circuits which form the heart of a USB interface.

Two other companies, DLP (http://www.dlpdesign.com) and Gigatechnology (http://www.gigatechnology.com) make life easier by putting the surface mount FTDI integrated circuits with their associated components in modules with 0.1" pin spacing. This project uses the Gigatechnology USB-02 module; I've used the DLP module with equal success.

The modules take in the USB bus and provide byte wide bidirectional signals. Four other signals control data flow. To take data from the PC, wait until the *RXF output is high and take the *RD input low; data appear on the bidirectional pins. After *RD goes high, the *RXF output goes high. Repeat the process until all the data have been read. Data are sent to the PC on the negative-going edge of the *WR input; the *TXE output goes high in response. When it goes low again, more data can be sent. (In this project, the data rate is low enough for *TXE to be ignored - see the main text.)

Data output...

In outline, to send data to the USB module from the PC:

- Open the device
- Send a string representing the data to be sent from the PC
- Close the device

When sending data to the module from the PC, the Visual Basic program detects changes in the check boxes representing digital data, or changes in the setting of the scroll bar that defines the output of the ADC. The program assembles a string where bit 5 and bit 2 of each character represent the analogue and digital data to be sent. Bit 3 represents a clock signal to clock the data into the 74HC595's input registers and the LTC1451 register. After the data proper have been sent, a further two characters follow. These raise and lower bit 1 to clock the data into the output of the 74HC595s, and to drive the *CS input of the LTC1451.

Although the DAC is a 12 bit device, it receives 16 clock pulses. It still works correctly because the *CS input is appropriately timed. Because it accepts data MSB first, bit 0 must be sent at the same time as bit 16 of the digital output word, with bit 11 being sent at the same time as bit 4 of the digital output word - this is accommodated by the software.

The ADC has an internal 2.048 volt reference, and a times two amplifier - thus the output in millivolts is conveniently equal to the code.

Figure 1: USB module and control circuitry.

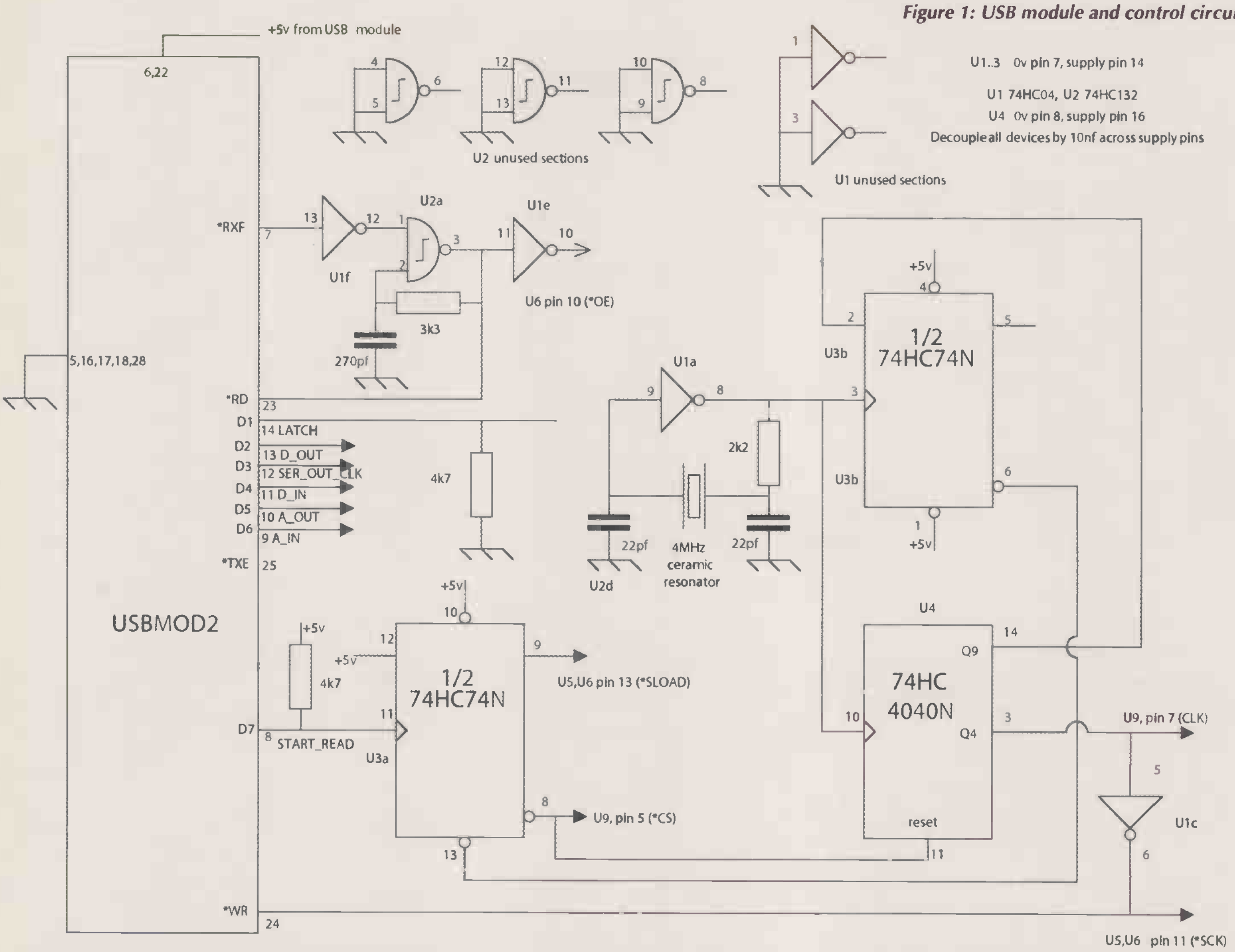
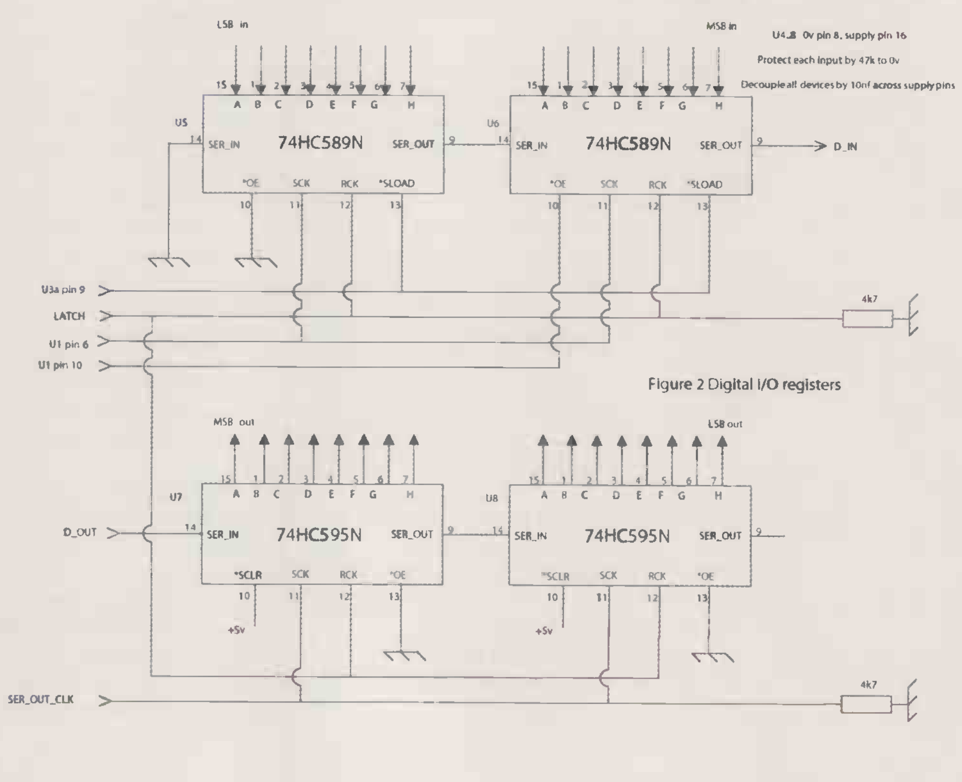


Figure 2: Digital I/O registers.



Software

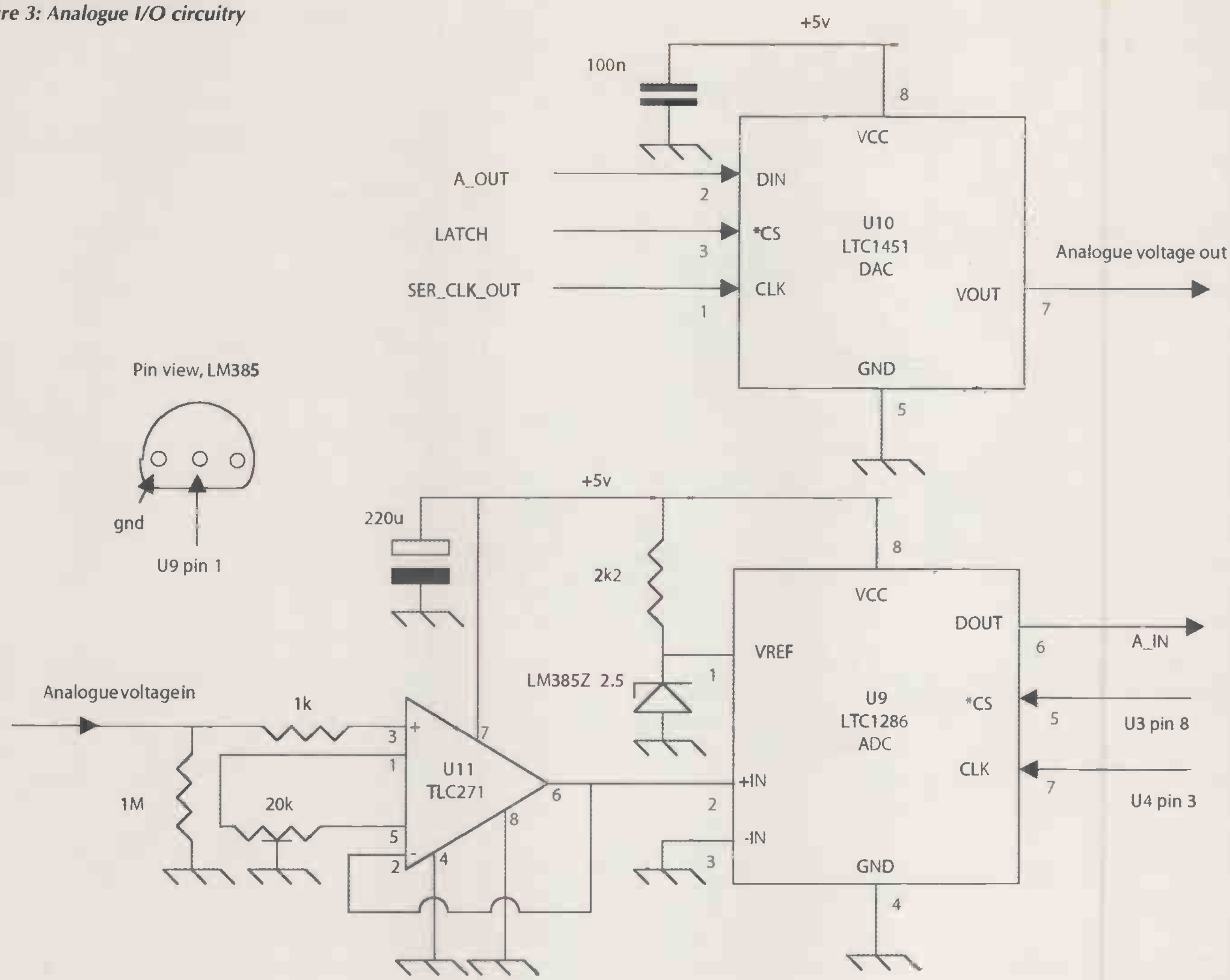
The software comes in three parts and is available by contacting Caroline Fisher at EWadmin@highburybiz.com;

- The Visual Basic code which is specific to this project
- A compiled version of the code so you can use the project even if you don't have Visual Basic
- A .zip file containing a dynamic link library (DLL) which lets the Visual Basic access the functions needed to control the USB module, and also drivers for the module. This can also be downloaded from the Future Technology Devices International website.

Unzip the DLL/driver file. The first time you connect the USB module, you'll be asked where to find the driver. Browse to the directory where you unzipped it, and let the system install it.

(Disconnect your machine from its internet connection temporarily while installing the driver, so the system listens to your choice of what driver to install.)

Figure 3: Analogue I/O circuitry



...and input

- Open the device
- Read a string representing the data from the module
- Close the device

To read data into the PC from the module, the program assembles a string which latches data into the input registers of the 74HC589 devices –again using bit 1. Subsequent characters of the string pulse bit 7 low and high again, clocking U3a, and sending its Q output to 1. The signals at the Q and *Q outputs of U3a control the *SLOAD inputs of the 74HC589 devices and the *CS input of the LTC1286. It also removes the reset signal from U4, allowing it to run until its Q9 output goes to logic 1, resetting U3a via U3b. While U4 is running, its Q4 output provides 16 clock edges to clock in data from the LTC1286. The inverse of this signal also clocks the 74HC598 and the USB module's *WR input via an inverter- the 74HC589 and the LTC1286 ADC shift data on different polarities of clock edge, and the circuit ensures that the USB module accepts data mid-way between active clock edges.

The analogue and digital data from the module are extracted from bits 6 and 4 respectively of the characters in the string returned by the module. The ADC gives the most significant bit (D11) of its output on the fourth clock pulse after the fall of *CS; other bits follow, with the least significant bit (D0) occurring during the fifteenth clock pulse. But we're giving it sixteen clock pulses, for commonality with the digital input; during the sixteenth clock pulse, the ADC outputs D1 again. Therefore software discards the last bit of the conversion received by the USB module, and shifts the remaining bits to the right.

Because the clock rate must be lower than in the digital-only case, there's no need for the *TXE signal from the module - the 200ns 'wait I'm reading in the last byte' pulse will have disappeared long before the next byte is presented, eight microseconds later. I've also attempted a little more elegance by abandoning the Schmitt-based oscillator and using an oscillator based on a ceramic resonator sustained by a CMOS inverter. There's nothing particularly special about the use of a 4MHz oscillator rate; if you use a different frequency, you may need to choose different outputs of U4 to get a clock rate below 200kHz for the ADC.

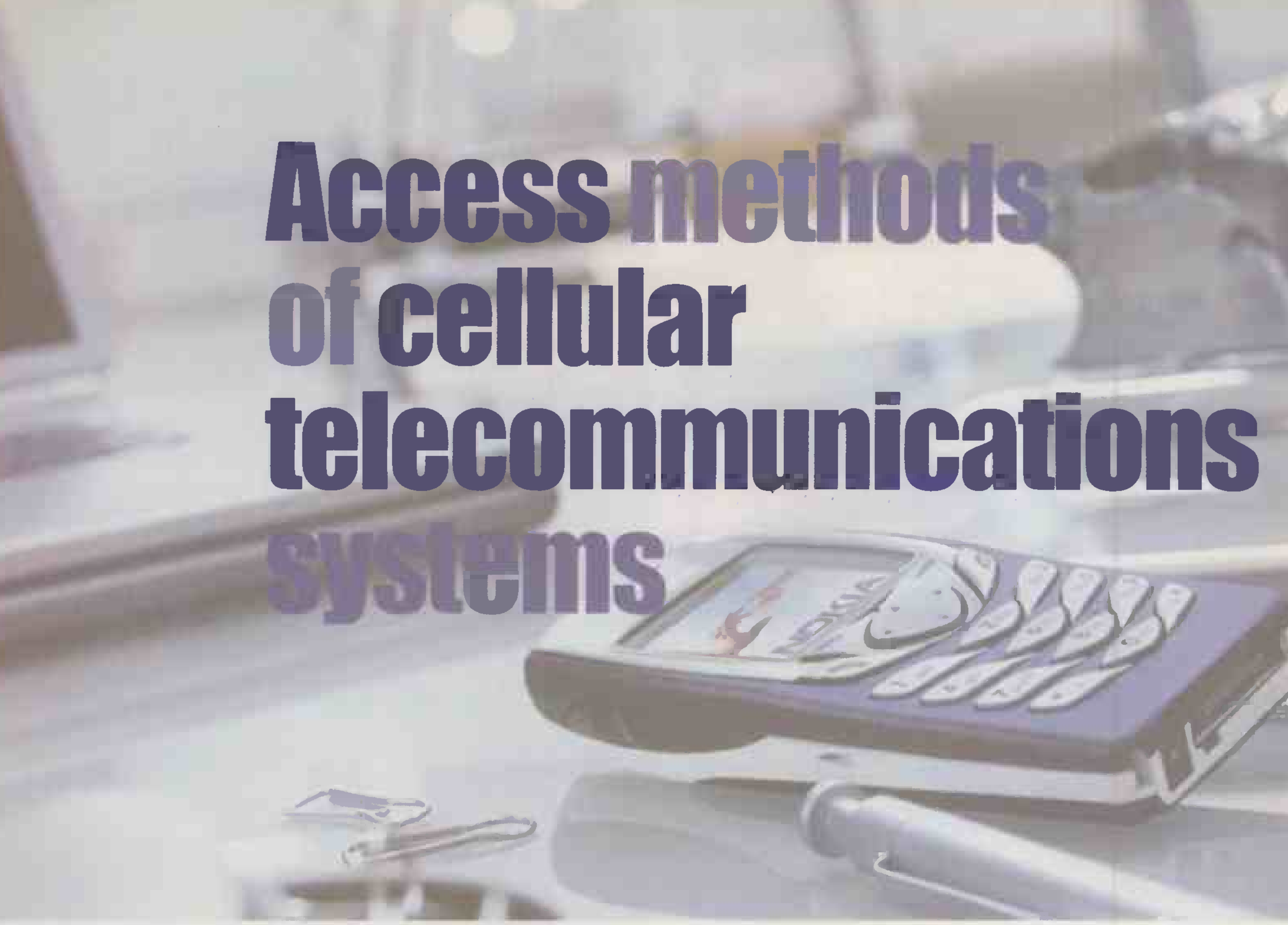
The ADC is preceded by a unity-gain op-amp to give high input impedance and to isolate the input from noise generated in the ADC; the potentiometer shown compensates for amplifier offsets, and should be set so that the ADC reads zero for zero input voltage. As the ADC is a 12 bit device, its output code is $4096*V_{in}/V_{ref}$

V_{ref} is 2.5 volts, provided by the LM385Z- 2.5.

Acknowledgements

I'm grateful to my employers, Cambridge Consultants Limited, for permission to publish this article- and to FTDI for their assistance.

Access methods of cellular telecommunications systems



It is now over twenty years since the first cellular phone systems were launched. By today's standards the early systems were expensive, coverage was poor and so was their performance. Furthermore when some of the old phones are seen on the movies they see incredibly large, especially when compared to the phones that are in widespread use today. Ian Poole gets connected.

Right: Mobile phone base stations are now small and can be installed very easily in many areas of our towns, cities and countryside

(pictures courtesy Nokia)

Since the early days of cellular phones there have been many major developments, and more are happening all the time. Nowadays the developments of the cell phone systems are categorised as occurring in three main phases or generations. The first generation (1G) phone systems were the analogue ones that were used in the 1980s and early 1990s. They are still in widespread use in the USA today. These included systems such as TACs (Total Access Communication System) that was used in the UK, AMPS (Advanced Mobile Phone System) in the USA, and NMT (Nordic Mobile Telecommunications) in Scandinavia. They were used in many other countries world wide, but there was also a proliferation of other systems that were also used.

These phone systems were very successful and it soon became necessary to look at ways to utilise the valuable spectrum allocations more efficiently. Accordingly new digital systems were developed. In Europe a system known as GSM was introduced. Initially the letters stood for Group Speciale Mobile, but as its use spread worldwide and the meaning was changed to Global System for Mobile telecommunications. Indeed today the system is by far the most widespread technology with nearly a billion users accounting for 72% of the world market. The system offers many facilities including the use of SIM cards to hold users identities whilst being able to easily swap phones. One of the facilities that has grown astronomically is the use of text messages with around 24 billion messages sent each month and its use is still growing.

The GSM system adopted a totally different approach to that used by the analogue systems and included a 200kHz channel spacing. In the US a different approach was used when they developed their digital system. The approach they adopted was to make it easier to migrate from the analogue to the digital system. It borrowed many features from GSM, although it did not possess many of the facilities available in GSM such as SIM cards. The system was known under several names including DAMPS (Digital AMPS), USDC (US Digital Cellular), and finally TDMA (Time Division Multiple Access) - as this is the technique that the system uses. In fact today it is normally referred to as US TDMA. The system operates on the same 30kHz channels that AMPS uses and this enables it to operate more easily along side the original analogue AMPS system.

In Japan they have a system that is based very closely on the US system, but goes by the name PDC. This can stand for either Personal Digital Cellular and Pacific Digital Cellular - both names as used to refer to this system. Although it has some minor differences from the US-TDMA system, is very similar.

Some time after GSM and TDMA were established, a totally new second-generation system was launched. This was to shape the whole future of cellular telecommunications. It was developed by a then little known California based company named Qualcomm who had been working on spread spectrum techniques for the US Government. The system known as CDMA (Code Division Multiple Access) used a new method of servicing the large number of subscribers to the base station that is discussed later.

The system that went under the trade name cdmaOne underwent its first commercial launch by Hutchison Telecom in Hong Kong in September 1995. Then in March of the following year the first service was launched in the USA and by December 1997 there were over 8 million cdmaOne subscribers.

By the mid 1990s, voice services were well established and new opportunities were seen for developing data services. However to achieve this, significant enhancements were needed. Although this was the main thrust of the third generation networks, these took a long time to develop and interim solutions were introduced, that allowed data services with lower speeds. For GSM networks the GPRS (General Packet Radio Service) was launched. Using what is termed 'packet switching' where individual packets of data can be routed to and from a particular phone instead of circuit switching where a complete circuit is switched all the time for a given user, this enabled much more efficient use to be made of the spectrum and higher data rates to be achieved. A further migration to EDGE (Enhanced Data rates for GSM Evolution) used a new form of modulation to increase the data rates still further.

There are currently two main contenders for third generation systems, both of which use CDMA. The GSM system is migrating to UMTS (Universal Mobile Telecommunications System), which is also known as W-CDMA (Wideband CDMA). Although it requires a significant upgrade in infrastructure and W-CDMA phones cannot operate on GSM networks, it is expected to have widespread uptake in the GSM areas. Phones are expected to be dual mode so that they can operate on both networks, handing over between W-CDMA and GSM as required by the coverage although this is causing some problems at the moment.

The cdmaOne system has an evolutionary migration to the full 3G standard. The first step is CDMA2000 1X. This provides data at speeds up to just above 300kbps and is technically termed a 3G system. However there are two alternatives to provide the full 3G data rates. The first is CDMA2000 1xEV-DO. This stands for EVolution Data Only. As the name suggests the idea is that this only provides data services, if voice is required then this is handled on a separate 1X channel. However the full data and voice service is catered for with the CDMA2000 1x EV-DV system which provides full voice capability and data up to 3.1Mbps.

Multiple Access Systems

In order to enable a cellular system to operate, it must allow many users to access the system simultaneously. This is one of the key elements of any cellular system, and as they have migrated through the different generations different approaches have been used.

The first analogue systems used a technique called FDMA (Frequency Division Multiple Access). Using this scheme different users are allocated different channels, and within any one cell, each channel can only be used once. The system has a control channel that all phones can access and information is passed to the mobile to enable it to move to the required channel.

With channel spacing of typically 25 or 30kHz, the rapidly increasing levels of usage meant that there was a considerable amount of pressure on the available channels.

A TDMA system uses a different approach. As the voice signal is digitised, it is possible to split the voice data into bursts or packets. These can then be interleaved so that several users can share the same frequency channel. Broadly speaking, a GSM signal has frames that are split into eight times slots. These have a defined data structure into which the data is fitted. The GSM channels are each 200kHz wide allowing for each cell to utilise a number of channels to provide access for the required number of users. This system provides a greater level of spectrum efficiency than the older analogue FDMA systems.

