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ELECTRONICS WORLD

SEPTEMBER 2003 £3.25

The history of the cathode

Calculus is for life

Professional SDI router

Capacitor sounds II

LED spotlight

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Who knows your whereabouts?

In Edinburgh, you can buy time on a parking meter with your mobile phone. You call the number displayed on the meter (with caller I.D. enabled), and a voice response system asks for the meter's I.D. number. This enables the parking system server to identify your location and activate the meter. The latter now lets you choose how long you want to pay for and prints out a ticket for you to place on view in your car. It also instructs the server to charge that amount to your credit card, or to a special account.

Obviously, in the process, the system knows just where you are. But this is not the only, or even the earliest system for locating you. Someone calling the U.K. emergency number 999 from a fixed line may be unable, or not in a fit state, to give his or her exact location. But the origin of the call can be traced via the exchange(s) involved, and the person thus located. In the United States, E911 (the 'Enhanced 911 mandate', passed 1996, revised 1999) requires all cell-phone operators to install facilities, able to locate a mobile caller dialling the 911 emergency number, to within 50 to 100 'meters', by 2005 (is the U.S. going metric at long last?).

In Europe, wireless network operators are already required by E112 to be able to locate a caller making a call to the emergency number 112. However, there is currently no accuracy specification, and most wireless network operators will simply return the location of the cell via which the call was set up - leaving a "fix" which could cover hundreds or even thousands of metres. The GSM system is now spreading in the U.S., and mobile network operators there use uplink time difference of arrival. This depends upon the mobile being received via at least three base-stations, and the system may presumably have to instruct the mobile temporarily to transmit at higher power, to reach enough base-stations. The dominant U.S. mobile technology, like GSM, also uses TDMA, and uplink time difference of arrival technology is appropriate there also. CDMA (code division multiple access) is a different problem as uplink time difference of arrival is not appropriate, and many CDMA mobiles have a GPS function built in. This returns good position information if the user is outdoors, but less accurate if indoors or in a heavily built up area. These systems are designed to identify a caller's location in an emergency, but in principle could be used by the police continuously to track any suspect, or by national security services for the same purpose, building up a record of an individual's movements up to the present time.

There are also other ways in which one's location, either current or at some time in the past, could be determined. RFID (radio frequency identification) tags are set to become ubiquitous. The Gillette Company of Boston, USA, proposes to buy up to five hundred million or so tags, to mark its razors and packs of blades. These tags are already incorporated in product being sold there, in U.K. and Germany, and the resulting improved inventory management is expected to save billions annually. The tags, read by scanners, will provide records giving details of the time of the sale and outlet, but will remain in the product and be accessible in principle thereafter. Similar tags could appear hidden in the hem of clothes, the binding of books, car tyres and almost any merchandise you can think of. The tags cost tens of pennies today and this will drop to just a few pence each before long. Almost any purchased item will be able to identify the whereabouts of the purchaser either in the past or in some cases, currently, creating - or breaking - an alibi. Even the humble credit card will leave a trace whenever used, creating a record of what and when you bought what where. Japan is well ahead of the game and before long there you will be able to opt for personalised targeted advertising. Knowing where you are, the system could ring your mobile to alert you that the shop you are approaching sells your favourite brand of chewing gum.

Some of these means of telling where you are, are obviously beneficial, even potentially life-saving. But others can be expected to raise anxious representations from civil liberty groups. For more details on this story, see the July 2003 issue of *Spectrum*, (the journal of the IEEE.)

Ian Hickman

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Mosfets for no-adjust audio amplifiers

The need to adjust output device idle current in audio amplifiers following construction has been completely removed by Japanese component maker Sanken.

It has introduced 150V n and p-channel power mosfets with laser-trimmed internal compensating resistors and diodes which mean all devices are matched within ±1% for temperature and ±20% for bias current.

Initially designed for a Pioneer hi-fi, the devices are called LEXAM (legend of excellent audio mosfet).

Temperature compensation is achieved by including a string of diodes in the gate circuit of the n-device. The diodes are doped to give them a characteristic which matches the combined temperature curve of both n and p-fets together.

Adding diodes in only one of the pair works because both transistors dissipate equal power in a class-AB amplifier. Designers have to be careful to heatsink both devices equally.