Similarly the North American

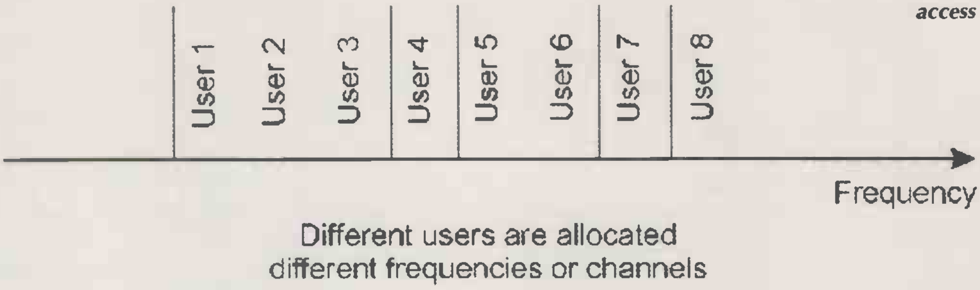


Figure 1 Frequency division multiple access

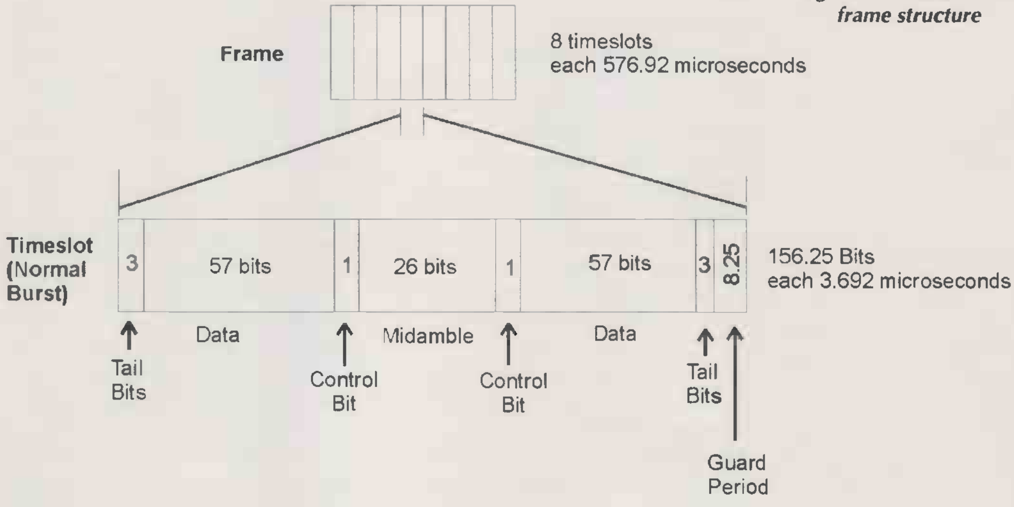


Figure 2: GSM data frame structure

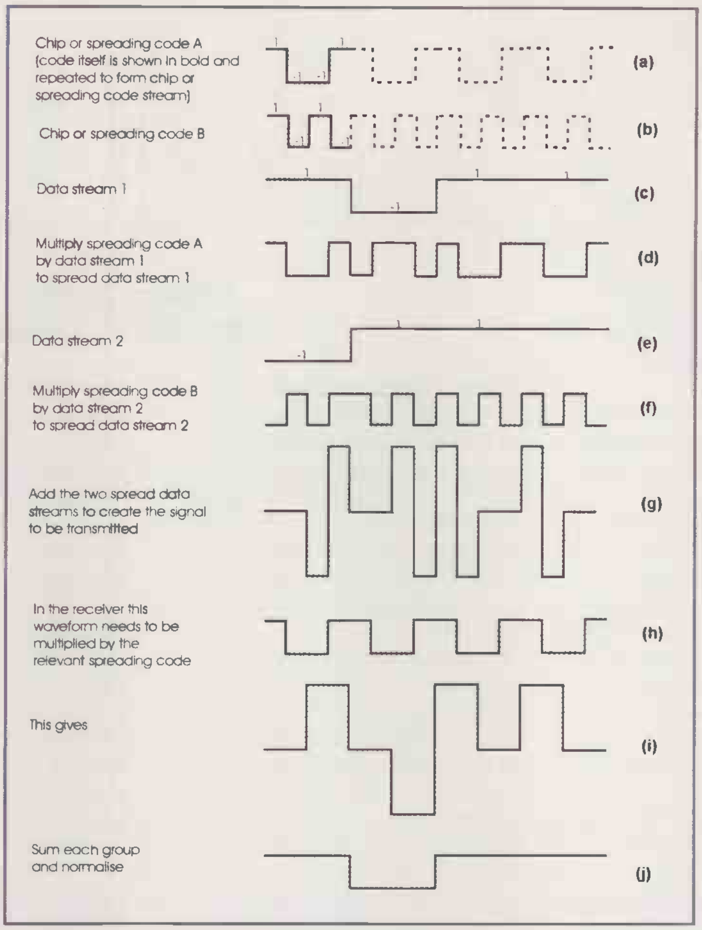


Figure 3: Operation of direct sequence spread spectrum

TDMA system splits the transmission into different time slots for different users although it operates on a 30kHz spacing to retain compatibility with AMPS.

CDMA

The technique being used for the third generation systems is CDMA. This technique came out of the direct sequence spread spectrum work that was being undertaken by Qualcomm. This system involved multiplying the wanted data with another code stream to spread it over a wide bandwidth. The signal could then be transmitted and received despite the presence of interference that may have been present on channels within the bandwidth of the spread signal.

Using the CDMA system different codes are assigned to different users rather than different frequencies or time slots. When the receiver and transmitter use the same codes then the signal can be received satisfactorily. In this multiple users can use the same channel, and the different users are separated by the use of a different code.

The operation of CDMA can be likened to being in a large room with many people all speaking together, although in different languages. Although the noise level is high, it is nevertheless still possible to pick out what someone is saying in your own language, despite the fact that they are no louder than others speaking different languages

Operation

To generate a CDMA signal the required data signal is multiplied with what is known as a spreading or chip code data stream. This has a higher data rate than the data itself and it enables the overall signal to be spread over a much wider bandwidth. To decode the signal and receive the original data, the signal is multiplied with the spreading code to regenerate the original data. When this is done, then only the required data is regenerated, all the other data that is generated from different spreading code streams is ignored.

The spreading codes can either be a random number (or pseudo random), or more usually what is termed an orthogonal code. Two codes are said to be orthogonal if when they are multiplied together and the result of the summation over a period of time is zero. For example a codes 1 -1 -1 1 and 1 -1 1 -1 when multiplied together give 1 1 -1 -1. When this is summed it gives zero.

Although pseudo random number codes can be used there is possibility of data errors being introduced into the system.

Example

To see how the system operates it can be seen that the waveforms (a) and (b) in Figure 3 are the spreading codes. The spreading code streams are multiplied with their relevant data. In the diagram spreading code stream (a) is multiplied with the data in (c) to give the spread data stream shown in (d). Similarly spreading code stream (b) is multiplied with the data in (e) to give (f). The two resulting spread data streams are then added together to give the base band signal ready to be modulated onto the carrier and transmitted.

The spreading code stream consists of the spreading code being sent repeatedly so that each data bit is multiplied with each bit of the spreading code. In other words if the spreading code consists of four bits, then each one of these four bits will be multiplied with each data bit. It is also worth noting that the spread rate is the number of data bits in the spreading code, i.e. the number of bits that each data bit is multiplied by. In this example the spread rate is four because there are four bits in the spreading code. This forms a basic data channel. It is then possible to combine several data channels by simply adding them together, and then modulating the resultant waveform onto the radio frequency carrier.

The signal is transmitted and once a receiver picks it up it undergoes the reverse process. First it is converted down to the base band frequency. The resulting data waveform is then multiplied by a spreading code stream with the relevant spreading or orthogonal code to extract the required data. This process is known as correlation and it results in the set of data for that code being extracted. By using a different spreading code stream, a different set of data is extracted.

In this case it can be seen that chip stream (a) is repeated in waveform (h). This is multiplied by (g) to give the waveform (i). Each group of four bits (as there are four bits in the chip code used in the example) is summed and from this the data can be reconstituted as shown in waveform (j).

Beyond 3G

Even though the 3G networks are only just starting to be rolled out, early work is already progressing on developing the fourth generation systems. Some trials to assess the best modulation and access techniques have already been undertaken. From this it seems that the systems will be based around COFDM (Coded Orthogonal Frequency Division Multiplex) techniques with data rates rising into tens or hundreds of Megabits per second. So we had better start thinking now what we are going to use this for.

Ian Poole is a freelance consultant and journalist who can be contacted via his website at www.adrio-communications.com

Voltage or current feedback?

Frantisek Michele investigates the differences between the current-feedback amplifier and the more common voltage-feedback amplifier, and explains how to decide which option best suits a given application.

One question continuously troubles analogue design engineers: "Which amplifier topology is better for my application, voltage feedback or current feedback?" In most applications, the differences between voltage feedback and current feedback are not apparent.

Today's voltage-feedback and current-feedback amplifiers have comparable performance, but there are certain unique advantages associated with each topology. In general, voltage-feedback amplifiers offer lower noise, better DC performance and feedback freedom. Aside from the well-known attribute of current-feedback amplifiers, gain-bandwidth independence, current-feedback amplifiers also tend to offer faster slew rates, lower distortion and feedback restrictions.

With these common attributes known, the design engineer may still ask: "Why?" This article will examine the basics of the current-feedback amplifier in comparison with the voltage-feedback amplifier. The following aspects of each topology will be examined:

- Closed-loop characteristics
- Open-loop characteristics
- Input-stage differences and advantages

Once these aspects are examined, it will become apparent why voltage-feedback amplifiers have better DC specifications. It will also be clear why current-feedback amplifiers have higher bandwidths for the same power and better linear phase performance over wider bands.

Finally, an internal look at the current-feedback amplifier will explain why distortion and slew rate are enhanced by its topology.

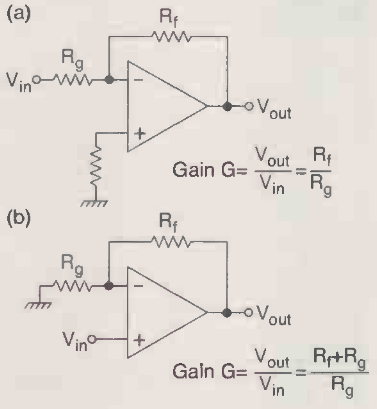


Figure 1: Basic inverting and non-inverting gain topologies hold true for current-feedback and voltage-feedback amplifiers.

Closed-loop characteristics

The basic amplifier design schematics and their equations hold true for both amplifier topologies. **Figure 1** shows the basic circuit topologies and transfer functions for inverting and non-inverting gain configurations. These hold true for both current-feedback and voltage-feedback amplifiers.

One point to remember is that the value of the feedback resistor is limited for current-feedback amplifiers. The current-feedback amplifier data sheet will provide the recommended value for R_f.

These transfer functions assume ideal conditions. Under such conditions, the open-loop gain A of a voltage-feedback amplifier and the open-loop transimpedance gain Z of a current-feedback amplifier are infinite. Therefore, the ideal transfer function, for the non-inverting topology, is generated as follows:

$$\frac{V_{in}}{R_g} = \frac{V_{out} - V_{in}}{R_f}$$

or,

$$\frac{V_{out}}{V_{in}} = \frac{R_f + R_g}{R_g} = G$$

Output voltage is equal to the input voltage multiplied by the gain, G.

Voltage-feedback open-loop characteristics

The fundamental differences between voltage feedback and current-feedback amplifiers begin to show when comparing their open-loop characteristics. **Figure 2** illustrates the open-loop characteristics of a voltage-feedback amplifier.

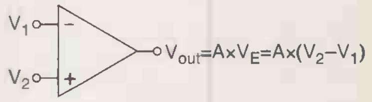


Figure 2: Open-loop characteristic of a voltage-feedback amplifier.

The ideal open-loop terminal characteristics are infinite non-inverting and inverting input impedances and zero output impedance. The output is a voltage source that is controlled by the potential difference between the two input terminals of the amplifier, also called the error voltage: $VE=V2-V1$

Output is equal to this error voltage multiplied by the open loop gain, A. Once the loop is closed, feedback attempts to drive the error voltage to zero, hence the term voltage feedback.

Gain bandwidth product

Refer to the non-inverting gain topology of **Figure 1**. Remember that the open loop gain of a non-ideal amplifier is finite. Re-evaluating, the non-ideal transfer function for a voltage-feedback amplifier becomes:

$$\frac{V_{in} - V_E}{R_g} = \frac{V_{out} - (V_{in} - V_E)}{R_f}$$

Let:

$$V_E = \frac{V_{out}}{A}$$

and,

$$G = \frac{R_f + R_g}{R_g}$$

$$V_{out} = V_{in} \times G \times \frac{1}{1 + \frac{G}{A}}$$

As long as A is much greater than G then the denominator becomes 1 and the amplifier behaves as it did in the ideal case.

The actual open-loop gain is large at DC and rolls off at a rate of 6dB/octave, through most of the frequency range. As the frequency increases, the value of A decreases.

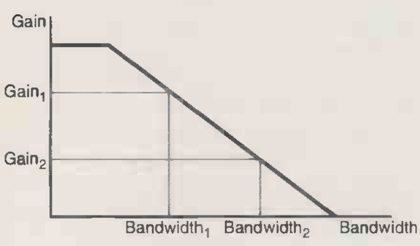


Figure 3: Illustration of the gain-bandwidth product for voltage-feedback amplifiers.

When $A=G$, the overall gain of the circuit will be half its DC value. This is commonly referred to as the –3dB bandwidth of the amplifier.

The rate at which the bandwidth decreases is proportional to $1/G$. For most of the frequency range, the product of gain and bandwidth becomes constant. This is referred to as the gain bandwidth product.

Gain bandwidth product prevents voltage-feedback amplifiers from obtaining high gain and high bandwidths simultaneously. This is illustrated in **Figure 3**.

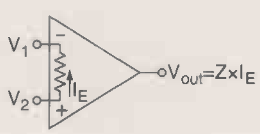


Fig. 4. Current-feedback open-loop characteristics.

Current-feedback open-loop characteristics

Figure 4 illustrates the open-loop characteristics of a current-feedback amplifier.

There is a unity-gain buffer between the two inputs of the current-feedback amplifier. Ideally, this buffer has infinite input impedance and zero output impedance. Therefore, the ideal open-loop terminal characteristics are infinite non-inverting input impedance, zero inverting input impedance and zero output impedance.

The output is a voltage source controlled by the error current I_E, out of the inverting input. Once the loop is closed, feedback will attempt to drive the error current to zero, hence the term current feedback.

Gain-bandwidth independence

Current-feedback amplifiers are known for their gain-bandwidth independence. The reason for this attribute is explained by calculating the transfer function of a non-ideal current-feedback amplifier.

An evaluation of the transfer function for a non-inverting configuration is shown. The transfer function for an inverting configuration also illustrates the gain-bandwidth independence.

$$I_E = \frac{V_{in} - V_{out}}{R_f} + \frac{V_{in}}{R_g}$$

$$V_{out} = Z \times I_E$$

$$G = \frac{R_f + R_g}{R_g}$$

$$V_{out} = V_{in} \times G \times \frac{1}{1 + \frac{R_f}{Z}}$$

The current-feedback transfer function looks very similar to the voltage-feedback transfer function. As long as Z is much greater than R_f then the amplifier behaves as in the ideal case.

Once Z drops to where it equals R_f, then the gain is lowered to half its DC value. This differs from the voltage-feedback case where gain is determined by both R_f and R_g. For current-feedback amplifiers, if the gain is increased by lowering R_g, rather than increasing R_f, then the bandwidth is independent of gain.

This expression explains the importance of Rf for current-feedback amplifiers. Current-feedback amplifier data sheets provide the recommended R_f values for various gain settings.

An excessively large or small R_f will compromise stability. Within reason, the feedback resistor can be used to adjust the frequency response. As a rule of thumb, if the value of the recommended R_f is doubled, then the bandwidth will be cut in half.

A look inside voltage-feedback topology

By observing the open-loop characteristics of both amplifier topologies, the differences begin to become apparent. However, a closer look at the input stages will shed more insight onto the issues relating to current feedback versus voltage feedback.

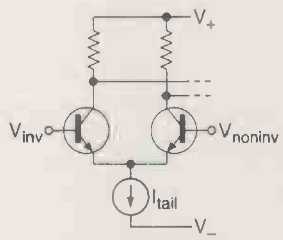


Figure 5: Typical input stage of a voltage-feedback amplifier.

A typical voltage-feedback amplifier input stage is shown in **Figure 5**. It is a common knowledge that voltage-feedback amplifiers tend to have better DC specifications than current-feedback amplifiers. Most voltage-feedback amplifiers have:

- Low input offset voltage (V_{io})
- Matched input bias currents (I_b)
- High power-supply rejection ratio (PSRR)
- Good common-mode rejection ratio (CMRR)

A close look at the input stages of both topologies will explain why voltage-feedback amplifiers tend to have better DC specifications.

The structure of the voltage-feedback input stage is the reason for better DC specifications. A voltage-feedback input stage is often a simple differential pair – two identical bipolar transistors at the same bias current and voltage. This configuration is often called a balanced circuit because of the symmetry between the two inputs.

Because of this symmetry, there will be no input offset voltage unless the devices do not match. The inputs are the bases of the two transistors. Although the absolute base currents, or input bias currents, may vary considerably due to process variation and temperature, again, unless the devices are not identical, the input bias currents will match.

When either the supply voltage or the common-mode input voltage is altered, the change in the collector-to-emitter voltages is matched for both of the input transistors. Changes in the devices' bias point could effect offset. Again though, due to the balanced topology, the bias currents match and offset voltage is little effected.

The result of this is good CMRR and PSRR.

A look inside current-feedback topology

The input stage of a current-feedback amplifier will also describe a few inherent DC traits of this type of amplifier:

- Non-zero input offset voltage
- Unmatched input bias current

The input stage of a typical current-feedback amplifier is illustrated in **Figure 6**. It is a voltage buffer. For the offset voltage to be zero, the supply voltage of the n-p-n transistors would have to match the supply voltage of the p-n-p transistors.

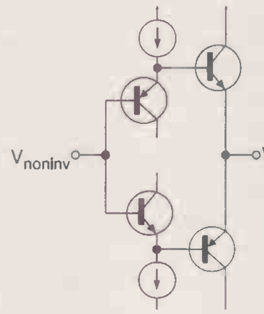


Figure 6: Typical input stage of a current-feedback amplifier.

Since these devices are constructed differently, there is no reason why they would inherently match. Bias currents in current-feedback amplifiers are also fundamentally mismatched.

The non-inverting bias current is the difference between two base currents where the inverting bias current depends on the errors produced in the next stage.

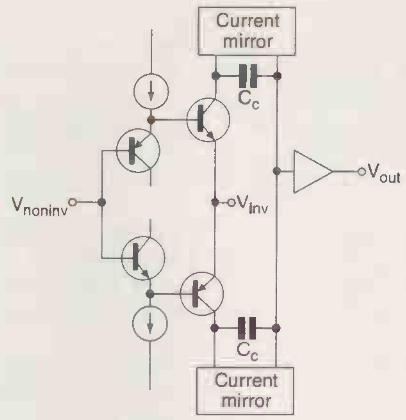


Figure 7: Basic current-feedback amplifier topology.

Advantages of current feedback

One hidden advantage of current-feedback amplifiers is that they usually require fewer internal gain stages than their voltage-feedback counterparts.

Often, a current-feedback amplifier consists of merely an input buffer, one gain stage and an output buffer. Having fewer stages means less delay through the open-loop circuit. This translates into higher bandwidths for the same power.

The basic current-feedback topology in **Figure 7** is a single-stage amplifier. The only high-impedance node in the circuit is at the input to the output buffer. voltage-feedback amplifiers usually require two or more stages for sufficient loop-gain. These additional stages add delay and yield lower stable bandwidths.

Distortion

The distortion .of an amplifier is impacted by the open-loop distortion of the amplifier and the overall speed of the closed-loop circuit. The amount of open-loop distortion contributed by a current-feedback amplifier is small due to the basic symmetry of the topology.

Figure 7 illustrates a typical current-feedback topology. For every n-p-n transistor, there is a complementary p-n-p transistor. Speed is the other main contributor to distortion.

In many gain configurations, a current-feedback amplifier has a greater bandwidth than its voltage-feedback counterpart. So at a given signal frequency, the faster part has greater loop-gain and therefore lower distortion.

Slew rate

Slew rate performance is also enhanced by the current-feedback topology. Refer to the typical current-feedback topology of **Figure 7**.

Slew rate is determined by the rate at which the second two transistors can charge the compensation capacitors C_c. The current that can be sourced by these transistors is dynamic. It is not limited to any fixed value as is often the case in voltage-feedback topologies.

With a step input or overload condition, the current flowing through the transistors is increased and the overdriven condition is quickly removed. To the first order, there is no slew rate limit in this architecture.

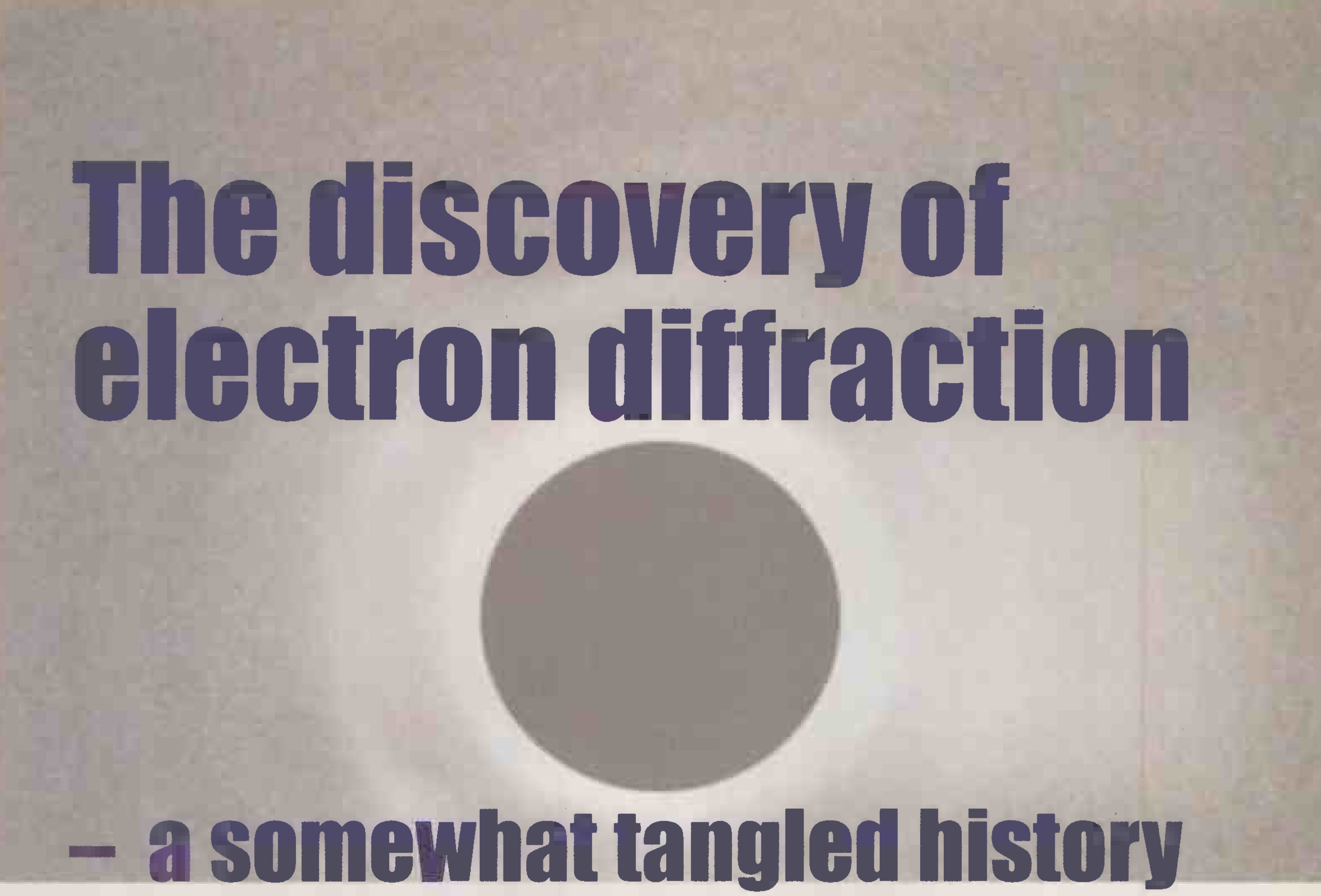
Some voltage-feedback amplifiers have input structures similar to current-feedback amplifiers in order to take advantage of the higher slew-rate possibilities. The combination of higher bandwidths and slew rates allows current-feedback devices to have respectable distortion performance while doing so at a lower power.

The basic current-feedback amplifier has no fundamental slew-rate limit. Limits only come about by parasitic transistor capacitances and many strides have been made to reduce even their effects.

In summary

The availability of high-speed operational amplifiers in both current-feedback and voltage-feedback topologies allows design engineers to select the best amplifier to fit his needs.

A current-feedback amplifier complements an application that requires high slew rates, low distortion, or the ability to set gain and bandwidth independently. voltage-feedback amplifiers complement applications where low offset voltage or low noise specifications are required.



The discovery of electron diffraction

– a somewhat tangled history

Richard Feynman, who contributed a great deal to quantum theory, called the interference of matter waves 'the great central mystery of quantum physics" and having no need to pretend to understand, was quite emphatic in saying that no one does. David Potter unravels.

If one can associate a travelling wave with a moving particle, it is natural to look for evidence of that wave. Broglie's relation $\lambda = h/p$, saying that the wavelength of a travelling particle equals Planck's constant over the particle's momentum, tells us immediately that a particle of baseball mass will have a wavelength so short as not to be measurable even in principle. However, electrons of moderate energy will have wavelengths comparable with the spacing of an atomic lattice, so that bouncing electrons off a metal surface might show the sort of diffraction pattern seen with light bouncing off an ordinary diffraction grating.

The words 'diffraction' and 'interference' will be used almost interchangeably here (Feynman once said he could never tell the difference in them)

The equation for diffraction by light waves and by electron waves is $M\lambda = d(\sin\beta' - \sin\beta)$, where β is the angle between the incident beam and the plane of reflectors, β' is the angle of reflection with the plane, M is an integer and d is the distance between reflectors. λ of course is the wavelength. When the two angles have the same value, the angle of the reflected particles with the incoming beam is twice the incoming angle, giving the more familiar Bragg equation $M\lambda = 2\,d \sin\alpha$ is used, where $\alpha = 2\beta$.

A web search will give many sites discussing electron diffraction, some with excellent diagrams showing how the patterns come about.

All this begs the question of whether the wave is 'real' or just an abstraction, and with what the wave is interacting. Sound waves are periodic variations in the density of the medium and we know how particles, even point particles, can interact with a lattice by momentum transfer. Diffracted electromagnetic waves (again, considering the wave aspect as more than an abstraction) are actually manufactured by the atoms of the lattice (on a higher level, the process is always treated as photon emission). But neither of these mechanisms seems pertinent to how matter waves can be diffracted. There would not be the periodicity if the mechanism were momentum transfer, unless one accepts the early quantum theories of Duane and Lande, and it isn't plausible that the atoms of the lattice are emitting matter waves (Broglie's later pilot wave theory did have the atoms somehow emitting pilot waves to guide the electrons). This later theory was independently worked out by David Bohm in the early 1950s, the beginning of a flood of attempts to bring a sort of reality back into quantum theory.