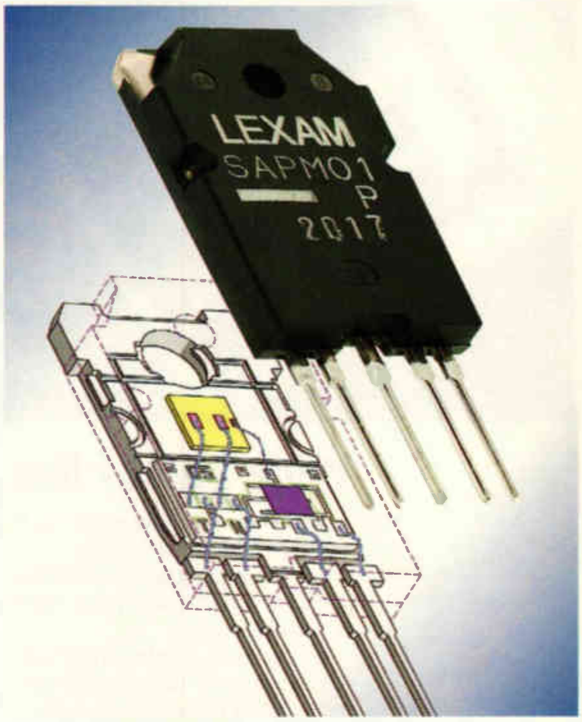
Sanken claims the internal compensation scheme is better than using a separate external sensing transistor mounted between the two devices, as is normal audio amplifier practice, because thermal lag is almost eliminated.

Gate voltage adjustment is achieved by mounting a laser-trimmable potentiometer alongside the semiconductor die in both n and p-fets.

The pot is connected to the gate and can is trimmed to match gate threshold voltage which, given a fixed idle voltage on the device gate during operation, sets quiescent current in the amplifier to 100mA (±20mA).

"Other characteristics such as forward transconductance are optimised to achieve the best possible audio performance," said Sanken.

In the UK, Sanken audio products are available from Magnatec, part of the Semelab Group.



Council raises the bar

The UK's Engineering Council is to raise the Chartered Engineer and Incorporated Engineer entry requirements for professional engineers and also for engineering technicians.

The latest rules will ensure that engineers and technicians must demonstrate competence before registration. Firms will also be encouraged to speed up the process and develop training and development schemes.

"We have high hopes that this new standard will help to ensure the UK continues to be recognised as one of the leading engineering nations of the 21st century," said council chairman Sir Colin Terry.

The three qualifications will remain the same: Chartered Engineer, Incorporated Engineer and Engineering Technician. The four-year MEng courses will still fast-track graduates towards CEng status.

The Engineering Council contains the national register for 250,000 professional engineers.

3D transistor is fastest yet

A three dimensional transistor with a channel length of just 30nm (nanometres) has been demonstrated by Intel. The chip giant is claiming record performance and leakage figures for the NMOS device. Dubbed Trigate, the transistor has three gate contacts to the silicon channel, which makes the device easier to manufacture than planar devices.

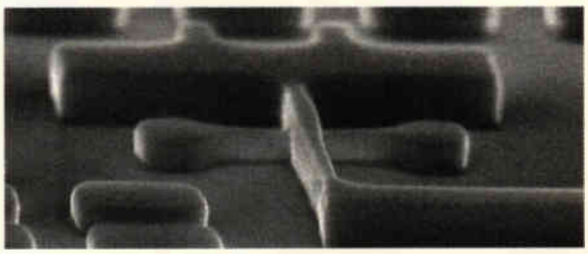
With planar transistors of the type used in microprocessors, the silicon channel needs to be made very thin. For a device with 30nm gate this channel would be perhaps just 10nm thick, creating what is known as a fully depleted transistor.

In Trigate, the silicon channel is the same thickness as the gate is long.

"There isn't any particular constraint now on lithography," said Ken David, co-director of the components research group at Intel. "It doesn't require unique modifications to the tooling."

Intel has so far characterised a 60nm device. At 1.3V it has a saturated drain current of 1.23mA/µm and an off current of 40nA/µm.

The firm is planning to use the 3D transistors when it reaches the 45nm processing stage. Trigate is now moving from a research phase into full process development.



This 30nm transistor has its silicon channel running from left to right - source to drain - with the gate passing over the top. Thus it contacts the channel on three sides.

Bistable LCD gets true grey-scale

ZBD Displays of Oxfordshire has produced a demonstrator to prove its bistable LCDs can produce multi-shade images.

"This is an extremely exciting time for ZBD. The development of the greyscale demonstrator shows the capabilities of our technology to offer both greyscale and eventually colour," said Henri-Luc Martin, CEO of ZBD.

ZBD, named after its technology: zenithal bistable displays, is developing and marketing technology which can be used in displays that use no power at all to maintain an image - only needing energy to change state.

Previous bistable technologies have had the problem that each pixel is either or off, producing images which are black or white with no shades of grey.

There are ways around this: by using several sub-pixels per pixel - which adds complexity, or rapidly turning the pixels on and off - which negates the power advantage.