Meanwhile in Paris...

At the Sorbonne, in 1924, graduate student Louis de Broglie had worked out that for consistency, the new restricted relativity of Albert Einstein must attribute certain wave characteristics to particles. Unless one goes to Broglie's original papers, one will find the best account of how it all came about in Jammer's *Conceptual Foundations of Quantum Mechanics*. Though the idea was not well received, either a chance visit of Einstein to the Sorbonne, or a letter written to him by Broglie's supervisor, kept the thesis from rejection. Both versions are in the literature. According to Jammer, even several years after this, Einstein was somewhat uncertain of the idea when Walter Elsasser's paper, which actually used Broglie's idea, was sent to him. It had occurred to several physicists in Germany not long after Broglie published his thesis that perhaps the reflection of electrons from a metal surface might test Broglie's idea of matter waves. However, perhaps partly due to the economic climate in post WWI Germany, this was not actually pursued in a laboratory.

It is interesting to speculate whether, if Broglie had not developed his thesis, some-

$$M\lambda = d[\sin \beta' - \sin \beta]$$

one else would have in a few years. Seminal ideas often seem to be in the air, with several people more or less thinking of them at about the same time. But the idea of matter waves really seems to have sprung from Broglie's anti-materialist philosophical outlook, which was one somewhat unusual for a physicist of that time. Broglie had been greatly influenced by the philosophy of Henri Bergson in his youth, and during the World War had worked at the military radio transmitter located at the Eiffel Tower. He was influenced at this time by General Gustave Ferrie, who is described in Feuer's book, *Einstein and the Generations of Science*, as a man infatuated by the reality and importance of electromagnetic waves. Thus both from his philosophical leanings and his wartime experience, Broglie was inclined to wave motion as a sort of anti-materialist approach to physics. Jammer describes a different set of influences, his physicist older brother (a specialist on X-rays, who had been involved in the controversy over whether they were particles or electromagnetic waves) and the great theoretical physicist Paul Langevin, who must have also contributed to this mindset.

Another angle

A somewhat different perspective on Broglie is given in Margarita Ryutova-Kemoklidze's book The Quantum Generation. It should be noted first that she is a physicist, a graduate of the Landau Institute. She describes Broglie as "an enthusiastic amateur", saying "Whenever he tried to expound his ideas at a seminar, they would cause general merriment". She quotes Einstein as writing to Born about Broglie's work: "Read it! Even though it gives the impression that it was written by a madman, it is a solid piece of work." Rather than read it,, Born and friends conducted a satiric seminar, making fun of Broglie's idea. Born later developed a probabilistic interpretation of the wave nature of matter, and received the Nobel Prize for that. He is also famous for the 'Born Approximation', found in every quantum mechanics text.

Ryutova-Kemoklidze describes the influence of Broglie on Schroedinger, in the process describing Broglie as not a professional physicist at all, but an art historian. Einstein had brought Broglie's idea to Schroedinger's attention, and Schroedinger's quick transformation of this into wave mechanics had alarmed his wife. When he told her he had made a discovery that was as important as anything Newton had done, she feared for his sanity. It is worth observing here that Schroedinger belonged to no group, was as interested (if not more interested) in philosophy and art as in physics, but had done distinguished work in physics already (he was 38). Schroedinger's wave mechanics made a working tool out of Broglie's idea. But the development of quantum mechanics as a probabilistic theory was never accepted by Schroedinger, as it was not by Einstein.

Without wave mechanics, our idea of the world would surely be quite different today, with the philosophical perspective of Dirac and Heisenberg perhaps having a much greater impact. Broglie and Schroedinger, both outsiders, might not have been easily replaced.

In 1919, Clinton Davisson, employed by the AT&T Research Labs, began to experiment with the scattering of electrons from surfaces. He was not unfamiliar with the new ideas coming into physics, and had published a paper on Bohr's atomic theory in 1916.

The latest technology in telephony then was the dialling switcher, a motorised switch having hundreds of contacts, its stepping motors driven by pulses from the new dial telephones just starting to be used. Naturally, with so many surfaces to become oxidised or corroded, the nature of metal surfaces was of interest to AT&T Labs. There was also some interest in the nature of the emitting surface of thermionic vacuum valves, already used as amplifiers in long-distance telephony.

Electron gun

Davisson constructed an apparatus to fire electrons onto copper, nickel and platinum surfaces, hoping to find just what was on the surfaces. A vacuum chamber placed a primitive electron gun close to the surface being investigated, and the charge 'bounced off' the surface was collected by a Faraday cup (just a metal cup connected to an electrometer). He doubtless expected that there would be absorption of the charge, varying in some way to give information about conditions on the surface, perhaps giving evidence of the shell structure of the atom. Davisson and Kunsman published a paper in 1921 with an account of these results. At this time, neither had heard of Broglie's ideas, and there was no attempt to bring in electron interference.

After this point, there is disagreement amongst various accounts. Max Born, or James Franck, or his student Walter Elsasser, seeing Davisson's article, or without seeing the article, considered the idea that electron diffraction from a crystalline surface might confirm Broglie's idea that material particles were associated with a wavelength which depended on momentum. It does seem established that Elsasser was the first person to analyze in detail Davisson's data.

Jammer states that at first Davisson did not accept the note on this published by Elsasser (which had been published with difficulty). As with so many physicists (even Einstein), waves associated with particles seemed hard to accept. He was introduced to the idea whilst in Europe at a conference, and read Broglie's papers on the homeward voyage.

Davisson resumed his experiments. An accident occurred (vacuum was broken) which required the target in the vacuum chamber to be greatly heated (to bake off the oxide coating resulting from the vacuum break), causing it to re-fuse with much greater regularity. Where there had been many crystals making up the target surface, now there were but a few. Resuming electron scattering, there seemed to be clear maxima at various angles, depending on the voltage used to accelerate the electrons. Davisson was able to relate the scattering angles to electron wavelengths and published a paper on this with Germer in 1927. After this, electron diffraction became an important tool for investigating surface structure, as it still is. Those who want to see the mystery deepen further, can read about the Bohm-Aharoni effect, in which the phase of matter waves, and thus an interference pattern, is affected by passing through a region in which a magnetic or electric potential is not zero, but where there is no electric or magnetic field at all. A good account of this effect is in Mark Silverman's *More Than One Mystery*.

Try this at home

Diffraction can be shown with little expense, using an oscilloscope-type cathode-ray tube and a bit of high voltage. Diffraction rings are seen, easily two, as many as six with more care, with a much brighter central structure, as is seen with photography of a bright star. With proper voltages, a linear diffraction pattern can be seen in the central structure. The rings can be seen over a wide range of voltages, though particular combinations of voltage will sharpen the rings. The central structure requires more care. The eye sees the rings easily, and can see some detail in the central structure at the same time. A video camera or digital camera or film will show either the rings or the central structure, but not at the same time, as the central structure is so much brighter. A better solution would be a CCD camera meant for use with a telescope, since these are more sensitive, exposure time can be varied and

Figure 1: A pair of rings, using a green phosphor 5LP1

Figure 2: The central diffraction pattern, on a green tube

Figure 3: More rings, using a blue phosphor tube

there is processing software to hand. The photographs here do not do justice to the rings as seen by the eye.

The high voltage can be derived from a single supply, as is done in oscilloscopes, using a proper voltage divider. The supply can be arranged to have high impedance outputs for safety. One can buy proportional high-tension supplies cheaply which will give an output two to six kilovolts as the supply voltage is changed from five to fifteen volts. The cathode-ray tube elements do not draw high currents, so that a voltage divider supply can have much more current flowing through the divider proper than is taken by the CRT, thus reducing the interactions of the individual outputs. Many books on oscilloscope circuitry discuss how to make such a divider. These experiments used separate power supplies for the various elements, as such were available.

Older types of cathode-ray tube may be better for this purpose, as they tend to be simpler in construction. Several 5LP1 and 5LP11 tubes were used, a type which has a fairly simple electron gun, and which has post-deflection acceleration. The 5LP1 is a green-phosphor tube and the 5LP11 has a more sensitive blue phosphor which shows more rings. However a newer type with mesh post-acceleration might give diffraction effects at the mesh without a field beyond the mesh to compress the image.

Many books on cathode ray oscilloscopes have a brief discussion of electron optics. One of the best is a manual issued by Tektronix. More detailed books are, for instance, Klemperer's *Electron Optics* (and his *Physics of the Electron*), and Pierce's *Theory and Design of Electron Beams*. Electron guns are usually briefly described in engineering physics texts, as such guns are very commonly found in electronic equipment.

Lensing

The electron gun has a cathode (and heater), a control electrode (often called 'control grid', as the corresponding element in an ordinary valve is a grid) which mainly affects the intensity of the beam, a focus electrode and an accelerator electrode. There is electron lensing by the electric fields between cathode and control electrode, control electrode and focus ring, and between focus ring and accelerator electrode. The mechanism of electron lensing to some extent mimics that of optical lensing, though some differences make one a little uneasy, an attitude palpable on page 37 of Thompson and Cochrane's 1930's book on electron diffraction. Higher voltage between elements contributes toward sharper focusing, but also makes deflection more difficult. The 5LP1, like many others, has post-deflection acceleration, that being a final electric field after the deflection plates. This allows for a sharper, brighter beam without greatly decreasing the deflection sensitivity, but as it has a lensing effect, compresses the image on the screen (this is discussed on pages 41-43 of the Tektronix manual).

For the 5LP1, a typical set of voltages for the ring pattern would be: final accelerator (2nd anode), 4000V, first accelerator, 2000V, focus 500V, control electrode –25V, all measured with respect to the cathode. For observation of diffraction by the deflection plates (as a linear central pattern), the plates can be tied to the focus electrode rather than to the first accelerator. This will cause more of the beam to hit the deflection plates. Voltages used will vary a great deal for different varieties of cathode-ray tube, and vary noticeably for different tubes of the same type.

To observe the rings, one adjusts voltages to get the smallest, sharpest spot, and turns up the intensity, which will burn the phosphor if left for long. One must get the pattern, observe or photograph, and turn the intensity down. For the central diffraction pattern, the same is true, save that one is not after a small central spot.

Figure 1 shows a pair of rings, using a green phosphor 5LP1. To give a sense of scale, an old burlap Royal Mail bag is draped over the tube.

Figure 2 shows the central diffraction pattern, on a green tube and

Figure 3 shows more rings, using a blue phosphor tube.

For safety's sake, final accelerator may be put at ground potential, with other voltages progressively more negative, as most books on the subject recommend. Doing this requires a filament supply for the CRT heater that is well-insulated.

Image capture

The pictures were made with a monochrome high-resolution video camera, fed into a video capture card. This was done rather than using a digital camera, as suitable lenses are more easily available for video cameras. A macro lens was used for the ring pictures, a shorter focal length macro lens used for the linear central structure. In effect, this was a low power video microscope, though nothing is critical or hard to improvise. However a high-resolution digital camera with a macro lens and manual shutter speeds, or an astronomical CCD camera would have been preferable.

In the usual demonstration of electron diffraction, electrons travel through a thin diffracting crystal, and go to a fluorescent screen. A discussion of this, with the pertinent equations, will be found on many websites. With a post-deflection acceleration cathode ray tube, there will be an electric field after the scattering, which has two effects. The field along the trajectory accelerates the electrons, changing the wavelength as the electron travels.

Also, the lensing action of the field compresses the image. Due to these two factors, the usual equation for image size in diffraction does not quite apply. It should be possible to use a ray-tracing program with a varying index of refraction in the post deflection region to work out electron paths but this was not done.

The central diffraction lines seem to be due to scattering off the vertical deflection plates. Where does the ring-pattern diffraction happen? It seems to be coming from the final aperture on the first accelerator electrode, as diffraction from an earlier source would not make it to the screen. As the aperture is too large for visible diffraction as an aperture, and the metal too thick for the usual transmission diffraction; it would seem that small imperfections on the inside of the aperture, as Thompson discusses on pages 138-140, must be the source. It is not impossible that a layer of gas on the surface may also contribute to the rings. From the usual equation, the electrons accelerated by 2000V would have wavelength about 0.27 Angstrom. This, with the last aperture-to-screen distance of 28cm and a first ring radius of about 1cm would give spacing between the atomic planes of about 3.8 Angstrom, which is too large for the nickel-copper electrode. However this doesn't take into account the acceleration of electrons after leaving the aperture, which will reduce their wavelength during flight, and the lensing effect of the final field, which will compress the image.

Most magnetically deflected cathode-ray tubes are focused magnetically as well. Lack of deflection plates would mean there is no central pattern. What effect would the magnetic focusing, which operates so differently from electrostatic focusing, have? One hopes someone will find out.

Of the books on electron diffraction listed below, probably the most friendly is Thompson and Cochrane. Pinsker is much more comprehensive. Beeching, probably the first book on the subject to appear, is easy and pleasant to read. Of the books on electron optics, that by Tektronix is the most accessible, with Klemperer close behind. Of the histories, that by Max Jammer is the gold standard.

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NEWPRODUCTS

Please quote *Electronics World* when seeking further information

Transflective colour STN modules

A 5.7 inch transflective colour STN QVGA module, offering sunlight readability and a temperature range from -20°C to 70°C in now available from Anders Electronics.

The module is one of a range of sizes suitable for a number of applications where performance in outdoor use under high ambient light levels is critical. Applications include data terminals, ticketing and vending machines and portable instruments.

With a long CCFL backlight lifetime, typically 40,000 hours, the 320x240 dot Nan Ya LM639N features built in contrast bias voltage generator, high space efficiency and easy integration into OEM designs. Other sizes available are 3.3in, 3.8in and 3.9in. It has a viewing area of 118.2mm x 89.4mm and operates from a single 5V supply.

Options include a 4-wire resistive touchscreen and a matching CCFL backlight inverter.

Anders Electronics
www.anders.co.uk

Filters represent significant step forward in health and safety in the workplace

Recognising asthma as a serious occupational hazard, Nederman has developed an all-gas filter as an optional extra for its EK pollutional control system. It has four times the absorption capacity of carbon and four times the life, yet does not add to the cost of the EK unit.

Both the EK 1000 and 3000 systems are still available with the original blue filter for dual particle and gas extraction.

Where space is at a premium, and workbenches may not need continuous bench-top extraction, the 2000 and 3000 have trolley mounted options, turning them into fully mobile units.

The adjustable hood on the EK2000 can be shaped to suit various applications, ideal for use in workshops where more than one process is carried out.

Nederman Uk
www.nederman.com

Designers free to choose encoders

Four new incremental encoder families which offer designers the freedom to choose the most cost-effective solution to match their specific requirements are available from ITT Industries.

Suitable for a wide range of applications, the encoders make use of electromechanical technology which delivers the best combination of reliability and low cost.

The 10mm NSE10 series hollow shaft devices have 24 indents and offer a rotational life of 100,000 cycles. NSE11 encoders control the 'play' in the shaft to a tight 0.4mm p-p maximum. NSE devices also feature increased functionality; either parameter validation of on/off switching using a 0.5mm travel, 4.5N actuating force SPST contact. NSE12 incremental encoders also offer the above functionality as well as a very distinct actuating force due to the detent torque controlled at 3 – 20mN.m. Finally the NSE16 features an extended plastic shaft to 31.5mm

ITT Industies, Cannon
www.ittcannon.com

Circuit protection and power switching in a single unit

Featuring a compact, trip free, rocker actuated design, the W51 thermal circuit breakers from Tyco Electronics are available in 5 to 20A ratings. The breakers deliver circuit protection to UL 1077 and power switching in a single unit.

Available with an optional indicator lamp, it can snap into the same 28.5x 13.5mm cutout as other common power switches on the market and provides a seamless retrofit or integration into an existing design. The devices may trip between 101% and 134%, but guaranteed to trip at 135% of rating within one hour. At 200% overload trip time is 4 – 40 seconds, while at 600% overload is 0.3 – 1.8 seconds. Typical resistance at 5A current rating at 25°C is 0.050Ω, while for a device rated at 20A it is 0.0125Ω.

Operating temperature is between 0°C – 60°C. Termination options include 6.35mm quick connects or solder terminals.

Tyco Electronics
www.tycoelectronics.com

Ready-to-connect ultrasonic proximity sensors

New from Contrinex is a range of ultrasonic proximity sensors. Available in M18 and M30 sizes these new devices are ideal for applications where distances have to be measured in air to targets that are solid, liquid, granular or in powder form.

The target material may be transparent or coloured, any shape and have either a polished or matt surface.

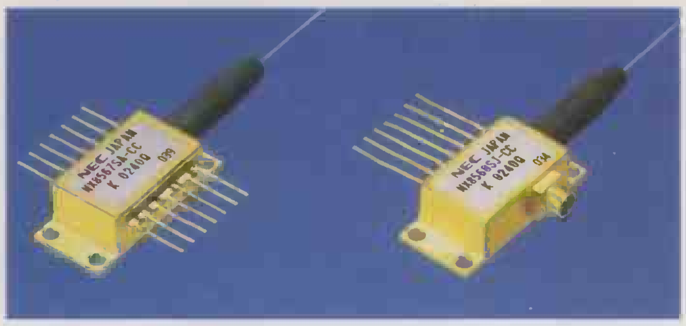
Available as diffuse or reflex sensors and in switched or analogue versions, sensors are notable for their high excess gain as well as a small blind zone and can achieve operating distances of up to 6,000mm.

Detection and switch parameters can be programmed to suit individual applications by means of a PC interface device and the accompanying CONPROG software.

Contrinex
www.contrinex.co.uk

Please quote *Electronics World* when seeking further information

High speed laser diode modules enable compact and economical DWDM optical system



NEC Compound Semiconductor Devices Ltd. and NEC Electronics (Europe) GmbH announced its laser diode modules featuring electro-absorption modulator distributed feedback (DFB) laser diode and built-in wavelength monitor enabling compact and economical dense wavelength division multiplexing (DWDM) optical transmission systems design.

The new laser diode modules are designed for use in backbone and metropolitan area networks (MAN) and are available in two device types: the NX8560SJ Series with a transmission rate of 10 gigabits per second (Gbps) and the NX8567SA Series with a transmission rate of 2.5Gbps. The products are designed for DWDM wavelengths from 1530 nanometers (nm) to 1560nm with 50GHz (O.4nm) spacing based on ITU (International Telecommunication Union).

The laser diode modules feature a built-in wavelength monitor with an etalon filter, which enables a precision-controlled emitted wavelength required from DWDM systems. These modules with built in wavelength monitor function reduce cost of an optical transmitter by more than 25% compared with discrete solution where a monitor module is used externally. The size of the unit is reduced by up to two thirds, allowing a compact and economical DWDM system design. To suit individual applications, two device types are offered. Customers can select from the 10Gbps NX8560SJ Series and the 2.5Gbps NX8567SA Series to match their application, allowing flexible system design.

The light source of the modules consists of:

- a DFB laser diode which is driven by a constant current to reduce the "chirping", i.e., signal transmission distortion caused by wavelength variations
- a monolithically integrated electro-absorption modulator. This enables a transmission distance almost four times longer than that of a directly modulated DFB laser diode with a large amount of chirping.

Mass production of the new laser diode modules is slated to start in April 2004, with annual shipments forecast of 10,000 units in total for all 4 models.

NEC
www.ee.nec.de

Low data rate wireless technology for the medical market

The latest member of the low data rate ASTRIC™ (application specific transmit and receive IC) product family from AMIS is the AMIS-52100. The new chip appeals to sub-5600MHz band wireless applications that require clock and data recovery, and is particularly suited to medical implantable devices. As an alternative to magnetic coupling, the band outlines a specific radio frequency range for two-way communication between medical devices to retrieve important information about a patient's status with improved data transfer rates.

AMIS engineered the 52100 to include its patent-pending Quick Start oscillator with an extremely fast 15μ turn-on time that allows the on-board receiver to quickly power up to check for the presence of a signal in the patented Sniff Mode™. Priced at $1.95 in quantities of 50 thousand units, assuming a 20-lead SSOP package.

AMI Semiconductor
www.amis.com

Mini contactors in three configurations

Aerco now stocks the miniature industrial control equipment from GE Power Controls.The GE miniature contactors are available in both three and four pole versions. IEC947 standard compliant, the range is supplied as 35mm DIN-rail mounted or screw fixing. All contactors in the range are available in three contact configurations and have terminations for screws, fast-on and PCB configurations. It is possible to mount up to four blocks in tandem and a full range of accessories is available.

Aerco
www.aerco.co.uk

High density modular copper cabling

The AMP Netconnect Division of Tyco Electronics has introduced the Mini RJ21 Connector System, a high-density modular copper cabling system.

This new 24-pair cabling and connector solution provides up to 12 ports with a single cable and accommodates applications including 10/100, POE, VoIP, up to Gigabit Ethernet. The traditional modular 4-pair plug and receptacle are unable to meet high density demands, but the Mini RJ21 solution combines reduced form factor, cable management, and channel performance to resolve those problems.

This solution is also applicable for any 'plug and play' environment, including data centres and zone-cabled or open office environments. In addition, the Mini RJ21 solution provides an application-independent copper platform for applications today and into the future, while reducing cable bulk in pathways and spaces.

Tyco Electronics
www.tycoelelctronics

The AMP Netconnect Mini RG21 connector system

ADVERTISERS INDEX

Low-cost logic analyser operates to 100 MHz

The TA320S from Thurlby Thandar Instruments (TTi) is a self-contained logic analyser that offers 32 data channels and 100MHz acquisition for under £600.

Highly compact, but with a built-in LCD screen capable of displaying high-resolution graphics or 40-column text, control and data entry is by a combination of 'soft' keys and an alphanumeric keypad. An RS-232 interface is incorporated which allows data to be sent to (or loaded from) a personal computer.

The TA320S offers 32 data channels at up to 25MHz in synchronous or asynchronous mode, and eight data channels at 100MHz in asynchronous mode. Glitch capture for events as short as 5 ns is also provided. A choice of data pods is available to suit a wide variety of applications.

The trigger sequencer has up to four steps, with event counting and re-start at each step. Clock delay can also be added, and the trigger can be positioned anywhere within the store. Three external clock inputs are provided, each with its own qualifier selectable for active edge and active level respectively. This gives highly flexible clocking for synchronous data capture.

State and timing displays can be selected, and data can be grouped as required under user-defined names. Full search and compare facilities are incorporated. Automatic comparisons between the memories can be performed on a user-specified area of the data, and acquisition can be stopped on an equality or inequality.

Non-volatile storage of both acquisitions and set-ups is also provided, with sufficient memory for ten acquisitions and ten set-ups.

Optional disassembler pods provide support for a range of popular microprocessors. The disassembler software resides within each pod, thus eliminating the need to install special software within the analyser.

The TA320S is highly compact and portable weighing less than 1.5kg. It costs £595 (plus VAT) in the UK.

Thurlby Thandar Instruments Ltd
www.tti-test.com

High performance from small case sized radial electrolytics

NRSZC miniature aluminium electrolytic capacitors from NIC Components Europe Ltd provide low impedance and high stability performance across a wide temperature range. Suitable for use in a wide range of applications including switching power supplies and converters, NRSZC capacitors provide an ideal improved performance update for applications that use NIC's established NRSZ series.

A capacitance range of 47µF to 18,000µF and rated voltage values of 6.3VDC to 35VDC mean that an NRSZC capacitor can be found to suit most requirements.

They have life expectancy of up to 70,000 hours, and an opertating temperature range of -55ºC to 105ºC.

NIC
www.nicomp.com

Please quote *Electronics World* when seeking further information

Mini ESD diodes ideal for high data rate applications

Featuring very low terminal capacitance ratings, the new miniature ESD protection diodes from Toshiba provide electrostatic discharge and surge protection in high-speed signal applications.

The new DFxA5.6Lxx and DFxA6.2Lxx are suited to portable equipment and other high data rate applications where space is at a premium. Configuration options of two, 2-in-one, or four 4-in-1 integrated diodes help to reduce component count and simplify assemble, while package sizes down to just 1.6x1.6x0.55mm (ESV) ensures optimum space savings.

Toshiba
www.toshiba-europe.com

Bluetooth antenna saves space and weight

EPCOS has begun volume production of an antenna for Bluetooth and WLAN applications with centre frequencies in the range fro 2.4 to 2.5GHz.

By using low loss materials and low temperature co-fired ceramic (LTCC) technology. Epcos has kept the antenna's dimensions down to only 10.1x2.6x0.65mm yet the device still features outstanding electrical properties. The antenna radiates up to 70% of the input power even if it is mounted on a conventional mobile phone board. It weighs 0.075g.

EPCOS UK Ltd
www.epcos.com

Breaking tradition – low cost SBC processor modules

An ultra-small ARM processor module, able to function as the processing core of a single board computer (SBC), and priced from less than $50 is now available from Anders Electronics. Based on Intel's Xscale architecture, the module breaks the traditional X86-based relationship of functional content to price and size. With a power requirement of under 1W it offers a viable embedded PC solution for hand-held appliances and consumer electronics where X86 implementations cannot.

Known as the ARMCORE it is part of a range of ultra-small modular SBC building blocks available from Anders, designed to reduce time-to-market and both component and production costs associated with the development of custom embedded PC applications.

Measuring 66x44mm the module offers feature sets comparable to a typical desktop PC and comprises an Intel PXA255 CPU up to 400MHz. Many features are optional according to the application's requirements. The ARMCORE also provides a local bus as well as PCI and LPC buses for interface to off-board expansions. The module is designed for mezzanine attachment to a standard or custom board via two miniature 140-pin connectors.

Prices for an Armbase with Armcore start from $93.

Anders Electronics
www.anders.co.uk

Test cable kit suitable for all standard portable or bench RF test equipment

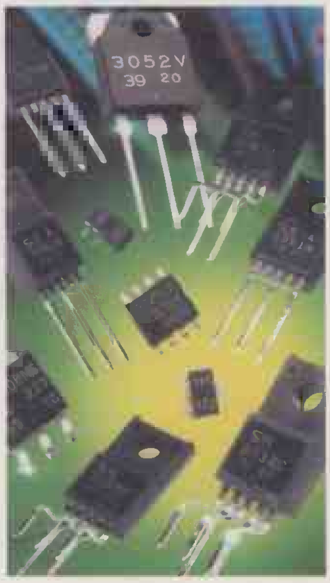
Times Microwave Systems has introduced its TM-2230RK/in36 Testmate TM 50Ohm test cable kit. Designed for operation up to 18GHz, Testmate test cables feature precision stainless steel interchangeable connector heads so expensive adaptors are not necessary. The kit includes the Testmate 230R three foot test cable, a full range of connector interfaces including two N-males, one N-female, one 716 DIN male, one 716 DIN female and wrenches all in a sturdy foam-fitted carrying case.

Times Microwavve Systems
www.timesmicrowave.com

Linear voltage regulator ICs cover wide current and voltage ranges

The SI-3000 Series of linear voltage regulator integrated circuits is available from Allegro MicroSystems Europe. The series includes devices with voltage ratings from 1.5 to 15V and current outputs from 240mA to 3A.

All the devices feature low dropout voltages between 0.3 and 0.8V and low 'off' and quiescent currents. Overcurrent and thermal protection are included as standard. The range includes single and dual output products with both fixed and adjustable outputs. A variety of surface-mount and through-hole package styles is available including ultra-miniature SOT-89 and SOP-8 types.



Allegro MicroSystems
www.allegromicro.com

Please quote *Electronics World* when seeking further information

Compact electronic load handles 80 A and 80 V

The LD300, new from TTi (Thurlby Thandar Instruments), is a DC electronic load with maximum input levels of 80A and 80V, making it ideally suited for use in investigating the behaviour of many different types of DC power sources such as batteries, solar cells, fuel cells or wind generators, as well as electronic power-supply units.

The new unit has a maximum power dissipation of 300W, and is designed to have very low internal resistance to allow operation at high currents with low voltage drop. Operation down to 500mV is possible at currents up to 10A, rising to 1V at 40A and less than 2V at 80A.

The LD300 provides five different operating modes: constant current, constant voltage, constant power, constant resistance and constant conductance. The value of the chosen constant parameter is set by 10-turn controls on the front panel. Alternatively, an external control voltage can also be used to set the level of the load. Any desired waveform can be applied, allowing complex load conditions to be simulated.

An internal transient generator can repeatedly switch the load between two different operating levels set on separate 10-turn controls. The frequency and duty cycle of the transients can be set over a wide range. The transients can also be initiated by an external logic signal. The transitions between the levels have a true linear slewing characteristic in all modes, with the slew rate adjustable over a wide range.

A low-voltage dropout facility is provided to protect sources such as batteries from damaging levels of discharge by reducing the load current when the source voltage falls below the dropout threshold.

Load conditions are displayed using high-accuracy 4-digit meters. The voltage of the source can be sensed either internally for convenience or externally for better accuracy. A current monitor output provides a voltage proportional to the current flowing, allowing the behaviour of a source to be viewed on an oscilloscope or external meter.

The LD300 is fully protected against excessive current, power dissipation or internal temperature, and minimises audible noise by automatically controlling the fan speed according to the power dissipation.

The unit is housed in a compact case measuring 130 x 212 x 435 mm (half rack width, 3U height) with a weight of 6 kg.

The LD300 costs £695 (plus VAT) in the UK.

Thurlby Thandar Instruments
www.tti-test.com

Significant benefits offred from new range of 150V tantalum capacitors

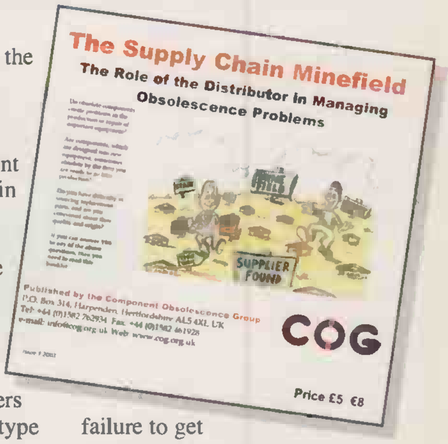
A range of 150V wet capacitors featuring an all-tantalum construction is now available from Arcotronics offering cost saving benefits for module configurations, and elimination of the silver-migration problems associated with silver cased capacitors. Available in four standard case sizes, T1, T2, T3,T4, with capacitance values ranging from 2.5µF to 82µF, the new addition to Arcotronic's TH range is rated at 150V at 85ºC, able to handle high ripple currents up to 1.86A at 40KHz and has reverse voltage capability.

The 150V version will allow the construction of smaller modules with increased operational voltage as well as reduce the number of components required to meet high-voltage requirements of series configurations.

With long life reliability, the products are available in leaded and surface-mount versions.

Arcotronics
Tele: +44 (0)1442 877769

New booklet on managing component obsolescence

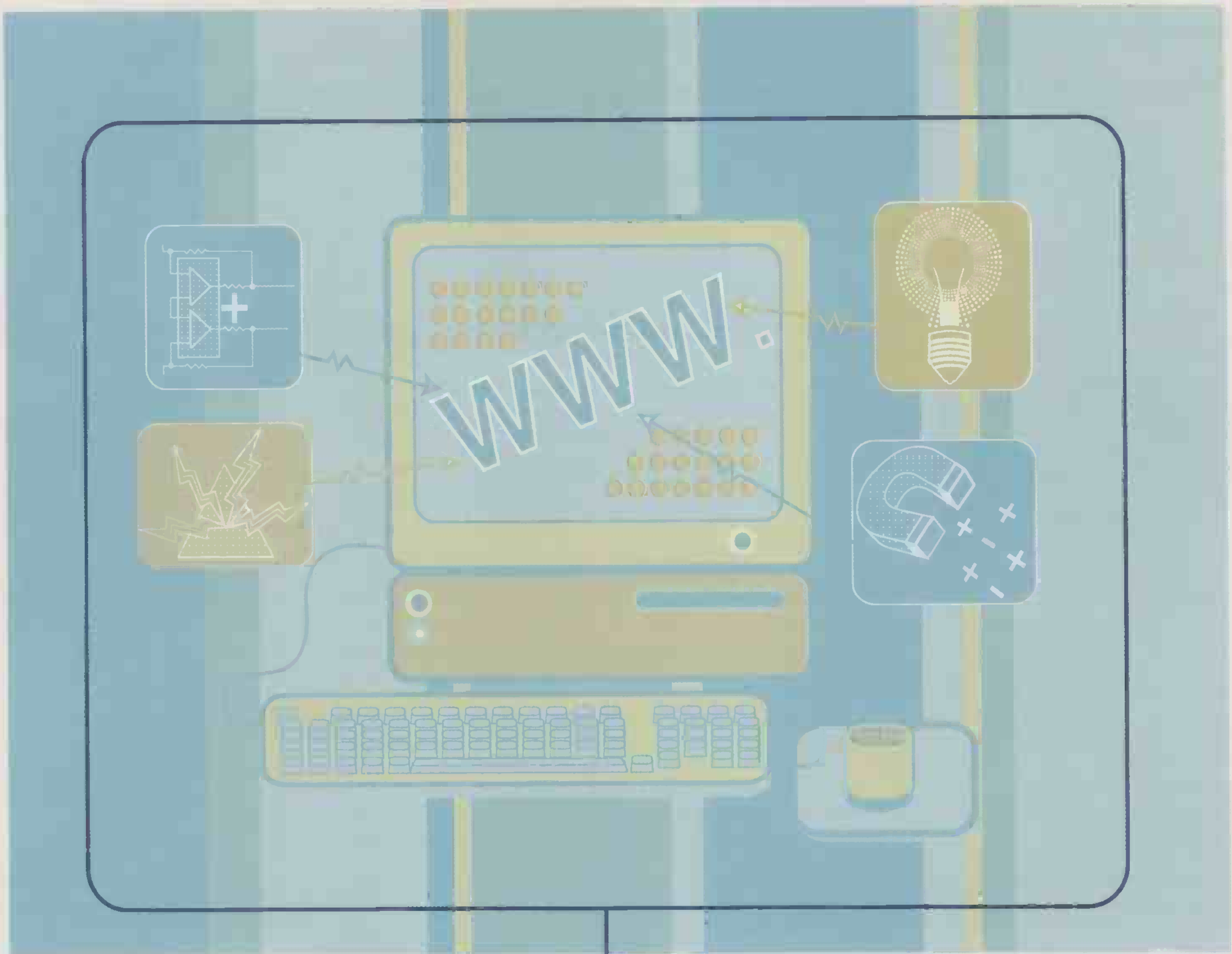


New guidance on managing the issue of component obsolescence to maximise supply chain efficiency has been issued by the component Obsolescence Group COG, in the third of its series of information booklets, 'The supply chain minefield – the role of the distributor in managing obsolescence problems'.

The publication aims to provide guidance for end users to help them identify which type of distributor can best provide the service they need and also gives advice on how suppliers and customers can work together to minimise obsolescent problems.

According to COG, if a component within a piece of equipment becomes obsolete, failure to get suitable replacement parts quickly or at all could incur considerable costs. The booklet costs £5. For futher information about component obsolescence contact:

COG
www.cog.org.uk


www.

Please quote *Electronics World* when seeking further information

New fan filters fare bigger and better

Aerco now supplies new large fan filters from ADDA, available to suit the three most popular fan sizes, 120mm^2, 127mm^2 and 160 x 172mm. They can be supplied separately or with suitable AC and DC fans.

The most popular filter materials are synthetic fibre or polyurethane foam but other materials of different densities can be supplied to suit virtually every application. All are washable and re-usable and the assemblies are louvered for applications that require regular hosing and washing. When a filter is used in front of a fan the cabinet and fan IP rating can be improved to IP 44 compared with the lower rating of a non-protected fan. The filter frame is manufactured from UL 94 VO material.

Aerco Ltd
www.aerco.co.uk

Double feed detection at top speed

Just announced by Murata is a high frequency ultrasonic transducer, the MA200D1, targeted specifically at printers and scanners used in a range of commercial office and banking equipment. This innovative device has the ability to detect the incidence of double feeding of paper through printers and scanners, even when the paper is very thin, very thick or different thicknesses.

The MA200D1 features a fast response time, short ringing time, wide bandwidth and is less influenced by reflection wave than high sensitivity devices. The transducer is specified with a nominal frequency of 220kHz +/-20kHz, with an overall sensitivity of 1 to 2.5V. Aplification gain is 60dS, directivity of 20° and a capacitance of 2300pF +/-20%.

The device is ideal for equipment such as commercial scanners used for cheques and payment slips, for high speed copy machines and printers for business use, and cash dispensers. Murata has responded to customer demand for a sensor that is not fazed by the colour, thickness or transparency of the paper, but which can clearly and rapidly detect a double paper feed, without confusion with a single sheet of thicker paper. Machines using this ultrasonic transducer do not need calibration for paper thickness nor do they require mechanical contact with the paper.

The devices provide a faster response than similar transducers in the range, primarily because it uses a shorter drive cycle (typically cycles at 20Vp-p) at 220kHz, and the signal stabilises faster as there is less reflected wave detected.

Murata's MA200D1 transducer measures just 18mm in diameter and has a profile of 9mm.

Murata
www.murata-europe.com

New ScopeMeters with enhanced features for video imaging engineers

The new upgraded Fluke ScopeMeter handheld oscilloscopes, with enhanced sensitivity and a new troubleshooting feature, are now available from TTi (Thurlby Thandar Instruments).

The new range includes four colour and monochrome models for engineers servicing medical imaging and high-resolution video equipment. With the speed, performance and analysis power usually found only on high-end bench oscilloscopes, and with safety certification to 1000V Category II and 600V Category III, the new instruments will help users to solve virtually all electronics measurement problems encountered in the field.

The new models offer double the maximum sensitivity on the y axis, giving 2mV per division for greater measurement accuracy. A new troubleshooting feature offers automatic waveform comparisons, against a reference trace, for 'pass/fail' testing.

TAll ScopeMeter models now have a large 320 x 240 pixel display, a fast display update rate, up to 1000V independently floating isolated inputs, 'connect-and-view' automatic triggering, a facility for measurement of effective output voltages of variablespeed motor drives and frequency invertors, a 5000-count true-RMS multimeter function, and optional FlukeView software for documenting, archiving and analysis.

Thurlby Thandar Instruments
www.tti-test.com

Search engine identifies parts in less than a minute

C&D Technologies has unveiled an online parametric search engine that will help engineers to dramatically reduce the time that they spend in identifying and selecting the most appropriate DC/DC converters and magnetic components for their power applications.

C&D's 'eFAE' (electronic Field Application Engineer) search engine is now available at www.cdpoweronline.com and allows engineers to select the key product parameters in the priority order that is most relevant for a particular application. The engine will then apply a scoring system based on the inputs given and will rapidly identify the most appropriate parts in a maximum of just six steps.

The parameters that engineers can prioritise when searching for DC/DC converters are input voltage, isolation rating, number of outputs, output voltage, package style and power rating. In the case of magnetic components, key parameters are current, inductance and package style. Parameters are entered in their order of importance, and at each step eFAE narrows down the part list available. Users can search for the most closely matching products at any stage of the process.

Unlike previous search facilities, eF AE allows users to specify parameter priorities, meaning that the most appropriate parts for the particular application can be identified in less than a minute.

C & d Technologies (NCL) Ltd
www.cdpoweronline.com

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AT/HP 8349A/001 20GHz 15dB 21dBm Amplifier	2500	99
AT/HP 8349B 2-20GHz +15dB >50mW Amplifier	2950	89
Amplifier Research 10W1000B 1GHz 10W RF Amplifier	2950	89
Amplifier Research 1W1000 1GHz 1W RF Amplifier	950	48
COMPONENT ANALYSERS		
AT/HP 4155B Semiconductor Parameter Analyser	24000	864
AT/HP 4194A/001/350 40MHz 50 Ohm Impedance Analyser	15750	788
AT/HP 4285A 30MHz Precision LCR Meter	8250	413
DATACOMMS		
AT/HP J3446C LAN Fast Ethernet Internet Advisor	3950	119
Fluke DSP4000 Cat 5e/6 LAN Cable Tester	3250	135
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Microtest PENTA SCANNER+ Cat 5 Cable Tester	975	50
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Dranetz TR2022 10-1000A Current Clamp For PP4300	595	25
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EMC		
Chase LFR1000 9KHz-150KHz Interference Measuring Receiver	850	43
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AT/HP 16500C/03 Logic Analyser Mainframe With 32M Mem	2350	85
AT/HP 16510A 100MHz Timing 25MHz State 80Ch Card	675	30
AT/HP 16510B 100MHz Timing 35MHz State 80Ch Card	890	38
AT/HP 1660A 500MHz Timing 100MHz State 136Ch Log Ana	3650	115
AT/HP 1662A 500MHz Timing 100MHz State 68Ch Logic Ana	2550	89
AT/HP 1662AS 500MHz Timing 100MHz State 68Ch with DSO	4500	178
AT/HP 1670A 250MHz Timing 100MHz State 136Ch Log Ana	4950	195
NETWORK ANALYSERS		
Advantest R3762B 300KHz-3.6GHz Network Analyser	4500	193
AT/HP 3577A 5Hz-200MHz Vector Network Analyser	4750	142
AT/HP 3589A 150MHz Network/Spectrum Analyser	5950	266
AT/HP 8510C Microwave Network Analyser 45MHz-110GHz	22500	975

	Sale (GBP)	Rent (GBP)
AT/HP 8510C/010 Microwave Network Ana 45MHz-110GHz	26500	953
AT/HP 8712ES 1.3GHz Vector Network Analyser c/w S Param	9500	342
AT/HP 8714ES 3GHz Network Analyser c/w S Param	13950	503
AT/HP 8719C/001/010 13GHz Vector Net Ana c/w S Param	19000	684
AT/HP 8753B/006 6GHz Vector Network Analyser	6500	195
AT/HP 8753ES 3GHz Vector Network Analyser c/w S Param	16950	508
AT/HP 89440A/AY7/AY8/9/A/B/H/1C2/1F0 DC-1.8GHz Sig Ana	12750	459
AT/HP 89441A-Various option sets available -Call prices from	14000	504
OSCILLOSCOPES		
AT/HP 54100D 2 Channel 1GHz 40MS/s Digitising Scope	1650	98
AT/HP 54501A 4 Channel 100MHz 20MS/s Digitising Scope	1250	38

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AT/HP 54600B 2 Channel 100MHz 20MS/s Digitising Scope	1350	62
AT/HP 54622D 2 + 16 Channel 100MHz 200MS/s Scope	2950	123
AT/HP 54645D 2 Channel 100MHz 200MS/s + 16 Ch LA	2850	90
AT/HP 54815A 4 Channel 500MHz 1GS/s Digitising Scope	5250	189
AT/HP 54825A 4 Channel 500MHz 2GS/s Digitising Scope	6950	255
Lecroy LC584AL 4 Channel 1GHz Digitising Scope	12250	485
Tek 11801C Digital Sampling Scope (mainframe)	8250	346
Tek SD20 20GHz Single Channel Loop-through Head	1600	85
Tek TDS340A 2 Channel 100MHz 500MS/s Digitising Scope	1700	62
Tek TDS420A/05 4 Channel 200MHz 100MS/s Digi Scope	3750	146
Tek TDS460A/XL 4 Channel 400MHz 100MS/s Digi Scope	3950	143
Tek TDS520A 2 Channel 500MHz 500MS/s Digitising Scope	2750	117
Tek TDS644B/4D 4 Channel 500MHz 2.5GS/s Digi Scope	5550	200
Tek TDS794D 4 Channel 2GHz 4GS/s Digitising Scope	13000	536
POWER SUPPLIES		
Many different units available - Call Us - ....Prices From	250	15
PULSE GENERATORS		
AT/HP 8012B 50MHz Pulse Generator	1100	65
AT/HP 8112A 50MHz Pulse Generator	1850	83
AT/HP 8130A/020 300MHz Pulse Generator	5950	245
AT/HP 8133A 33-3000MHz Pulse Generator	18500	795
AT/HP 8160A 50MHz Pulse Generator	2550	92
RECORDERS		
Sony PC208AX 8 Channel DC-20KHz DAT Recorder	5950	245
RF SWEEP GENERATORS		
AT/HP 8340B 10MHz-26.5GHz Synthesised Sweep Generator	9950	399
AT/HP 83650A 50GHz Synthesised Sweeper	22550	812
AT/HP 83751A/1E1 2-20GHz Synthesised Sweeper	11650	473
AT/HP 83752B/1E1/1E5 10MHz-20GHz Synthesised Sweeper	18500	769
Anritsu 68147B/2A/18 10MHz-20GHz Synthesised Sweeper	9500	395
Anritsu 68377B/2C 10MHz-50GHz Synthesised Sweeper	22750	819
SIGNAL & SPECTRUM ANALYSERS		
Advantest R3261C 9KHz-2.6GHz Spectrum Analyser	5250	235
Advantest R3465 9KHz-8GHz Spec Ana With Digital Tx Mode	6950	298
Advantest R9211A 10mHz-100KHz Dual Channel FFT Analyser	2950	89
AT/HP 11848A Phase Noise Interface	12500	492

	Sale (GBP)	Rent (GBP)
AT/HP 3561A 100KHz Dynamic Signal Analyser	2750	99
AT/HP 3562A 100KHz Dual Channel Dynamic Signal Analyser	3650	110
AT/HP 35660A 102.5KHz Dual Channel Dynamic Signal Ana	3250	98
AT/HP 3585A 40MHz Spectrum Analyser	3950	119
AT/HP 53310A 200MHz Modulation Domain Analyser	3950	119
AT/HP 85024A 3GHz Active Probe	1450	43
AT/HP 8560A 2.9GHz Spectrum Analyser	6750	284
AT/HP 8562A 22GHz Spectrum Analyser	10950	329
AT/HP 8564E 40GHz Spectrum Analyser	23500	846
AT/HP 8591A/010/021 1.8GHz Spectrum Analyser With TG	3950	119
AT/HP 8591E/041 1.8GHz Spectrum Analyser	4500	179
AT/HP 8594E 2.9GHz Spectrum Analyser	6250	225
AT/HP 8595E 6.5GHz Spectrum Analyser	8950	356
AT/HP 8901A/001/002 1.3GHz Modulation Analyser	950	48
AT/HP 8901B 1.3GHz Modulation Analyser	1950	71
AT/HP 8903B/001 20Hz-100KHz Audio Analyser	1800	54
Anritsu MS2601A/1/5 2.2GHz Spectrum Analyser	2950	107
Anritsu MS2667C 9KHz-30GHz Spectrum Analyser	14250	584
Anritsu MS610B 10KHz-2GHz Spectrum Analyser	2650	80
Anritsu MS710C 10KHz-23GHz Spectrum Analyser	7500	225
SIGNAL GENERATORS		
AT/HP 83732B/1E1/1E5/1E8 0.01-20GHz Synth Signal Gen	22500	675
AT/HP 8644B/002 2GHz High Performance Synth Signal Gen	7500	225
AT/HP 8656B/002 0.01-990MHz Synthesised Signal Generator	950	30
AT/HP 8657A 1GHz Synthesised Signal Generator	1600	48
AT/HP 8664A 3GHz Synthesised Signal Generator	16750	685
AT/HP E4421B 250KHz-3GHz Synthesised Signal Generator	5350	161
AT/HP E4432B 250KHz-3GHz Synthesised Signal Generator	7250	261
AT/HP E4433A/1E5 250KHz-4GHz Synthesised Signal Gen	7950	239
Marconi 2032 10KHz-5.4GHz Signal Generator	13250	477
R&S SMY02 9KHz-2GHz Synthesised Signal Generator	3150	95
TELECOMS		
AT/HP 37717C/UKJ PDH Transmission Analyser	2450	74
AT/HP 37721A/004 PDH Transmission Analyser	2750	99
AT/HP 37732A 50BPS-2MBPS Telecom/Datacom Analyser	2950	135
Trend AURORA DUET Basic & Primary Rate ISDN Tester	3250	98
Trend AURORA DUET Basic Rate ISDN Tester	995	50
Trend AURORA PLUS Basic Rate ISDN Tester	350	28
TTC 147 2MBPS Handheld Communications Analyser	3750	113
TTC Fireberd 6000A Communication Analyser	4250	153
TTC Fireberd Interfaces - Many diff types avail from stock...	Call	Call
W&G PFA-35 2MB/s Digital Transmission Analyser	3850	115
WIRELESS		
AT/HP 11759C RF Channel Simulator	6950	209
AT/HP 83220A DCS1800 (1700-1880) Test Set	1750	63
AT/HP 8902A/002 1.3GHz Measuring Receiver	12650	575
AT/HP 8920A/3/4/5/50 1GHz Radio Comms Test Set	4750	143
AT/HP 8920B/1/4/13/14/51/102 1GHz Rad Comms Test Set	5950	179
Anritsu ME4510B Digital Microwave System Analyser	10950	329
IFR 1600S/16/20/21/22/35 1GHz Radio Comms Test Set	3950	119
Marconi 2945 1GHz Radio Comms Test Set	6500	195
Marconi 2955A/2957A 1GHz Rad Comms Test Set with AMPS	2750	99
Marconi 2955R 1GHz Radio Comms Test Set	3150	114
R&S CMD55/B1/4/6/9/41/42/43/44/51/61/U18/U20 RCTS	6550	236
Racal 6103/001/002 Digital Mobile Radio Test Set	6950	279
Wavetek 4201S Triband Digital Mobile Radio Test Set	3500	105
Wavetek 4202S/AM Triband Digital Mobile Radio Test Set	3500	105
WaveTek M248330 Antenna Coupler	285	23

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Phase-selector for three-phase mains supply

Modem residences are usually three-phase supplied. On the other hand most domestic equipment is single phase. While complete failure of all the three phases are nowadays rare, brown-outs and blackouts on one or two phases are not uncommon. Uninterruptible Power Supplies (UPSs) provide a short-term solution and they do not come cheap; also under most mains conditions 'decorative'. What is needed to improve the availability of single phase mains operated equipment is a device that would detect intolerable brown-out or black-out in the mains phase on which the equipment is operating and effect automatic switching to any one other phase with tolerable line voltage.

The design also provides a measure of protection against brown-out on the operating line by a switch 'search' to a more tolerable line. If no brown-out tolerable line is available, the supply to the appliance is switched off. In operation, each active line of the A.C. Mains voltage is converted to D.C. control line voltage of approximately 2.5V in the absence of brown-out by the use of the IN4007 rectifier diode. The 22mF capacitor and resistors form an R-C filter network. The IN754 provides voltage stabilisation for a level of deviation of the A.C. Mains from the nominal 220V. The 1k resistor in conjunction with the other resistors form a potential divider with values chosen to provide the needed D.C. control line voltage and a brown-out A.C. cut-in voltage of approximately 110V. The three D.C. control line voltages are fed as inputs to a 'prioritized' line switching logic controller consisting of the combination of 7404 and 7411 logic gates switching in one line of the A.C. mains to the output driver transformer consisting of three separate primary windings each of which has a ratio of 1:1 to the secondary winding, in accordance with the designed switching logic priority. The line switch priority engages Phase 1 A.C. mains line to the output transformer driver if the Phase 1 A.C. line voltage is above the design brown-out cut-in voltage irrespective of the states of the other two lines that are automatically disengaged from the output driver transformer. Phase 2 line is engaged to the output driver transformer if there is Phase 1 black-out or Phase 1 voltage falls below the design brown-out cut-in level, irrespective of the state of Phase 3 line which in conjunction with Phase 1 line is automatically released from the output driver transformer. Phase 3 line is engaged in operation and Phase 1 and Phase2 lines automatically released from the output driver transformer if black-out occurs in both Phase and Phase 2 lines or their line voltages fall below the designed brown-out cut-in voltage level.

Sode-shinni N.J. RUMALA
Minna, Niger State
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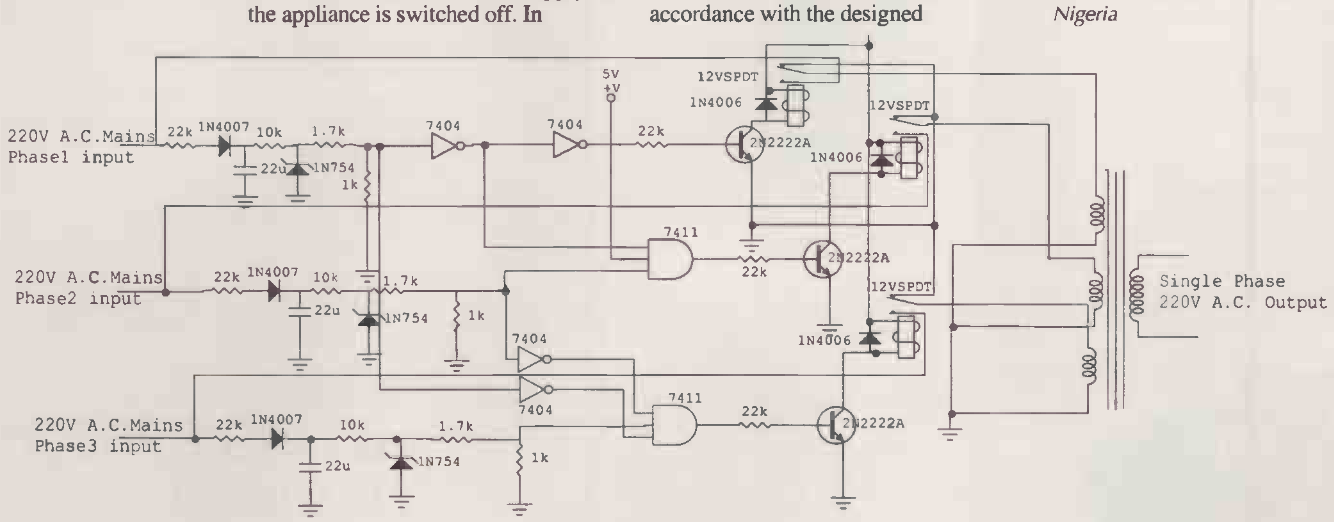


Intelligent electric fence with burglar alarm

Crude electric fences that are used with a live electric wire around the compound may cause many problems to the locality such as a fence kept for animals like donkeys may affect a dog or smaller animals which are not our target. The circuit presented here differentiates a dog and a donkey or any creatures having somewhat different sizes (taking account of its body resistance). This circuit also works as a burglar alarm. The cost of making this kit is much less £3 pounds excluding the power supply. Normally electric fences cause heavy shocks that may lead to death of the intruding organism. With this circuit there will be a shock for about 22 milliseconds that will be helpful to push the intruder away from the fence. This circuit will be highly useful for farmers, homes and security people.

The working of this circuit is very simple, as every body knows that when a phase and earth is short-circuited a current will be induced in the wire. This principle is used for making this circuit. The change in electric current is sensed and made to operate a relay via a operational amplifier.

The heart of this circuit is the transformer T1 which can be made easily with parts from a old power supply eliminator transformer from the junk box.

For the construction of transformer T1; take a 6-0-6 PSU transformer of 300 to 500mA capacity, then remove its secondary windings. The primary windings in the transformer is the winding C pointed out in the circuit diagram. A&B are 23 turns of 15SWG bifflar windings with terminals Al, B1, A2 & B2.

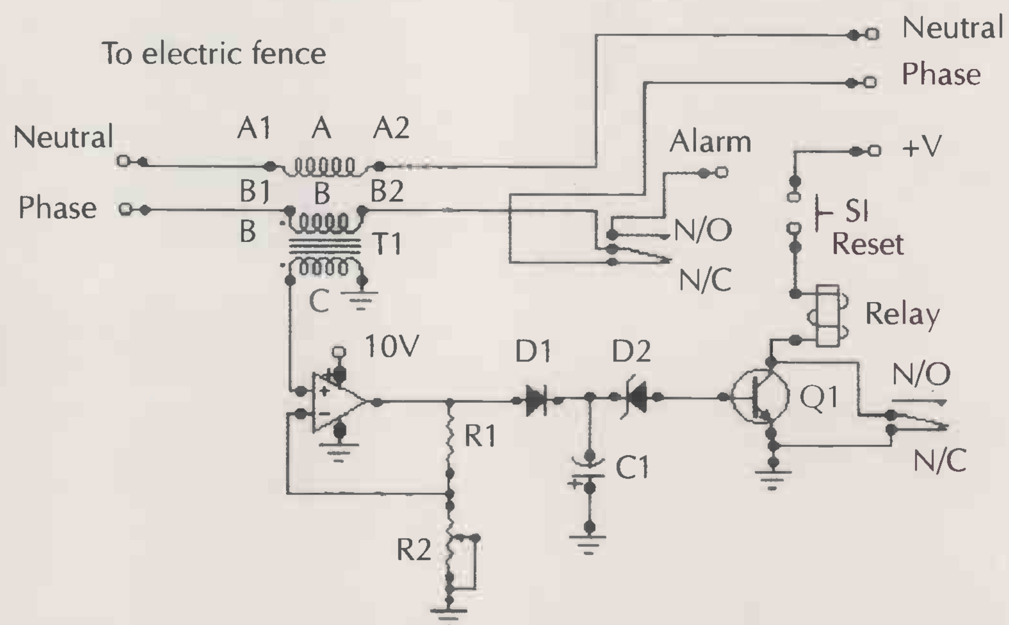
As stated above, the main principle is that the induced current is fed to an operational amplifier where it is amplified. A 10k potentiometer is used to adjust the sensitivity of the relay according to our needs. Diode D1 is used to rectify the output from the op amp and zener diode D2 is used to to cancel offiset voltage and noise effects. The push to on switch is used to reset the system and transistor Q1 is a npn switching transistor, but any transistor of this type can be substituted. The power suppley is an ordinary 10V dc.

This circuit can also used to prevent electric accidents. The same arrangement can be used with the main power supply when any short occurs the main power will be automatically cut off within 15-20 milliseconds. So this circuit is a worthwile one for any electronics enthusiasts who often get a shock!

P. M. Prabhu
Kerala,
India

Components:

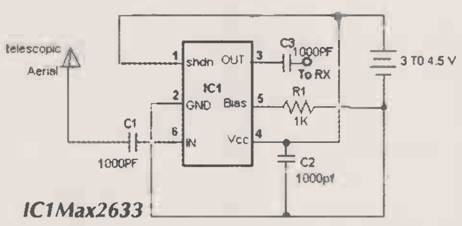
- Transformer T1 (see text)
- IC MC1458/LM741
- Diode DI IN4001
- Diode D2 5.2V Zener
- Relay DPDT 12V 200 Ohms 5A
- Capacitor Cl 4.7mF 25V
- Resistor R1 100k
- R2 10k potentiometer
- Alarm any type
- Transistor Q I SI, 100
- Switch on-off switch or push to off switch



VHF Preamplifier using Max2633

Here is a high performance RF amplifier for the entire VHF band that can be successfully built without any special test equipment. The grounded-gate configuration is inherently stable without any neutralisation if reasonably good layout techniques are employed. The performance of the amplifier is quite good. The noise figure is below 2dB and the gain is over 13dB. The low noise figure and good gain will help car radios or home stereo receivers pick up those weak distant stations or the lower power 'talk radio' and university stations or distant amateur VHF stations. FM receivers loose signals abruptly, so if your favourite station fades in and out as you drive, this amplifier can have a dramatic effect.

The MAX2633 is a low voltage, low-noise amplifier for use from VHF to microwave frequencies. Operating from a single +2.7V to +5.5V supply, it has a flat gain response to 900MHz. Their low noise figure and low supply current make them ideal for receive, buffer, and transmit IF applications. The MAX2633 is biased internally, has a user-selectable supply current, which can be adjusted by adding a single external resistor (R1). This circuit draws only 3mA.



IC1Max2633

Aside from a single bias resistor(R1) required for the MAX2633, the only external components needed for this familyof amplifiers are input and output blocking capacitors(C1 and C2) and a VCC bypass capacitor (C2). Input and output series capacitors may be necessary to block DC bias voltages generated by the amplifier from interacting with adjacent circuitry. These capacitors must be large enough to contribute negligible reactance in a 50W system at the minimum operating frequency. Use the following equation to calculate their minimum value:

D. Prabakaran
Tamilnadu
India

Leakage current jig

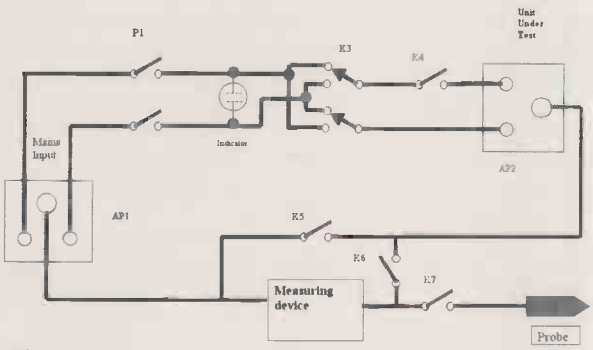


Diagram 1

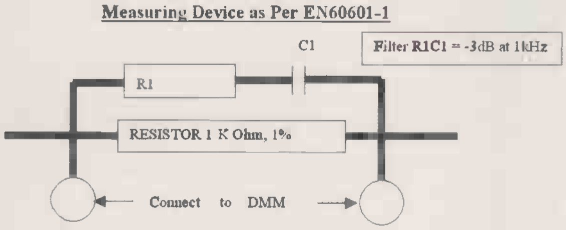


Diagram 2

The following was generated after a request for a simple and relevant leakage current jig required by manufacturers who were manufacturing for a hospital environment and which was not required to be physically touched by a patient but there presence in the hospital is required.

Most of the manufacturers do get their equipment tested for the general electrical requirements as per EN 60601-1, the prime standard for all medical electrical requirement. One of the most important parameters to be investigated in the equipment under test as per the specification is the leakage currents.

The classification of Medical Electrical Equipment standards is as in **Table 1**. Most of the equipment which does not have the necessity of connecting directly to the patient or act as supporting equipment can be classified as Class I, Type B equipment. This limits the area of the investigation regarding the leakage currents. The types of leakage currents applicable and their limits are as in **Table 2**. The jig described here makes a simple tool for measurement of the leakage currents.

The block diagram depicts the workings and connection logic for the measurement of the leakage currents. **Table 3** details the status of the contacts for the relays for the test number.

The box marked as 'measuring device' is for measuring the leakage current at different conditions. The details of the measuring devices are in **Diagram 3**. A true RMS digital multimeter in auto range in AC voltage measurement setting is connected across the 'measuring device'. The current is measured as voltage across the Measuring Device (at the highest resolution setting for meters which don't have auto-ranging facility).

The circuit **(diagram 2)** is the heart of the unit. The micro-controller was used because it will be very handy if you have to modify the same board for some other jig or add some new feature, which would be required by the manufacturer.

The operation of the jig is very easy. On power on via the switch P1 in **Diagram 1**, the display DP lights and is ready for making measurements.

The next step is to select the test number by pressing the key K1. After the DP lights, every time the K1 is pressed the seven segment display increments by 1 starting from 0. The relation of the displayed number on the display with the test in progress is as given in **Table 2**. **Table 2** gives the maximum limits of current which is allowed as per EN 60601-1 for the Class I, Type B equipment.

Jayant Kathe
Mumbai, India

Editor's note: the code for this project is available by contacting Caroline Fisher (details page 3) quoting reference CI 65.

Parts list:

1 AT89C2051P	IC1
2 4511N	IC2
3 7805T	IC3
4 12MHz	Q1
5 Seven Segment Display (Common Cathode)	D1
6 Transistor PNP TIP42C	T1, T2, T3, T4, T5
7 Transistor PNP BC557	T6
8 Switch	S1, S2
9 Relays (12VDC type)	K3, K4, K5, K6, K7
10 Terminal	X1, X2, X3, X4, X5, X6
11 Appliance Coupler	AP1
12 Socket	AP2
13 Resistor 560Ω	R1, R2, R3, R4, R5, R16, R17, R18
14 Resistor 10KΩ	R19, R6, R7, R8, R9, R10, R20, R21
15 Resistor 24Ω	R11, R12, R13, R14, R15
16 Capacitor C1	10µF
17. Diodes 1N4004	D3, D4, D5, D6

Table 1
Classification/Type of Equipment to be Tested

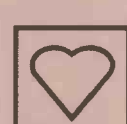
Class I		There is no Symbol for Class I equipment, however Class I equipment will generally have a protective earth marked with the symbol as indicated
Class II		Test Equipment will be marked with the symbol as indicated, It has double or reinforced insulation as the protection against electric shock
Type B		Test Equipment will be marked with the symbol as indicated. It is defined as having a protective earthed applied part, suitable for internal and external application to the patient, except for direct application to the heart
Type BF		Test Equipment will be marked with the symbol as indicated. It is defined as having an F-type isolation (floating) applied part suitable for internal and external application to the patient, except direct cardiac application.
Type CF		Test Equipment will be marked with the symbol as indicated. It is defined as having F-type isolated (floating) applied part suitable for direct cardiac application.

Diagram 1

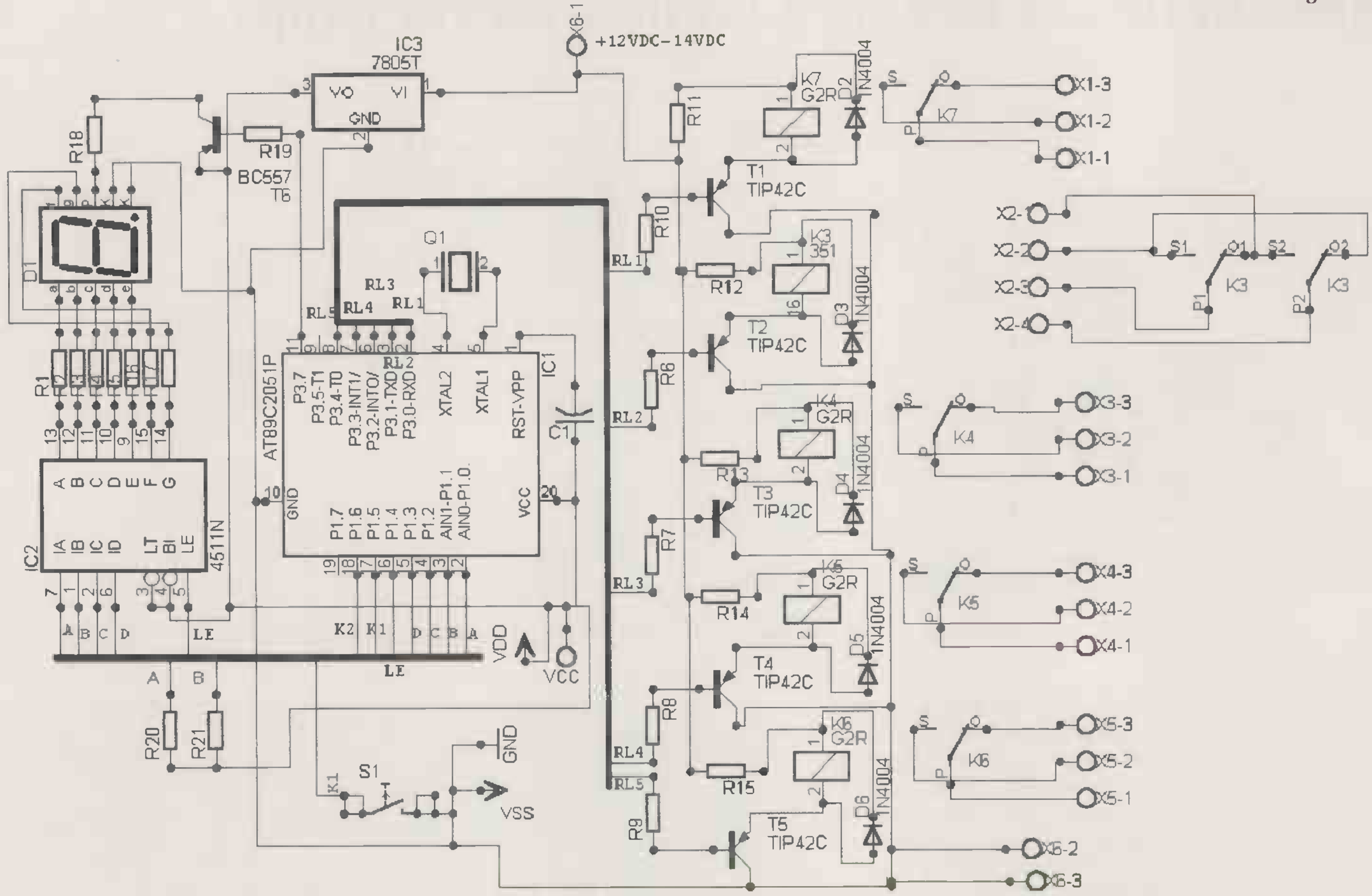


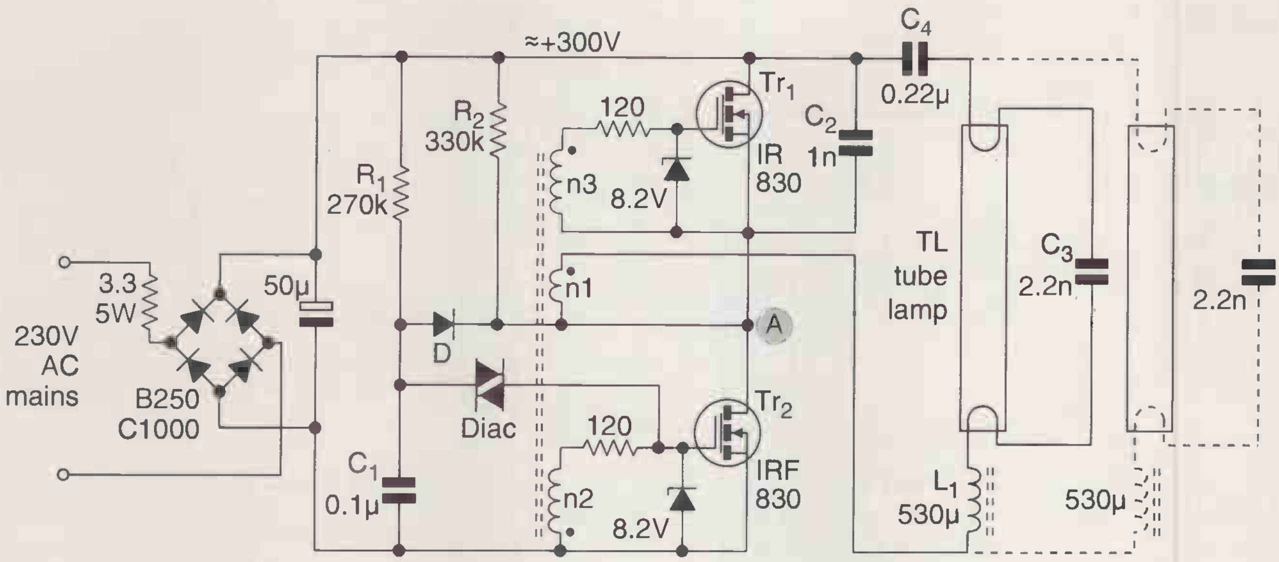
Table 2

Test No.	*Limits of Leakage Current as per Spec EN 60601-1*	*Test Name*
0	500µA	Earth leakage Current : Normal Mains Input Condition
1	500µA	Earth leakage Current : Reversed Mains Input Condition
2	1000µA	Earth leakage current : Normal Mains Input: Single Fault condition (Supply Open)
3	1000µA	Earth leakage current : Reversed Mains Input : Single Fault condition (Supply Open)
4	1000µA	Enclosure Leakage Current: Normal Mains Input Condition
5	1000µA	Enclosure Leakage Current: Reversed Mains Input Condition
6	500µA	Enclosure Leakage Current: Normal Mains Input: Single Fault condition (Supply Open)
7	500µA	Enclosure Leakage Current: Reversed Mains Input: Single Fault condition (Input Open)
8	500µA	Enclosure Leakage Current: Normal Mains Input: Single Fault condition (Earth Open)
9	500µA	Enclosure Leakage Current: Reversed Mains Input: Single Fault condition (Earth Open)

Table 3

Test No.	*Relay K3*	*Relay K4*	*Relay K5*	*Relay K6*	*Relay K7*	*Test Name*
0 .	OFF	ON	OFF	ON	OFF	Earth leakage Current : Normal Mains Input Condition
1	ON	ON	OFF	ON	OFF	Earth leakage Current : Reversed Mains Input Condition
2	OFF	OFF	OFF	ON	OFF	Earth leakage current : Normal Mains Input: Single Fault condition (Supply Open)
3	ON	OFF	OFF	ON	OFF	Earth leakage current : Reversed Mains Input : Single Fault condition (Supply Open)
4	OFF	ON	ON	OFF	ON	Enclosure Leakage Current: Normal Mains Input Condition
5	ON	ON	ON	OFF	ON	Enclosure Leakage Current: Reversed Mains Input Condition
6	OFF	OFF	ON	OFF	ON	Enclosure Leakage Current: Normal Mains Input: Single Fault condition (Supply Open)
7	ON	OFF	ON	OFF	ON	Enclosure Leakage Current: Reversed Mains Input: Single Fault condition (Supply Open)
8	OFF	ON	OFF	OFF	ON	Enclosure Leakage Current: Normal Mains Input: Single Fault condition (Earth Open)
9	ON	ON	OFF	OFF	ON	Enclosure Leakage Current: Reversed Mains Input: Single Fault condition (Earth Open)

Instant flicker free turn-on fluorescent lamps



Electronic power supply devices for lighting purposes are widely used in low-power, so called energy saving lamps. However, in the larger power TL or TLD tube lamps for domestic use, no such solutions are found. This circuit was developed to provide instant, flicker-free turn-on of the popular 1.2/36W and 1.5/50W lamp types by means of a h.f. power oscillator working at about 115kHz. An additional benefit of the h.f. feed is the better light efficiency as compared to the present-day 50/60Hz installations.

After switching-on the mains, resistor R1, capacitor C1 and the Diac form a low-frequency sawtooth oscillator which feeds a series of short pulses into the gate of T2 until the gate capacitance is sufficiently charged and T2 starts to conduct. T2 draws current from the power supply via n1 of transformer TR, inductor L1, capacitor C3 and capacitor C4. The current through n1 induces feedback voltages in n2 and n3, as a result of which the h.f. oscillator starts. Resistor R2 keeps diode D blocked until the start of the main oscillator after which the voltage on C1 is kept low by D and T2.

The frequency of the h.f. oscillator is in the first instance determined by the series-resonance circuit L1 - C3, and is about 145kHz. In resonance, the voltage on C3 exceeds the ignition voltage of the tube (about 1600V) and the tube turns on. After turn-on, the voltage on C3 collapses to the value for normal working conditions, about 320Vp, and the frequency drops to 115kHz due to the heavy loading of C3.

COMPONENTS:

Transformer TR

n1, n2 and n3 wound on ferrite ring core, outer diameter 14mm, me 2000 - 3000

n1: 4 turns*

n2: 6 turns

n3: 6 turns

All in solid insulated copper wire

***with 2 lamps in parallel: n1 = 2 turns**

Inductor LI

Ferrite potcore 26/16mm, me 220, 28 turns of stranded insulated copper wire (litz) (The use of 0.7mm solid copper wire is an alternative but may result in a too low Q value to turn the lamp on)

Capacitor C3

A high quality polypropylene type is needed here, again because of circuit Q Working voltage 1000Vdc at a minimum.

The signal at point A is a clean square wave with an amplitude equal to the supply voltage, about 300V. Capacitor C2, removes any possible switching spikes, The current through the tube, about 470mA, is controlled by L1; a smaller inductance gives a higher current. The transistors operate in an on/off mode and will need only a little heat sink, if any. The values for frequency and current are valid for one tube connected. However, the circuit is capable of feeding two tubes in parallel (and is in use as such). The only change needed is halving the number of turns for n1.

Fred J. Hofman
Bellingwolde
Netherlands

A novel power good indicator circuit for isolated power supplies

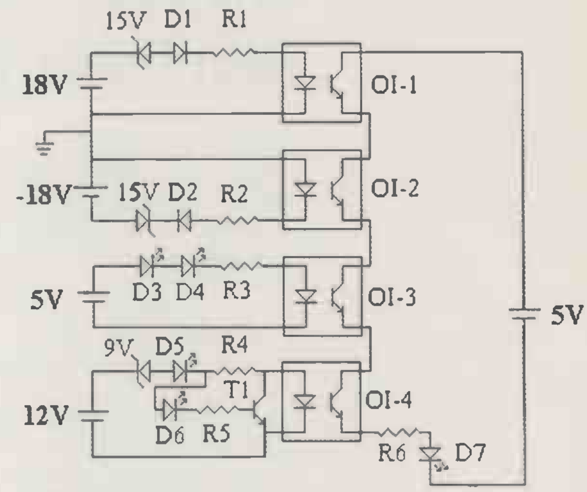
In many electronics systems isolated power supplies at various voltage levels are used. Ground isolation of these power supplies is a must to achieve electromagnetic compatibility. A circuit that gives single power good indication maintaining ground isolation among various power supplies is required for such power supplies.

The circuit presented here is a simple and effective solution to a generate power good signal in multiple output power supplies. The circuit is used for a SMPS in which ±18V, 12V and 5V isolated supplies are generated. It is required to give a power good LED indication on front panel while maintaining ground isolation when the ±18V supply voltage level is above ±17V, and when 12V supply level is between 11.5 and 13V and when the 5V supply voltage level is above 4.7V. To achieve this each power supply voltage level is compared with a respective threshold level. The threshold level is set with combination of zener diode and diode or LED. When supply voltage is higher than the threshold set level, current flows through the photodiode of the respective opto-isolator. The threshold level for the 18V supply is set by a 15V zener diode in series with diode 1N4148. For the 5V supply voltage two green LEDs (D3-D4) are connected in series to set the threshold.

In a case where higher level is also to be sensed, a transistor is added to the basic threshold detection circuit mentioned above that bypasses the current in the diode of the opto-isolator. In this circuit it is incorporated for the 12V supply. For the 12V supply the lower threshold is set by a 9V zener in series with a green LED (D-5). When the input voltage exceeds 11.5V, the opto-isolator diode conducts. If the supply voltage is higher than the higher level (13V) the transistor (T1) turns on and the current in the photodiode of the opto-isolator is bypassed that turns off the opto-isolator transistor. All the opto-isolator transistors are connected in series. When all the voltage levels are proper all the opto-isolator transistors are on and then only power good indicator LED glows. A suitable supply voltage (5V here) among the various available is selected to power up the power good indicator LED and accordingly the resistor value R2 is calculated. This circuit function can be described as wired AND of optically isolated signals where parallel electrical input signals are logic high when each input voltage level has particular range.

In this circuit four pin opto-isolators (HCPL 817 or equivalent) are used that provide a compact package for this application. The circuit can be easily adapted for sensing of any other voltage levels (or ranges as done for 12V supply) by properly setting the threshold voltage levels as per specific requirements.

A novel power good indicator circuit



D1-D2 Diode 1N4148, D3-D7 LED, T1 BC547C, OI 1-4, Optoisolator HCPL817 or equivalent, R1-R5 220Ohm, R6 1.8kOhm. (all 1/4W) D7 is Front panel LED.

S.V.Nakhe
Indore,
India

Digital Dice

IC1a & IC1b operate as an oscillator at a frequency of about 4kHz. The frequency of oscillation is not critical, it simply needs to be high enough to prevent cheating.

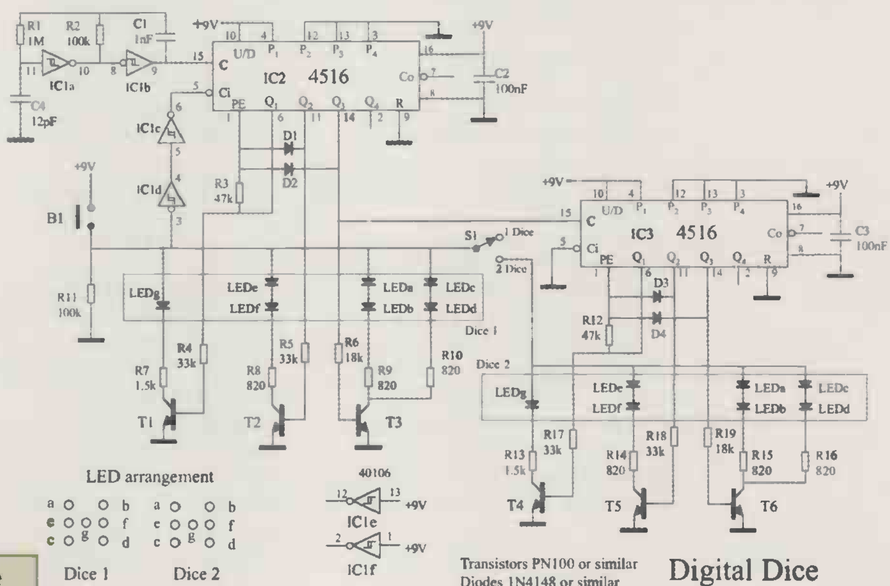
IC2 and IC3 are Binary Counters configured to count in binary from 1 to 6. I found C4 necessary to prevent an oscillation on the transitions. The count sequence is:-

.A 'power on reset' is not required since, if the initial state is outside the correct range, the counters will count into the correct range after a few clock pulses.

Consider IC2 first. When the counter reaches 7 (i.e. 111), the AND gate formed by R3, D1 & D2 applies a High to PE and this presets the counter to 1 (i.e. 001) thus PE goes Low. The counter then increments in the normal manner until it reaches 7 again. Counter IC3 operates in the same manner except that the clock signal is derived from IC2/Q3.

Count Sequence

Q3	Q2	Q1
0	0	1
0	1	0
0	1	1
1	0	0
1	0	1
1	1	0



Normally, the counters are incrementing continuously. When button B1 is pressed, IC1d/4 goes Low and IC1c/6 drives the Ci input of IC2 High thus stopping the counters.

B1 also applies +9 Volts to the LEDs to enable them. Transistors T1 to T6 are turned on by Highs on the Q outputs thus the LEDs indicate the states of the counters. When B1 is released, counting continues.

If two dice are required, S1 is set to the '2 Dice' position thus enabling the second dice.

Len Cox
Forest Hill,
Australia

Analogue single span 0-180° phase shifter with linear phase control

This novel analogue circuit has a variable, single span 0-180° phase shift, virtually linear depending on the setting of a pot. By taking 90° phase shifting and the control function apart, an extremely simple control is possible. The essential part of the circuit consists of a potentiometer loaded with a negative resistor.

Common analogue phase-shifters are hampered by a strong non-linear relationship between control and the resulting phase shift. Another nuisance of many circuits is a voltage gain depending on the selected phase. Analogue circuits that accomplish large variable phase shift like the all-pass filter, never combine a linear single span 0-180° phase shift with only one variable control element. With exception of the all-pass network, all the phase shifters have an absolute gain that varies with the phase setting. Unfortunately the all-pass network exhibits a non-linear relation between control resistor and resulting phase. Furthermore the 0-180° range requires the control resistor to vary from zero to infinity. The presented circuit has a nearly (±1.05°) linear relation between potentiometer setting and resulting phase shift. The maximal gain change is a mere ±3.4%.

The circuit consists of a potentiometer with known resistance loaded with a negative resistor as indicated in **Figure 1**. The output voltage is taken from the wiper. U_0 is the input voltage, -U0 is its inverse and jmU_0 is a scaled, 90° shifted voltage source. The setting of the pot is given by _ ; 0 ≤_ ≤ 1 . _ =0 corresponds with 0° phase shift, _ =1 corresponds with 180° phase shift. At the halfway setting, _ =0.5, the real components cancel and only the 90° shifted signal stays. These three points are one straight line. *k* is the ratio of the absolute value of the resistor and the total resistance of the pot. The gain of this circuit as a function of the pot setting is given by

$$\frac{U_1}{U_0} = \frac{k(1-2\alpha) + jm(\alpha - \alpha^2)}{k + \alpha - \alpha^2}$$

The modulus equals

$$\left|\frac{U_1}{U_0}\right| = \frac{\sqrt{k^2(1-2\alpha)^2 + m^2(\alpha-\alpha^2)^2}}{\left|k+\alpha-\alpha^2\right|}$$

, the argument is given by

$$\varphi = \tan^{-1}\left(\frac{m}{k}\frac{\alpha-\alpha^2}{1-2\alpha}\right)$$

Minimizing the peak error of

$$\left|\varphi - \pi.\alpha\right|$$

results in a peak phase error of ±1.054° at *m/k* = 2.7105.

Minimizing the gain error,

$$\left|\frac{\sqrt{k^2(1-2\alpha)^2 + m^2(\alpha-\alpha^2)^2}}{\left|k+\alpha-\alpha^2\right|} - 1\right|$$

while using *m/k* = 2.7105, results in *k* = -0.7752. With *m/k* = 2.7105 implies this the value *m* = -2.101 . The gain varies only ±3.4% around 0.966, its nominal value.

Figure 2 shows the circuit of the variable-phase oscillator as used in our low-cost low frequency lock-in amplifiers. The essentials are drawn in bold. All resistors are 1% metal film types, the capacitors are 10% polyester foil types. The 10kΩ pot (R), a wire-wound precision 20 turn potentiometer, sets the phase. Conductive plastic potentiometers cannot be used, due to their large tolerances (typical 20%) on the total resistance. The division ratio of an unloaded potentiometer doesn't depend on its resistance. Opamp #IV together with the resistors 10kΩ, 10kΩ and 7752Ω form the negative resistor kR. 7752Ω can be realised by the E24 resistors 8k25 and 121k in parallel. The factor *m* has been realised in the two-phase oscillator by changing the time-constant of the integrator containing Opamp #II. The circuit with Opamp #I is a positive integrator, allowing for easy implementation of gain control needed for stabilising the amplitude of the oscillations. See ref. 1 for details on the oscillator circuit. Opamp # III is a sign inverter and the buffer amplifier, Opamp #V, removes any unintended loading of the pot. A not depicted amplitude stabiliser completes the variable phase oscillator. The odd value of 2k265 (10k*1/m2) can be obtained by the series connection of two standard E24 resistors: 2k21 and 562Ω. By changing the value of this resistor, one can compensate for tolerances in the capacitor values at expense of a frequency change. The frequency of the oscillator depends on the two integrator time-constants and equals

$$f = \frac{m}{2\pi\sqrt{R_1 C_1 R_2 C_2}}$$

R1=R2=10kΩ and C1=C2=100nF, giving 334Hz. The measured 322Hz deviates because of capacitor tolerances. In our lock-in application the 0° and -90° outputs are fed to voltage-comparators that drive the MOS-switches. The comparators allow ±3.4 % amplitude changes. The sine output is made really independent of the phase setting by action of the amplitude stabiliser.

Checking the circuit's actual performance necessitates two minor changes in the diagram shown. The amplitude stabiliser has to be connected to the output of Opamp #II in order to stabilise its voltage. In our case at 2.10Vrms. The second modification is the addition of a switch in the connection of the negative resistor, the + input of Opamp #IV, to the pot's wiper. The small residual voltages at the inputs of Opamp #II and #III, 0.46mV ∠-90° and 0.22mV∠-90° respectively, make correction of the

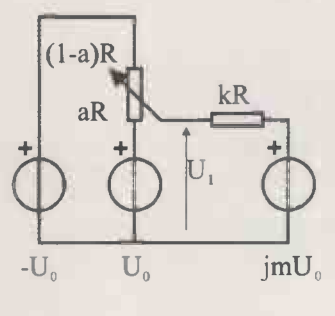
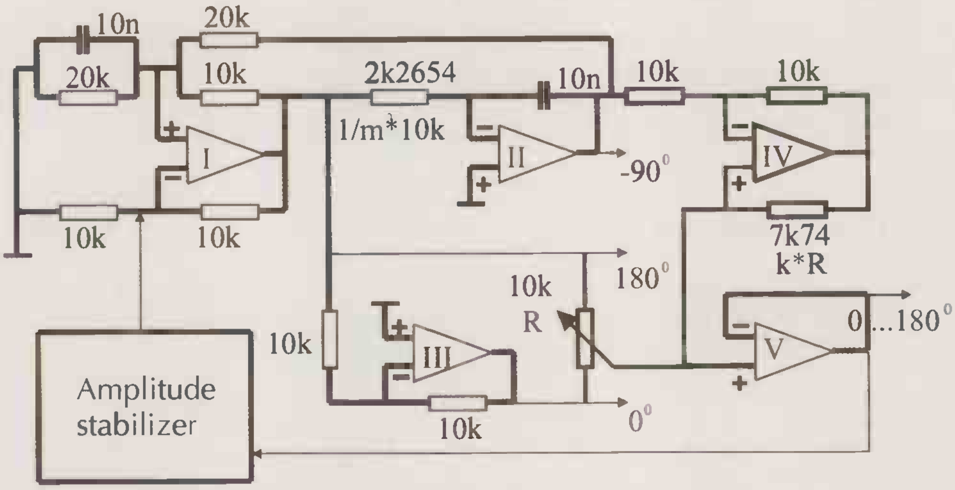


Figure 1

Figure 2



Variable-phase 3 kHz oscillator. OpAmps 741 type

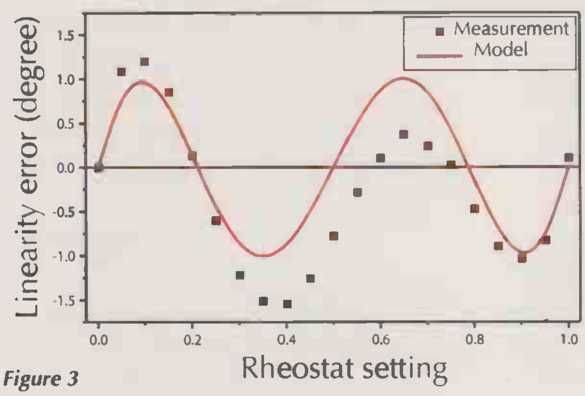


Figure 3

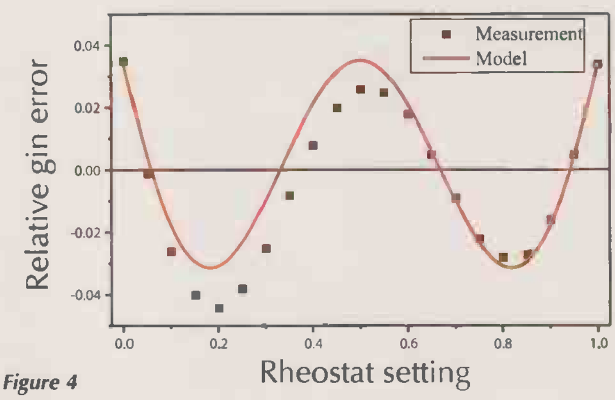


Figure 4

ideal transfer functions unnecessary. The distortion, mainly 2nd harmonic, is 54dB below the fundamental. The 2k26 resistor is tuned to have 1.000Vrms at the 0° output. To do the measurements on the circuit we used a PAR model 128A lock-in amplifier. Its reference input is connected to the 0° output of the circuit. Open the switch between the negative resistor and pot and measure, via a voltage divider if necessary, the In-phase output voltage of Opamp #V at 0∞ and 180∞ settings of the pot. These U_{zero} and U_{full} are used in conjunction with $U_{actual\ setting}$ to measure the actual pot setting

$$\alpha = \frac{U_{zero} - U_{actual\ setting}}{U_{zero} - U_{full}}$$

This removes any non-linearity of the pot setting from the measurement. Having determined _, the switch can be closed and the circuit operates as described. Now the In-phase and Quadrature voltages U_I and U_Q can be measured, giving

$$U_{abs} = \sqrt{U_I^2 + U_Q^2}$$

in the actual circuit about 1.0 V_{RMS} and

$$\varphi = \tan^{-1}\frac{U_Q}{U}$$

Figure 3 displays the phase error

$$\left(\frac{\varphi}{\pi} - \alpha\right)$$

* 180 and **Figure 4** displays the gain error

$$\frac{2U_{abs}}{U_{zero} - U_{full}} - 0.966$$

as a function of _. The similarity of the simple electrical model and the actual circuit is for practical applications only limited only by the precision of the components used. The phase shifter circuit can also be used to shift a whole spectrum of frequencies. The necessary 90° shifted spectrum can be acquired by a so-called dome network[3]. For a broad spectra with large f_{max}/f_{min} ratio a poly phase sequence network4 is a more appropriate method for generating the necessary 90° shift.

K. Heeck,
Amsterdam, The Netherlands

References:

Modern Operational Circuit Design, John I. Smith, John Wiley & Sons Inc.
ISBN 0-471-80194-1, page 161-162

Aktives Potentiometer mit Tangens-Kennlinie, Dipl.-Ing. Bernd Lücke, Elektronik pp. 62-64 Heft 11 1980

Wideband Phase Shifter Networks, R.B.Dome, Electronics pp. 112-115 December 1946

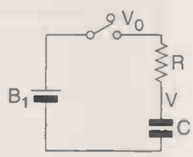
A symmetric poly phase network, M.J.Gingell, British patent 1,174,710 filing 7th June 1968

LETTERS to the editor

Letters to "Electronics World" Highbury Business Communications, Nexus House, Azalea Drive, Swanley, Kent, BR8 8HU
e-mail EWletters@highburybiz.com using subject heading 'Letters'.

Charging challenge

Charging a capacitor through a resistor is a basic element of electrical theory. The illustration shows the circuit.



The derivation for the voltage across the capacitor seen in at least three text books I have on my shelf goes something like – and here I have not deliberately introduced errors but I have used voltage whereas some use charge.

On closing the switch, the following holds.

The rate of change of voltage on the capacitor

$$\frac{dV}{dt} = \frac{i}{C}$$

The current flow to the capacitor

$$i = \frac{V_0 - V}{R}$$

So the capacitor voltage is given by

$$\frac{dV}{dt} = \frac{V_0 - V}{RC}$$

Re-arranging,

$$\frac{dV}{V_0 - V} = \frac{dt}{R}C$$

Integrating,

$$\log(V_0 - V) = \frac{t}{RC} + k$$

where k is the constant of integration. Anti-logging gives

$$V_0 - V = \exp\left(\frac{-t}{RC}\right) \times \exp(k)$$

As k is constant, the term exp(k) is also a constant. At $t=0$, $V=0$, making the constant V_0. This gives

$$V = V_0\left(1 - \exp\frac{-t}{RC}\right)$$

This expression is correct, but the derivation contains some howlers. I suspect that readers of *Electronics World*, who never knowingly let errors pass them by, may be able to state what is wrong with the above.

John Ellis

War time radio

This is a follow-up to letters I have written to you in recent months concerning the Nazi development commercially available Wireless receiver sets. As was pointed out in the original article, these sets lacked sensitivity. But they did not need to be - in the 1940's to avoid Allied Aircraft from using Commercial Radio Stations from using the German Transmitters as homing beacons to bombing raids over their cities, the Germans used a sort of 'Wired-wireless' landlines to carry the RF signal directly to home receiver sets.

In Britain in the 1930's PBX signals were sent directly to homes without any RF transmission at all, just audio signal on an electric current running at 85 Volts. I discovered this in the recent issue of Practical Electronics Vol. 32 # 11.

Chad Castagana
Woodland Hills, California, USA

Political correctness

Following Phil's request for a more politically correct version of Master Slave, here is my suggestion:

My auntie Ethel has had an idea which might fit the bill.

All devices have equal status, (thus removing the offensive Master, Slave relationship) and they all contend for use of The Medium (a Mrs. Cable at number 12).

A message is passed to Mrs. Cable and she blabs it all round the neighbourhood.

If any house is busy or empty she returns later and tries again.

I think she might be on to something here, we might patent her idea.

Ethelnet would seem a good name.

Just a thought.

Charles Coultas
By email

Puzzle

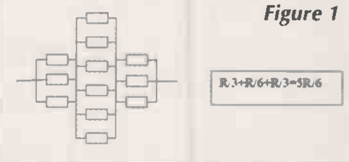


Figure 1

In reply to Raymond G. Lee in *EW* Jan 2004 issue, I was introduced to this problem by either Chris Priest or Dr. Robin Moffet, two colleagues at Plessey Telecoms Research Ltd. in the 70s. I tackled it by remembering a technique taught to me at college - namely simplifying the circuit by shorting out points of equal potential. (Cyril Bateman & Hugh Mirans used the same technique in the December issue). The circuit becomes as per Figure 1).

A technique used by my colleagues was basically based on Kirchoff and inspection. This is much easier and more obvious with a space model rather than an isometric drawing.

Note that upon leaving and entering the circuit the current splits into three and then in between it splits in two again giving:

V=IR/3 + IR/6 + IR/3
V=5R/6.................. as before.

Ray D. Smith (Ex PTR, GPT & Marconi)
Appleton
Warrington
UK

Stolen identity

Please keep the history articles coming! The latest, about J. A. Fleming's work on the thermionic triode, covers a particularly important episode. But that photograph of Fleming looked familiar. Then I remembered: it isn't Fleming at all. The very same picture appears on the front cover of Paul Israel's biography of Thomas A. Edison. Perhaps it's a good thing Edison was part of the story as well!

Alan Robinson
By email
Whoops! – Ed.

Not worthy

WOW!! I must have upset Seb. I thought my previous letter would be my last, a more snobbish and arrogant letter I've yet to read.

He seems to be saying that I am not worthy to read *EW* and that I should buy a 'lesser' mag, and that you should not allow someone like me to have a letter printed in *EW*.

I have been buying *EW* & WW since 1981 on a permanent basis, I find it provides 'cutting edge' audio circuitry. I realise his 'mentor' is D. Self, although I am on JLH's side of the fence. In my last letter I praised D. Self as someone who deserves 'worldwide acclaim'. I also said I could live with someone who is arrogant and patronising. I should have qualified this by saying I can accept this from people who are worldwide winners in their fields, as is D. Self, Linford Christy and Micheal Shumacker.

Can Seb explain why all power amps which have 100dB distortion can 'sound' different? I.e. reproduce music, with a different tonal basis, even when the frequency responses are identical.

If we were talking about hoovers, TVs or washing machines then I would have no problem with his replies but we are talking about music.

Seb can't reply to me without being subjective ie from his point of view, all life is subjective, unlike him I can see both points of view and will praise those who deserve it, from both camps.

Cyril Bateman's articles on the capacitor distortion are excellent plus, the very reason I buy *EW*. Somebody wrote into *EW* to say that Cyril's demolishment of expensive electrolytes is 'one in the eye' for the 'golden ear', quite true but a bit of tunnel vision, did he not read November 2002 article in which he says that metallised pet capacitors distort the musical reproduction, JHL and the 'Golden ears' have been saying this for 22 years now, therefore should JLH insure his ears as they seem to on a par with the latest' cutting edge' computer software. How that science has proved JLH right, will we get an apology from his critics?

Justin Underwood writes in critical of Cyril's work as far as need is concerned, Why don't Justin and Seb write to each other as Seb worships science, and, quite rightly, praises D. Self for zero distortion, and Justin seems to say it is not required. I'm audio reproduction. I'm on Cyril's side.

As a last comment on my poweramp, Seb seems to say less is better (number of stances). I'm not D. Self, and have no intention of ripping off D.Self's Power amp circuit. My amp incorporates part circuits from JLH, D.Self, and others and yes it is more complicated than D. Self's. Do you not know the pleasure I get from a home built amp that isn't an exact copy of anybody else's. My only problem was a 3 millivolts (RMS) of noise, I changed every BJT to low noise, very disappointing, little difference. I then removed the Hitachi T03 Mosfets from the right angled metal strip and sanded down the surface. I then fitted four ceramic washers taken from an industrial power supply; surfaces must be smooth, tightened it all down and bolted back onto the heat sink. I powered up, shorted input and connected an 8 Ohm load and connected my oscilloscope probe to the output as well as my audio millivoltmeter.

I was very pleased to see that the noise was, as I thought, all coming from the output devices, when hot. I measured 170 microvolts a gigantic drop, leaving on for ½ hour it rose to 190 microvolts, not to bad for a 1¼A quiescent current, for +/- 26 VDC voltage rails at 8 Ohms. Distortion is now down to –95dB at 20 KCs. Still not in D. Self territory buy I'm happy.

I hope you don't ex-communicate me from *EW* and strange as you may think I don't hold any animosity for Seb, only sorrow.

Mr D Lucas
Anstruther,
Fife,
Scotland,
UK

Poor Circuit Ideas

From a brief scan of your magazine Feb 2004, I decided to buy a copy. The article on analogue switching by D. Self is excellent. However the standard of some of the 'circuit ideas' needs some improvement.

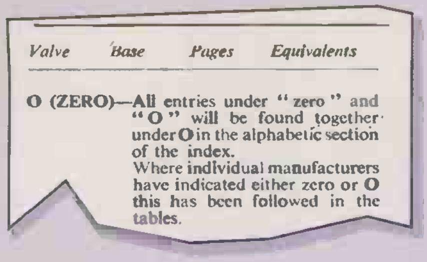
The article Electronic water level interlock, Page 45, I expect might work, however there are a few errors. The sponsors have no limiting resistor for the I Base of Q1. The use of 'iron nails' in water would be O.K. for a short-term use only because of corrosion. Also arcing will occur at the N.C. contacts, as the diode I feel ought to be across Relay 2 coil, and not the D.C. supply.

The Alkaline charger article Page 39 has the same oscillogram displayed on the left & right hand side of the page. Also there is no explanation of what is happening within the BC337 the base / emitter being reversed biased, presumably goes into reverse breakdown. I wonder about long-term reliability problems? Also a normal type of trickle charge would seem adequate for a 1V battery. So; why is the 4700μF (10V) and BC337 necessary for a single cell? The test refers to a red LED. The diagram shows only green or orange. There is a specific comment that 'only the specified transistors, LED colours, zener voltage and power ratings should be used.' Why?

It would appear that the circuit is difficult to repeat. In what is not generally a poor quality magazine, might we see some improvement in the future.

P. G. Diestlin
Manchester
UK

You are quite correct about the two identical oscillograms – this was a cock-up on my part. The two figures were in fact two different scans of a paper copy. I forgot to tell the layout dept. that it was an 'either or' situation not both. And I did not spot it whilst proofing. I would also point out that your very own letter had more than a few typos.
Pot, kettle and black?



Valve	Base	Pages	Equivalents

O (ZERO)—All entries under " zero " and " O " will be found together under O in the alphabetic section of the index.
Where individual manufacturers have indicated either zero or O this has been followed in the tables.

Ooer

The 0 or O debate may be settled for the OC series but may just rumble on a bit longer for the 0Z4 gas rectifier. This page from the RCA receiving tube manual clearly shows the 0Z4 with an '0' and the OZ4A with an 'O'.

Paul Bennett
By email

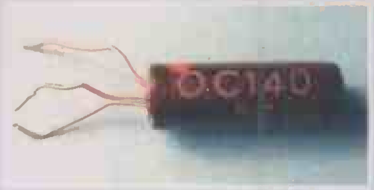
`The O or 0 controversy

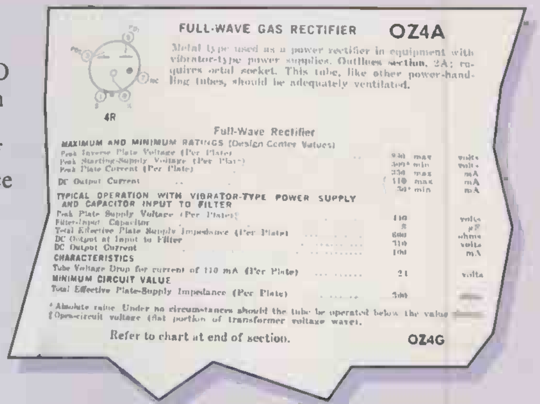
The following may be a source of the 'O', '0' confusion. I'm still not sure what exactly it's saying.

From Radio Valve Data compiled by the staff of Wireless World 1965 edition, page 124: "O (ZERO)-All entries under zero and O will be found together under O in the alphabetic section of the index. Where individual manufacturers have indicated either zero or O this has been followed in the tables."

I also attach a photo of an OC 140 and the source material.

Tony Meacock
Norwich,
Norfolk
U.K.





FULL-WAVE GAS RECTIFIER **OZ4A**

Metal type used as a power rectifier in equipment with vibrator-type power supplies. Outlines section, 2A; requires octal socket. This tube, like other power-handling tubes, should be adequately ventilated.

4R

Full-Wave Rectifier

MAXIMUM AND MINIMUM RATINGS (Design Center Values)

Peak Inverse Plate Voltage (Per Plate)	[illegible] max	volts
Peak Starting-Supply Voltage (Per Plate)	[illegible]* min	volts
Peak Plate Current (Per Plate)	330 max	mA
DC Output Current	110 max	mA
	[illegible]* min	mA

TYPICAL OPERATION WITH VIBRATOR-TYPE POWER SUPPLY AND CAPACITOR INPUT TO FILTER

Peak Plate Supply Voltage (Per Plate)†	110	volts
Filter-Input Capacitor	8	μF
Total Effective Plate Supply Impedance (Per Plate)	600	ohms
DC Output at Input to Filter	110	volts
DC Output Current	100	mA

CHARACTERISTICS

Tube Voltage Drop for current of 110 mA (Per Plate)	21	volts

MINIMUM CIRCUIT VALUE

Total Effective Plate-Supply Impedance (Per Plate)	300	

* Absolute value. Under no circumstances should the tube be operated below the value
† Open-circuit voltage (flat portion of transformer voltage wave).

Refer to chart at end of section. **OZ4G**

EMC

Responding to the Cyril Bateman (always respected) reply in your January issue to my November issue missive, I concur with most of what he says, excepting perhaps that I fail to properly understand EMC filters.

Axiomatically, of course efficacy is down to VSWR with both the filter and the source imparting attenuation. Cyril nicely elucidates the situation, especially specifically for a 50Ω source and load. That's not a common luxury though. I merely countered by way of extreme examples and reference, that ferrites can confer the resistive component, when Cyril's letter blanket stated minimal absorption by EMC filters. On first reflection the absorption will generally be minimal but reflections blat back and forth. Something somewhere in the system has to dissipate the undesired, and if ferrites be the determining resistive element then ultimately the EMC filter will be the main agent of attenuation.

Attention to ferrite characteristics can optimise performance. Other times the EMC filter resistive contribution can only be minimal. Ach, Cyril knows all this and one could air the subtleties of disparate systems till the kye come hame but EMC is pretty simple stuff really. Dull too.

On a more profound level it is true that I don't understand – knowledge unveils avenues of ignorance.

Dunno why Cyril (may I call you Cyril? Andrew to you) infers I don't use caps and resistors for EMC. One exploits what is appropriate; ferrites, caps, resistors, lead dressing, screening, soggy cabbages if they do the job. Didn't say the washing machine was out of the box either. Do pay attention in the back row Bateman Major – we shall be asking questions later :-) On one occasion, expedience even led to the use of a multi-band receiver to determine radiation and ameliorate it. The EMC test centre didn't object.

On the subject of my Norwegian Blue washing machine whose door glass is now happily reincarnated as a salad bowl, do I take it that Cyril is not of the Zen and the Art of Washing Machine Maintenance persuasion? It can be a life changing experience to run a washing machine 'out of the box'. Never scoped a washing machine and have no burning desire to do so either. Wilful things. The beast was just mega noisy over a wide range of photon energies.

As I said, justifiably anthropomorphising, it snubbed its nose (rather than its spikes) at the statutory regs which Cyril mentioned. The igniter in my central heating system is even worse, though admittedly it is so old it has flood marks. Sends the cordless phone into paroxysms – on the 'to do' list. Another annoyance is TV radiation on my VLF metal detector designs (just a tad more advanced than the recent discussions) but now't I could do about the submarine and geophysics VLF except shift my frequency.

On a slightly desultory note I would like to thank Cyril for his energetic and assiduous contributions. It's heartening to have confirmation of component characteristics, known but hitherto somewhat undocumented. Thanks too to *EW* for being the vehicle. My only preference, rather than criticism, is that it would be good to have more of 'Cyril' in his writing.

Essence can be drowned in a welter of punctiliousness. Electronics is fun, even hilarious – *Circuit Ideas* sometimes testifies to this. At work, last week's lab discussions ranged from naked singularities in the canteen, to Pentiums defaulting to 8086 mode, to a simple little triac circuit blowing the server trips, to the influence of J-Lo's posterior on tectonic subduction.

Tell us your stories Cyril.

Andrew S Robertson
Girvan
Ayrshire
UK

Airborne lasers

I note that Mr. Phelan of Dublin (Letters, EW, March) is amazed at "your sense of wonder as to why CD/MD/DVD players are banned on some flights"

So, yes, it does seem that Fairy Stories are still popular in Ireland! I am not aware of the standards applied to aircraft maintenance in the Republic. But with this possible exception, the rest of the flying public need not be concerned. Passengers are asked not to use electronic equipment during take off and landing as a sensible precaution against RFI. If every passenger tried to use his or her mobile phone, the RF noise level inside the externally screened cabin could be very considerable. Nice try Edward!

Chris Chapman
By email

Airborne lasers II

I was amazed to see the ludicrous suggestion from Edward Phelan *(EW Letters Mar 2004)* that the ban on portable CD players on aircraft had something to do with the laser - even more worrying that a pilot could show such ignorance. There is nothing 'magic' about laser light – it's just light, and infinitely less bright than that from the cabin lights.

The actual reason stems from when portable CD players first appeared, as they were the first common consumer portable devices to use high speed digital clocks (tens of MHz) and switch mode DC-DC converters.

At the time, aircraft were being designed and certified for high immunity to external RF sources (radar, radio transmitters etc.), but internal sources had not been considered, so some airlines restricted them as a precaution.

However the initial concerns about CD players seem to have 'stuck', even as other digital devices came along using far higher clock frequencies. I heard a particularly ridiculous announcement on a plane few years ago: "Laptop computers may be used, but the CD drive must not be accessed." Such technical ignorance is a little worrying to say the least!

Most airlines now seem to have settled down to what most people would agree is a reasonable compromise, by prohibiting the use of any electronic devices during takeoff and landing only.

Mike Harrison
By email

Re: Self

The notion of 'multi-path' reflections at the ionosphere in long distance propagation was used in a recent article[1] about interference to short wave reception (from internet transmission through mains electric cables), although the evidence suggested otherwise. Pat Hawker G3VA illustrated[3] two alternatives, chordal hops or surface waves, the latter supported by recent sub-ELF data[2], 0.8Hz (z=Zed) in $c = \lambda f$ gives λequal to Earth-Moon spacing (3.75×10^8m), with a spatial node, allowing provision for the stronger 0.4 Hz half-wave fundamental as well as the weak 0.2Hz signal analogous to the closed-pipe fundamental – for longitudinal waves!

Tiller's long-period (26.087 minutes, $f=6.39 \times 10^{-4}$ Hz) data[2] in $c = \lambda f$ is inconclusive but, in $c = 2\pi Rf$, correlates well with an 'interspatial belt' between Earth and Mars for a limit-cycle involving resonance decoherence, which would explain the 'echo-effect' in 'whispering-galleries', inter alia4!!!

1. 'New Scientist', 10th January 2004, page 30; 6th December 2003, page 26
2. 'EW', January 2003, Letters page 42, ref 1; December 2003, page 58, ref 3
3. 'Amateur Radio Techniques', RSGB Pub., 4th Edn. 1972, pp.214-5, 207
4. 'Horizon', BBC TV, Seismic Resonance, Bernard Chouet.

Mr. A G Callegari BSc., MPHIL. (Lond.)
Much Hadam, Herts, UK

Wheatstone

As the author of the Wheatstone Bridge article (EW, April 2003) which seems to have initiated exchanges on experimental error, I would like to make a couple of points.

I agree with the theory of Mr Bailey's comments in his letter printed in EW, February 2004. However, he and earlier correspondents have missed an essential point, which relates both to mine and most practical Wheatstone Bridges. In these, one of the resistance arms is a compound component, being built from four decades of resistors. For this arm, a small value 'units' component which is as much as 100% inaccurate will add little error to the overall value of this resistor arm provided (a) it really is small (e.g. a marked 1 Ohm component is in fact 2 Ohms but not a 9 Ohms resistor being 18) and (b) the thousands decade value is large and as accurate as possible. It would seem from Mr. Bailey's argument that having one low value resistor 100% inaccurate would render all measurements potentially subject to a 100% error. Clearly this is absurd. In fact it is rather difficult to determine a general value for the maximum error when using a compound component.

Secondly, the article described a particular technique to achieve very high accuracy when using my Bridge design to measure resistors in the range from about 1k to about 10k Ohms. This involved the arithmetic averaging of two experimental results; the first being produced normally and the second by reversing appropriate arms of the Bridge. As I showed algebraically, this technique appears to remove all first order errors in two of the resistance arms.

Analogue switching

Reading the first instalment of D. Self's article on electronic analogue switching (EW Jan 2004, pp 11) gave me a feeling of Déjà Vu. Indeed, some 24 years ago I occupied myself with similar research, which led to the design of a Programmable Audio Attenuator, which used electronic analogue switches to produce a gain change range of 60dB in 1dB steps (WW May 1980, pp 65). I finally adopted the CD4007 IC as switching elements, as these contain in a single 14 pin DIP a trio of SPDT JFET switches. The need for a combination of series and shunt switches in some cases, as also identified by Mr. Self, is therefore quite easily satisfied. The 4007 has all gates directly accessible, allowing soft switching to be implemented, almost completely suppressing switching transients. I used a combination of 1M ohm resistors and 1.8nF caps for this. It is a pity that this IC is apparently not known to Mr. Self; it solves some identified problems elegantly. A few other refinements that I missed in Mr. Self's articles are the use of asymmetrical supply voltages for the 4000 series. By using +7.6VDC and –8.2VDC, the distortion of the complete unit was further decreased in comparison with the case of +/- 7.9VDC (Using the max allowed voltage of course minimises THD to begin with). The other refinement concerns the switching of small capacitors in simple RC LP filters in combination with high attenuation switching to compensate for the frequency response rise resulting from feed through in off-switches. (On the other hand, the use of the gate bootstrap resistor is a nice touch, one I didn't think about at the time). By using highly optimised circuit topologies and component values, each channel of the attenuator is realised with just 5 inexpensive '4007's.

I realise that it is difficult for an author to know everything published on a subject, but it is slightly disappointing if a publication in our own beloved EW (then still WW) is missed.

Johannes M Didden
Strassen
Luxembourg

The longest project ever?

We all have those projects that we start but never get round to finishing but here is a challenge to your readers. I think that I have completed the longest running project ever – unless, of course, you know otherwise.

I left university in 1979 and completed my electronics apprenticeship at British Aerospace surrounded by sophisticated test equipment. I decided that I wanted a frequency counter and I was going to design it myself. I built the oscillator-display-counter board over the summer of 1979 and drafted some additional circuits for range switching and the input block. I then moved house and changed jobs into IT so had little time for completing it. Then I got married, had kids and the above board languished at the bottom of my junk box. In the mid 1990s I found time to tinker with wires and such and came across this lost, lonely and dusty board and decided to complete the project. I dabbled with high speed input amplifiers (which always seem to prefer being oscillators) and function switching logic. The dabbling did not come to much other than to prove that I had forgotten all the laws of physics. So, again the board returned to its dust collection role in 1998.

In late 2001 my kids were teenagers, Y2K was no more than an embarrassing memory in IT departments and I had a bit more time. So, I again played around with high speed input circuits that still wanted to oscillate but, after many hours, tamed the beast and proceeded to build the rest of the circuits. By now, the functional requirements of the unit had grown like topsy and I wanted it to do everything. Dozens of spider-web prototype circuits piled up in the corner of the workbench as I converged on a design that did almost everything and discarded the failures. Survival of the fittest, I suppose.

The final test and assembly was completed in January this year and the project has ended. I even opened a bottle of Spanish Champagne to celebrate. Of course, my wife has no interest in what a frequency counter/period timer/pulse width timer/event counter with continuous or one-shot modes does. Or even cares. She politely humours me and my project perhaps because I started it before I met her.

My tardiness does bring me a particular problem: the older parts of the circuit were built with chips that are now obsolete so don't ask about serviceability! Of course, it would have been much more sensible (and cheaper) to go out and buy a second-hand frequency counter for £50 but we spend too much of life being sensible. Have fun!

So, twenty-four and a half years to successful completion. Any advance on that?

Mike Arnold
Sale
Cheshire
UK

Vibrator replacement

Concerning Jeremy Stevens' circuit idea 'Electronic Half Bridge Replaces Mechanical Vibrator.....' *(EW, Feb04)*, I am not convinced that the circuit is a true half bridge, since unlike a normal commutating version; the power mosfets are turned on simultaneously. Furthermore, these two devices are connected in series with opposite ends of the floating transformer primary winding; the switched current is unidirectional and the same through both devices.

This implies that similar results would be achieved using a simple power mosfet, so enabling the majority of the circuit to be eliminated.

I do not understand how the transformer can 'see exactly the same input waveform' as it did when the vibrator was used; the primary drive current is simply switched and no longer reversed.

I do not dispute that the circuit can generate the required 1+T (probably because the transformer's secondary winding is tuned by CI to resonate at the drive frequency) but I question its mode of operation. It would be interesting to observe the effect of shorting out Q5.

K Cummins
Chale Green
Isle of Wight
UK

Vibrator replacement II

I was impressed with Jeremy Stevens' method of converting an ancient radio to 12V operation without adding an external box (Electronic half-bridge replaces mechanical vibrator in 6V to 12V conversion' *(Circuit Ideas p40 EW Feb04)*.

However, and correct me if I am wrong, I think he could save a few components next time. As far as I can see, the circuit is not actually acting at a half-bridge converter, as both Q3 and Q5 conduct at the same time. It is more of a forward/fly-back converter with both ends of the primary inductor switched.

If I am right only Q3 is required. Q5 with all of its associated drive circuitry (Q1, 2, 4 & 5) could be omitted – Q5 being replaced by a short circuit across its drain-source connections. D3, 4 & 5 could also go. And if D6 was replaced with a faster device, R10 could be replaced with a less power hungry series RC with quite a small C and a lower-power R.

Unfortunately, these changes would remove Mr Stevens' clever way of preventing over-voltage across C1 during warm-up.

So either:

- Add a simple switch-on timer (replace IC1 half a hex inverter and use some of the spare gates as the timer) or
- Short Q3's base drive with a voltage monitor, made with a couple of diodes, a zener and a transistor, connected to T1's outputs or
- Keep Q5 and its drivers, and ditch Q3 instead, making appropriate alterations to the diode bridge.

I hope you can pass this on to Mr Stevens, with my thanks for an inspiring circuit and something to fill the time with on the train home tonight.

Steve Bush
Surbiton, UK

Battery tester

In Circuit Ideas January issue, D. Di Mario described a very useful car battery tester. I built a basic version of it, but could not make his exact circuit as I there is a misprint.

Could he please give the correct wiring for the x1/x10 switch? In the text he says that the 100 Ohm pot is marked 2-100Ah. I assume it should say 32-100Ah? Also, what purpose does the 5.1V zener serve? As pin 5 of a 555 is set at 8V internally (on a 12V supply) there is about 4V across the zener. One final point that confuses me: the ripple across the battery is of the order of tens of mV, so what does the IN4006 in the meter circuit do?

These comments are not meant as criticism: I'm just interested! Thanks.

Jonathan Wellingham
Bristol , UK

The text error was in fact ours – this CI came in on paper and the OCR mis-read some bits. – Ed.

The New Scholasticism

There is widespread refusal to confront alleged problems in the reigning basic theories in science. The science I am most familiar with where this occurs is electromagnetic theory, though I know of other blatant cases, for instance theory of flight.

On the subject of displacement current, our article in December 1978 pointed out that electric charge entering the plate of a capacitor did not immediately desire to traverse the space between the capacitor plates. (Bleaney is wrong when he writes that the field between the plates is uniform.) After entering the capacitor plate from the input wire, the charge first has to spread itself across the plate. Only then can it express a desire to traverse the space between the plates.

This desire led to "Maxwell's leap of genius", Displacement Current. Maxwell himself, and all those who followed him and worshipped him, failed to notice that after entering the capacitor plate from the input wire, the charge had first to spread itself across the plate. This intermediate step has been ignored by all text books and lecturers. Since we pointed it out in 1978, it has been ignored for a further quarter century. All of today's textbooks are written as though this problem, of charge spreading out across the plate, remains unnoticed, like the Emperor's nakedness.

The spreading out of electric charge across the capacitor plate is real electric current, and must cause a real magnetic field, according to Ampere's Rule or the Biot-Savart Law. The alleged genius of Maxwell was that the notional electric current, called by Maxwell "Displacement Current", was invented to produce a magnetic field and so lead to key conclusions. Since the key (and only) purpose of Displacement Current is to cause a magnetic field, it is unacceptable that there continues to be no discussion of the magnetic field which must be caused by the much more real electric current as the electric charge spreads out across the plate from the incoming wire.

So, I pose the question - when a TEM step travels at the speed of light down the vacuum between two parallel plane conductors, a problem was noticed in 1982, now renamed "The Catt Question". The TEM Wave travelling in a coaxial cable with vacuum dielectric is a more easy way to picture the same question. The Catt Question, camouflaged by w for a century, was first noticed in 1982. Prior to that, the only signal discussed was a sine wave, which buried the problem in fancy maths. If the sine wave is replaced by a simple step, the problem becomes obvious for the first time. It is now discussed.

After the step has passed, there appears extra negative electric charge on the surface of the negative conductor to terminate the lateral lines of electric flux between the positive conductor and the negative conductor. Where does this extra charge come from? It took many years of painstaking work to elicit a single reply from each of two luminaries, who totally contradicted each other, and then went silent. All other accredited "experts" also remain silent.

For more than a century, it has been fashionable to drool over Maxwell's Equations, and assume that others have grasped their physical import. For decades, I insisted that I had never doubted Maxwell's Equations. I knew that a hint of such behaviour would lead to ex-communication. Like everyone else, I kept away from them and avoided investigating them. In spite of this, my major advances in electromagnetic theory, and also my computer inventions, were totally suppressed by all journals in the world for some decades.

Some time after Tom Ivall, then editor of Wireless World, began to publish my material, I ventured to investigate Maxwell's Equations. I was shocked by what I discovered, and published what I found in Wireless World. Since Ivall was my ally, and all other journals in the world still totally boycotted me, I felt I would lose nothing by rocking the Maxwell boat. Ivall had already been threatened for publishing less controversial material by me. There has been more or less no response to my publications on Maxwell's Equations.

In all these three cases, all publication and teaching continues as though what I have said has never been said. The reader is challenged to give reference to any textbook or syllabus that refers in any way whatsoever to my discussions.

We assiduously add more and more bells and whistles onto a brittle structure which has been frozen since about 1920. The structure, which requires avoidance of the above questions, serves no purpose beyond rewarding those who live within its glass home, who live off those they can entice within it. My co-author researched key insights removed from later editions of a standard textbook. This raises the interesting spectre, that we are not just standing still. We are moving backwards.

I have spent many years trying to understand why there exists so little grasp of the physics of a logic step travelling from one gate to the next. I found that not only students, but also lecturers, have no access to information on the TEM Wave. The TEM Step is the key electromagnetic element in all digital computers, and therefore in 99% of all electronics today. I have found that none of the books in the British Library or in the IEE Library in London discuss the TEM Wave. Heaviside had a complete grasp of the TEM Wave. He had to, because he was sending Morse pulses, or TEM pulses, down a cable from Newcastle to Denmark. A century later, when I arrived in Motorola R&D at the inception of high speed digital electronics (1nsec ECL), I also had to master it. The whole of digital electronics is vulnerable because even today's lecturers have no access to insight into the TEM Wave. They will certainly not learn from Heaviside, whom their textbooks and lectures ignore, or from me. They insist that I do not exist. Ask your lecturer about Catt. He will reply; "Who?"

Ivor Catt
St. Albans
Hertfordshire
UK

Futher reading:
The material in this letter can be reached via www.ivorcatt.com/41.htm or www.electromagnetism.demon.co.uk/41.htm.
Theory of Flight: http://www.ivorcatt.com/2606.htm
Displacement Current: http://www.electromagnetism.demon.co.uk/z001.htm
http://www.ivorcatt.com/2635.htm
Catt Question: http://www.ivorcatt.com/28anom.htm
http://www.electromagnetism.demon.co.uk/catanoi.htm
Maxwell's Equations: http://www.ivorcatt.org/ic3804.htm
http://www.ivorcatt.com/2804.htm
Moving Backwards: http://www.ivorcatt.com/2607.htm
TEM Wave: http://www.electromagnetism.demon.co.uk/17136.htm
http://www.electromagnetism.demon.co.uk/20136.htm
The Heaviside Signal: http://www.ivorcatt.com/2604.htm
http://www.ivorcatt.com/1_1.htm
figures 4, 5.

Schematic Capture
PCB Layout
SPICE Simulation
Auto Placement
CPU Models
Auto Routing
VSM
Virtual System Modelling

Bare LCD display drive in embedded applications

In embedded applications it is often needed to interact with the user by means of displaying numbers or simple texts. LED displays with seven or 14 segments per character are available at low cost and in many different sizes, however they consume a lot of current and this restricts their use in battery powered applications. Daniel Malik explains.

LCD modules driven by HD44780 or compatible controllers have simple interface and low power consumption, however they cost more and their dimensions are often to large to fit into small enclosures.

Bare LCD displays offer both low power consumption and small size, however their drive is usually considered non-trivial. This article aims at explaining the basic principles of Twisted Nematic displays and disclosing one possible method of their drive without a specialised interface circuit or microcontroller peripheral.

Principle of LCD operation

Properties of Liquid crystal materials were discovered in 1888 by an Austrian botanist, F. Renitzer. These materials were not suitable for commercial use however. The first nematic crystals which retained their properties even at room temperatures were developed in 1960s, but the real breakthrough came when cyanobiphenyl materials were discovered. These have large positive dielectric anisotropy and a strong birefringence, which makes them almost ideal for the twist cell.

The most common LCD is called the twisted nematic (TN) display. This display consists of a nematic liquid crystal sandwiched between two glass plates. The inner glass surfaces are coated with a transparent metal oxide film which acts as an electrode used to apply voltages across the cells. A polymer alignment layer is placed on top of the electrodes and microscopic grooves are created in it during the manufacturing process, which force the crystal molecules to align in parallel to the groves. Layer of polymer spacer beads is eventually applied to one of the glass plates to maintain uniform gap between the two, the plates are placed together and the edge is sealed with epoxy. A small hole is left in the epoxy and the liquid crystals are injected between the plates through this hole under a vacuum. After the hole is sealed, polarizers are applied to top and bottom surfaces of the display. In TN displays the alignment layers and polarizers are created perpendicular to each other, which forces the crystal molecules to twist by 90 degrees under novoltage conditions - see left side of **Figure 1**.

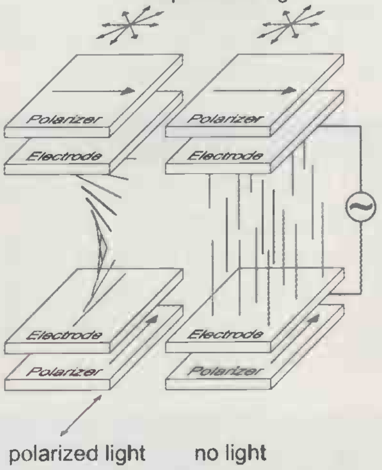


Figure 1: Basic prinicple of TN display operation

The light entering the display from the top is polarised by the top polarizer and as it travels through the liquid crystals its polarisation rotates with the molecules. When it emerges, its polarization has been changed by 90 degrees and it passes through the bottom polarizer. However when a voltage is applied to the electrodes, the molecules will arrange vertically - see right side of **Figure 1**. In this case polarisation of the light passing through the liquid crystals remains unchanged and is blocked by the bottom polarizer.

It is important to minimise DC component of the display drive signal, otherwise electrolysis process will develop and eat-up the electrodes eventually. The optical effect or contrast ratio produced by a segment depends on the applied RMS voltage. An example of TN display optical characteristics can be seen in **Figure 2**.

TN display drive

When using the LCD display, the goal is obviously to keep voltage below the threshold voltage VT on those segments we want to appear invisible and above the saturation voltage VS on those segments we want to appear dark. There is one more parameter used to describe LCD displays and their drives: bias ratio. This is simply the ratio VS / VT. It can be seen that bias ratio of the drive (i.e. ratio between the RMS voltage on the dark segments and RMS voltage on the invisible segments) must be bigger than bias

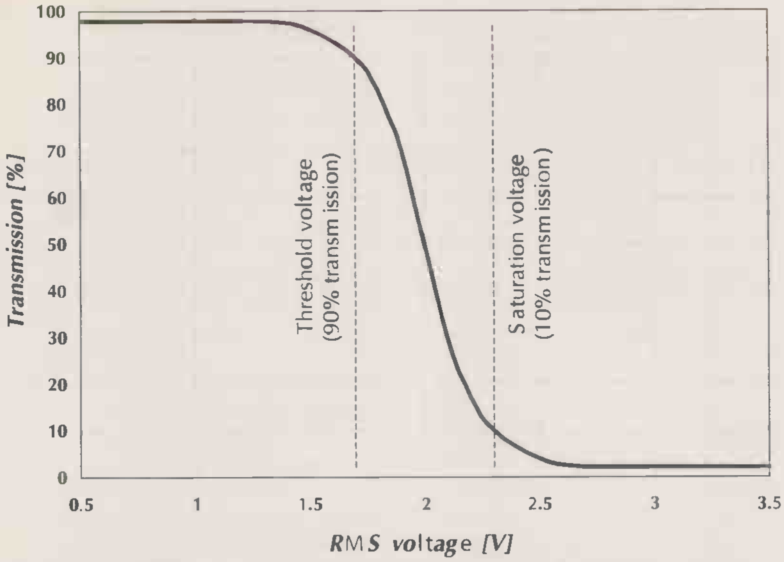


Figure 2: Typical optical response of TN display versus applied voltage

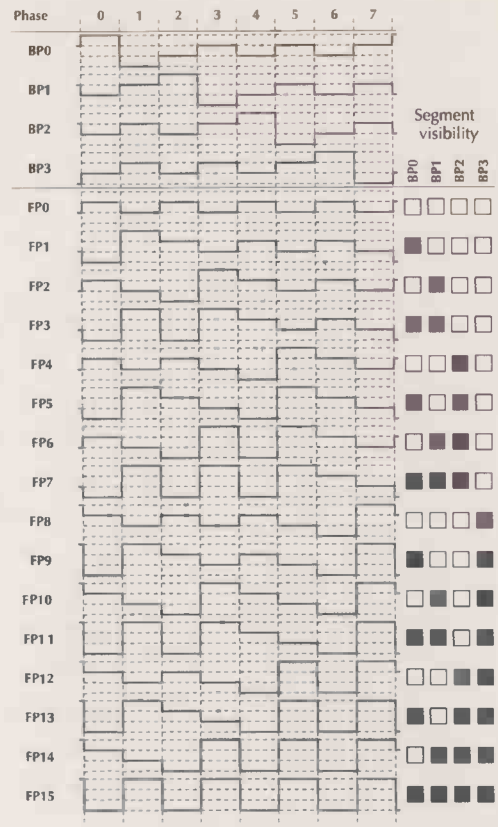


Figure 6: Traditional LCD waveforms.

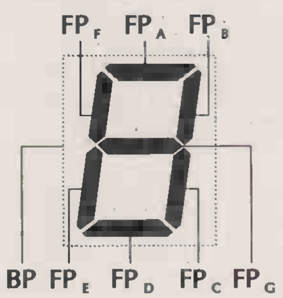


Figure 3: Example of statically driven LCD.

ratio of the LCD. There are two basic types of LCDs as far as their drive is concerned: static and dynamic.

Drive of static LCDs

Static LCDs have only one background electrode and one terminal for each segment they can display.

Therefore 7-segment static display capable of displaying one digit will have 8 terminals in total (see **Figure**

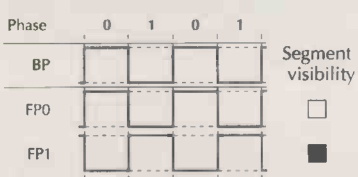


Figure 4: Drive waveforms for static LCDs.

3). Drive waveforms for such display are shown in **Figure 4**.

Voltage on the invisible segments approaches zero and voltage on the dark segments approaches full supply voltage. The drive bias therefore approaches infinity and no other drive scheme can be better as far as display contrast is concerned. This drive scheme is very simple to implement on general purpose I/Os of a microcontroller and this is why this type of displays is very popular.

Drive of dynamic LCDs

If the driving scheme for static displays is so simple to implement why should we bother with any other type of LCDs? Since the static displays have one terminal for each segment, the number of terminals starts to rise very quickly when we try to add more digits on the same display. In case the LCD has pins (as opposed to rubber strip or thermically bonded flat cable), the added pins increase cost of the display. Another problem is to place all the terminals at the top and bottom edges of the display and it may therefore prove difficult to make the display small enough. Another fact is that we need one GPIO pin for each display segment on the microcontroller side.

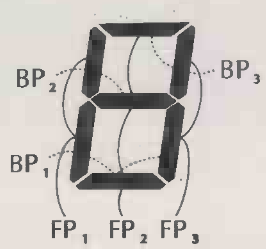


Figure 5: Example of dynamically driven LCD.

The higher the pin count of the microcontroller, the larger the package and cost (number of pins and package size contributes to the microcontroller cost more than one would guess). All these reasons led to attempts to organise the display segments into a matrix (just like buttons in a keyboard).

The dynamic LCDs (also called multiplexed) have multiple backplane electrodes and the frontplane pins are shared by multiple display segments. Example of dynamic LCD is shown in **Figure 5**. Now the challenge is to create waveforms for all the frontplane and backplane pins which would ensure that all the segments we want to appear invisible receive voltage below VT and all the segments we want to appear dark receive voltage above VS. How the waveforms should look like is far from obvious. Specialised LCD drive circuits and microcontroller peripherals normally use waveforms outlined in **Figure 6** (shown for the case of 4 backplane electrodes).

These waveforms have bias ratio of 1.73 and use 4 discrete voltage levels on all pins. It is easy to see that synthesis of these waveforms without the specialised circuit or peripheral would be quite difficult. Fortunately another driving scheme exists, which can be easily implemented on GPIO pins of a microcontroller. The modified waveforms are shown in **Figure 7**. These have bias ratio of 1.53 (approx. 12% lower than the original waveforms).

The main advantage is that now we need just 3 discrete voltage levels for the backplane electrodes and only 2 voltage levels for the frontplane electrodes. This is much simpler to implement and circuit similar to the one shown in **Figure 8** can be used. The third (middle) voltage level on the backplane electrodes is achieved by configuring the GPIO pin in question as input and allowing the

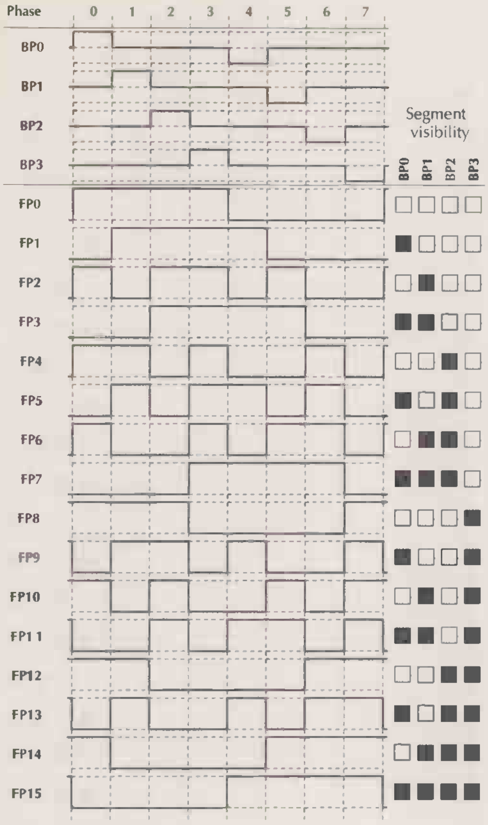


Figure 7: Modified LCD drive waveforms.

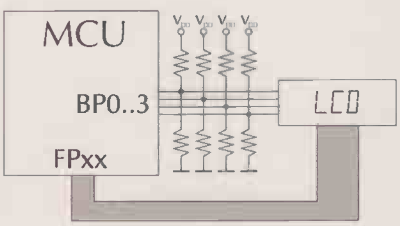


Figure 8: Application circuit.

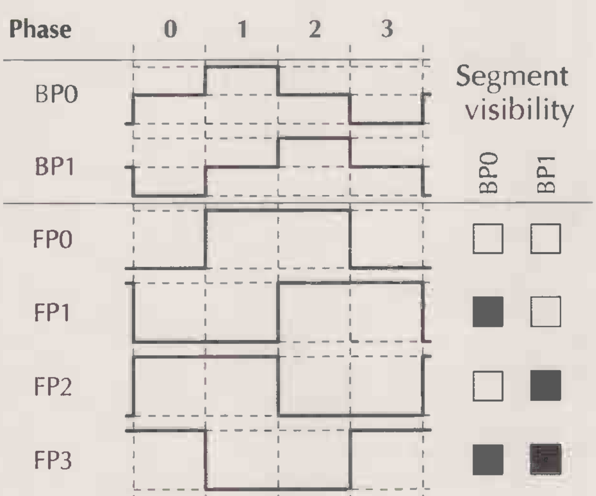


Figure 9:Modified waveforms for two backplane electrodes.

external resistors to define the voltage level. Of course similar waveforms can be devised also for other numbers of backplane electrodes, waveforms for 2 backplane electrodes are shown in **Figure 9**. It is common property of all the driving schemes, that the bias ratio goes down with the number of backplane electrodes. Therefore higher supply voltage of the microcontroller is needed for displays with higher level of multiplexing. Displays with 2 backplane electrodes can be driven from supply voltage of 3V, however displays with 3 and more backplane electrodes require higher supply voltages of the microcontroller. Since modern microcontrollers run happily from below 3V up to 5V, adjusting the supply voltage is the easiest way of matching the drive voltage requirements of a particular display. In case the supply voltage of the microcontroller is fixed at 5V, dummy cycles can be introduced into the driving scheme to lower the voltages between the display electrodes.

Driving algorithm

An algorithm for driving the display can be devised from the driving waveforms. An example algorithm for display with 4 backplane electrodes is shown below.

This algorithm is relatively easy to implement. Reaction times of TN displays depend on temperature and are usually around 150ms. This allows relatively very slow refresh rates, display manufacturers usually recommend rates around 30Hz. Since the above algorithm has 8 phases, the required interrupt rate to drive the display is 240Hz, which implies very low workload for the MCU. Using higher refresh rate only increases the microcontroller workload and power consumption (since the display is effectively a capacitive load).

Photographs of displays with four and two backplane electrodes driven by general purpose MC68HC908GP32 microcontroller from Motorola are shown in **Figures 10 and 11**.

Phase	Action
0	BP0 high, BP1,2&3 middle, FPx receive negation of data for BP0 segments
1	BP1 high, BP0,2&3 middle, FPx receive negation of data for BP1 segments
2	BP2 high, BP0,1&3 middle, FPx receive negation of data for BP2 segments
3	BP3 high, BP0,1&2 middle, FPx receive negation of data for BP3 segments
4	BP0 low, BP1,2&3 middle, FPx receive data for BP0 segments
5	BP1 low, BP0,2&3 middle, FPx receive data for BP1 segments
6	BP2 low, BP0,1&3 middle, FPx receive data for BP2 segments
7	BP3 low, BP0,1&2 middle, FPx receive data for BP3 segments

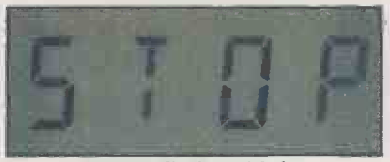


Figure 10: LCD display with four backplane electrodes.

Figure 11: LCD display with two backplane electrodes.

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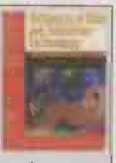

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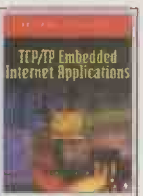

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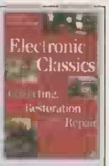

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This text encompasses all aspects of buying, collecting, restoring, repairing, sourcing parts, professional services, clubs and societies. The first part covers technical aspects of restoration and details where components can be found. The second part presents useful information for collectors.

Aug 1998 ▲ 256 pages ▲ Index
10 halftones ▲ 50 line illustrations ▲ PB
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INTRODUCTION TO DIGITAL SYSTEMS

John Crisp

This self-study text introduces digital electronics from first principles, before going on to cover all the main areas of knowledge and expertise. It covers the practicalities of designing and building circuits, including fault-finding and the use of test equipment.

Feb 2000 ▲ 302 pages ▲ Glossary ▲ Index
PB ▲ Published in UK

Code 0-7506-4583-0 **£18.99**

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S W Amos; R S Amos

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

4th edition ▲ Mar 2002 ▲ 394 pages
100 illustrations ▲ PB ▲ Published in UK

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Eugene Trundle

An exploration of television and video technology. It covers the fundamentals of digital television (satellite, cable and terrestrial) and digital video, as well as providing a grounding in analogue systems.

3rd edition ▲ Feb 2001 ▲ 432 pages ▲ Index
PB ▲ Published in UK

Code 0-7506-4810-4 **£17.99**

NEWNES GUIDE TO DIGITAL TV

Richard Brice

Covering all aspects of digital television, this text encompasses the electronics of the equipment, data compression, television production, servicing and the different transition methods - terrestrial, satellite and cable. The text has been updated with developments since the 2000 edition.

2nd edition ▲ Oct 2002 ▲ 304 pages ▲ Index
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Robin Pain (Design Engineer, Cotag International Ltd)

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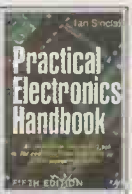

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A collection of all the key data, facts, practical guidance and circuit design basics needed by a spectrum of students, electronics enthusiasts, technicians and circuit designers. It provides explanations and practical guidance, and includes new sections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

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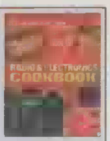

Radio Society of Great Britain

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

Nov 2000 ▲ 336 pages ▲ PB ▲ Illustrations
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Mac E Van Valkenburg; Edited by Wendy Middleton

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9th edition ▲ Aug 2001
1568 pages & CD-Rom ▲ 1385 line illustrations
HB ▲ Published in UK

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Oct 2003 ▲ 312 pages ▲ PB

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March 2001 ▲ 288 pages ▲ PB
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Farid Dowla (Lawrence Livermore National Laboratory, University of California-Davis, USA)

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November 2003 ▲ 720 pages ▲ HB

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A detailed manual for those who need to get to grips with digital audio and video systems. It sheds light on the differences between audio interfaces and shows how to make devices "talk to each other" in the digital domain. Also includes detailed coverage of all the regulorly used digital video interfaces. New information included in this third edition: dedicated audio interfaces, audio over computer network interfaces and revised material on practical audio interfacing and synchronisation.

3rd edition ▲ September 2003 ▲ 392 pages
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Edited by Peter Marlow

A distillation of the most-used fault reports from 11 years of *Television* magazine. Arranged by make and model, it features over 200 reports on over 300 models of television, including diagnosis and repair advice.

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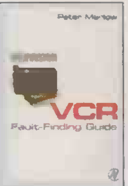

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Steve Beeching

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5th edition ▲ Apr 2001 ▲ 323 pages
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Keith Jack

This edition has been updated to include information on digital television, datacasting, interactive video, digital camcorders and VCRs, and video interfacing. Coverage is international, including European, Asian and North/South American video standards, methods and techniques.

3rd edition ▲ Jul 2001 ▲ 784 pages & CD-Rom
References ▲ Glossary ▲ Index ▲ PB
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ANALOG ELECTRONICS: CIRCUITS, SYSTEMS AND SIGNAL PROCESSING

D Crecraft (formerly Open University); S Gergely (formerly University of Coventry)

Designed to complement the digital systems modules and develop the essential skills needed for RF circuit design, this book demystifies the art of analogue circuit design and analysis. The content meets the requirements of first and second year electronics engineering courses.

May 2002 ▲ 435 pages ▲ 150 line illustrations
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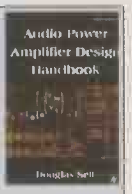

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This text on the design of audio amplifiers is based on Douglas Self's work in *Electronics World* magazine and a career at the cutting edge of audio design. This handbook aims to provide a practical guide to the state of the art, and includes detailed design and construction information.

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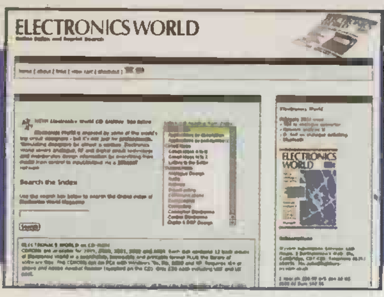

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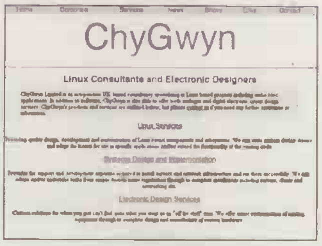

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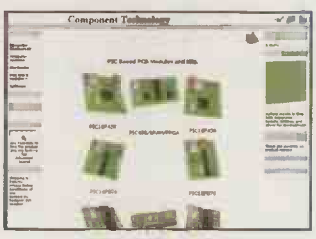

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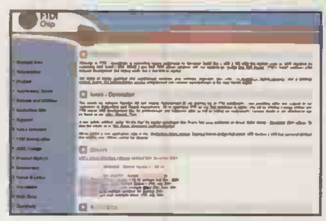

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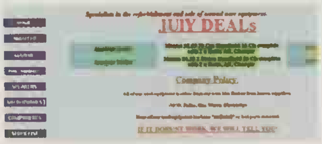

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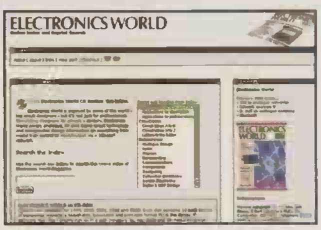

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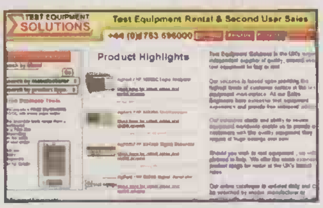

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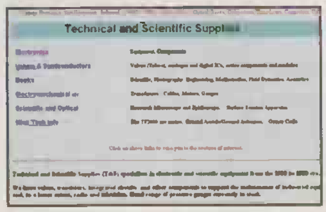

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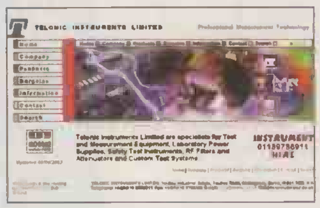

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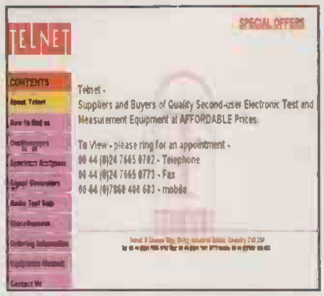

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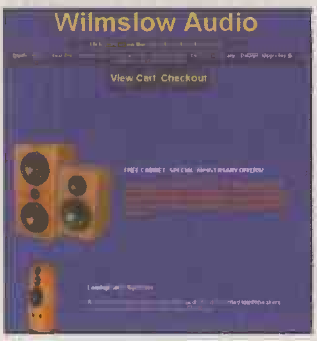

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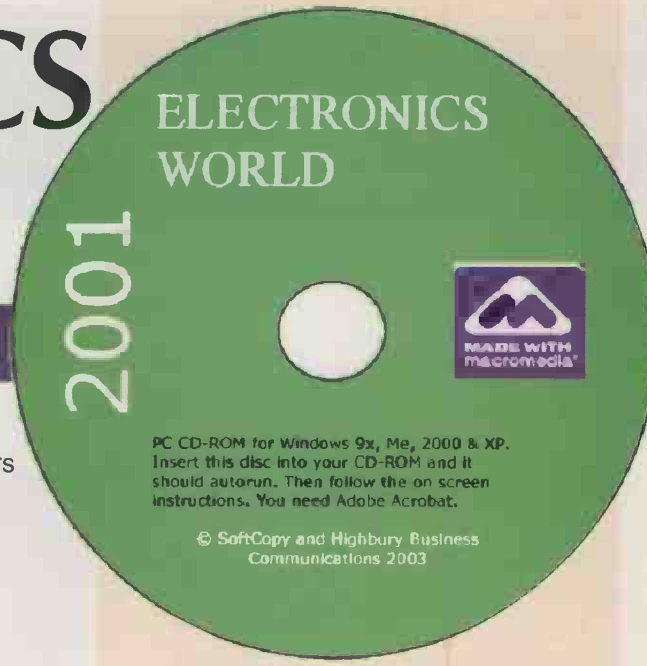

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3 Marriage Bells, Bells & xylophone duet, Burckhardt & Daab with orchestra, 1913
4 The Volunteer Organist, Peter Dawson, 1913
5 Dialogue For Three, Flute, Oboe and Clarinet, 1913
6 The Toymaker's Dream, Foxtrot, vocal, B.A. Rolfe and his orchestra, 1929
7 As I Sat Upon My Dear Old Mother's Knee, Will Oakland, 1913
8 Light As A Feather, Bells solo, Charles Daab with orchestra, 1912
9 On Her Pic-Pic-Piccolo, Billy Williams, 1913
10 Polka Des English's, Artist unknown, 1900
11 Somebody's Coming To My House, Walter Van Brunt, 1913
12 Bonny Scotland Medley, Xylophone solo, Charles Daab with orchestra, 1914
13 Doin' the Raccoon, Billy Murray, 1929
14 Luce Mia! Francesco Daddi, 1913
15 The Olio Minstrel, 2nd part, 1913
16 Peg O' My Heart, Walter Van Brunt, 1913
17 Auf Dem Mississippi, Johann Strauss orchestra, 1913
18 I'm Looking For A Sweetheart And I Think You'll Do, Ada Jones & Billy Murray, 1913
19 Intermezzo, Violin solo, Stroud Haxton, 1910
20 A Juanita, Abrego and Picazo, 1913
21 All Alone, Ada Jones, 1911

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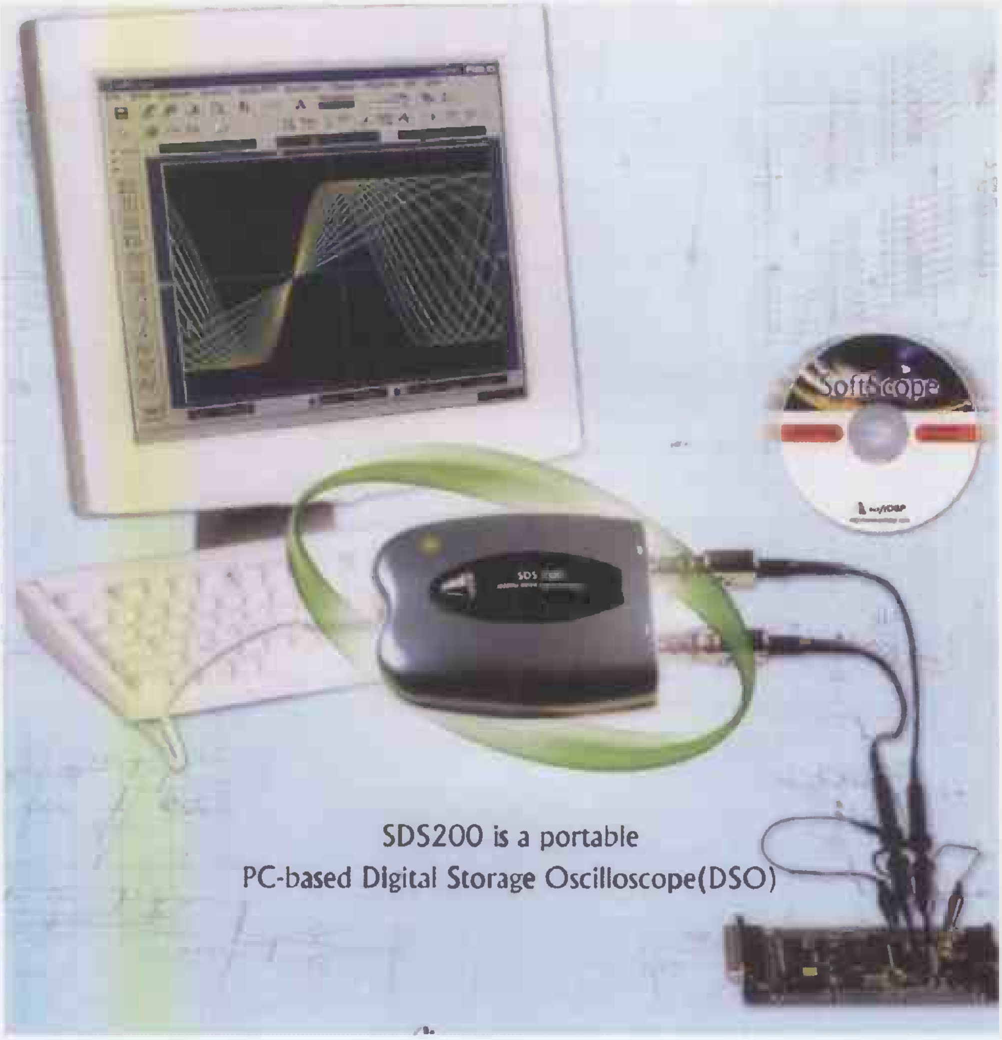
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