What ZBD has done is make a pixel which can be set to one of several darkness settings and will hold the setting indefinitely.

Behind the ZBD technology is an in-pixel diffraction grating what aligns the liquid crystal within.

By varying the grating across each pixel, different parts of the pixel can be made to switch at different voltages - effectively making sub-pixels without needing separate connections to each.

The firm is claiming four error-free grey levels per pixel over a whole display - enough to make 64 colours if the technique was applied to, for instance, a colour display in a phone or PDA.

"The path to greyscale and colour is essential to match the requirements of e-books, electronic readers, shelf-edge labels, PDAs, mobile phones and smart watches," said Martin.

Wide band - low power

A firm from Cambridge reckons it will soon be making wireless systems that can transmit 100Mbit/s of data across 20m using just 50μW of transmit power.

Artimi claims its ultra wideband (UWB) chips will be made purely from CMOS processing and will conform to US and European standards.

UWB is touted as the future for wireless home networks. In its present form the system uses the band between 3GHz and 10.6GHz. Pulses are spread across the whole band with very low transmit power.

"Because you treat the entire spectrum as one flat band it makes the analogue design simpler," said Mark Moore, chief technology officer at Artimi.

In fact the power limit of 50μW has been defined by the US FCC for unlicensed communications in the band.

"The EU is tracking that ruling, and it's expected they'll grant a comparable licence," explained Moore. Until then, the firm has a licence from the Radiocommunications Agency.

In Brief

Liquid crystal lens varies focal length

A liquid crystal lens with electronically variable focal length has been developed by researchers at CRL Opto and Durham University.

Similar work has been carried out by institutions such as University College London. However, the Durham lenses are much larger, with diameters of up to 10mm.

Chris Hughes, senior principal engineer at CRL Opto, said the lenses could be used in applications such as image zoom, wavefront correction and laser beam control.

"It could be used in variable focus optics systems and, depending on how clever you are, zoom elements with no mechanical components," he said.

The lens has a focussing value between 0 and 2 dioptre, meaning it can focus a parallel beam of light between 50cm and infinity.

The design is based on nematic liquid crystal with electrodes around the edge. A voltage potential is introduced across the lens that changes its refractive index.

The clever, and secret, part is getting a zero potential in the centre of the lens, which increases towards the outside edge.

Both spherical and cylindrical lenses can be made to focus light longer than 400nm.

Government gets £7m for wireless

The Government has completed its sale of licences for public fixed wireless access in the 3.4GHz band, raising £6.955m in the process.

After 41 rounds of bidding all fifteen licences were sold to just three bidders.

Poundradio, owned by Hong Kong firm PCCW, won thirteen licences, paying a total of £6.3m. This included nearly £2m for the London licence. Red Spectrum took the Northern Metropolitan licence paying £330,000, while Public Hub paid £330,000 for the Southern Provincial licence.

"The aim of the auction was to see the licences in the hands of the operators best able to take advantage of them, and in turn, to see consumers - including those in areas currently without ADSL or cable - benefit from fixed wireless broadband access," said Stephen Timms, Minister for e-Commerce and Competitiveness

Twice the brightness, no more power

Oxford display developed Ocuity has revealed a switchable brightness display which can double its intensity for almost no power increase.

Based around something Ocuity calls a 'polarisation activated microlens', the add-on optics trade-off viewing angle for brightness when a boost is required.

The microlenses are in a thin sheet and can be switched between focussing and plain states by a voltage. They are also behind the company's other novel display which can be switched from normal 2D viewing to a 3D mode which does not need special glasses.

"We are already talking to manufacturers about licensing production," said company co-founder Graham Woodgate.

The Company first publicly showed its microlens technology, on a 2D/3D display, in February.

www.ocuity.co.uk

RF probe detects cancer

Italian military electronics company Galileo Avionica has developed a non-invasive probe which it claims can find cancer and other anomalies in the body.

Called TRIMprob (Tissue Resonance InterferoMeter Probe), it uses an effect accidentally discovered by the physicist Dr Clarbruno Vedruccio who was working on a mine detector.

"During laboratory experiments he noted and investigated the interference of this probe with live biological substances and consequently pursued his studies until the development of a demonstrator," said Galileo.

Inside the probe is an RF source, invented by Vedruccio, called a hybrid-state maser which "generates highly coherent space and time electromagnetic fields," said Galileo, "and through miniaturised sensors interacts microscopically with the organic substance under examination."

Operating in bands around 460, 930 and 1,390 MHz, it can detect in real time and at an early stage various disorders from inflammatory conditions to cancers, said the firm.

"When the electromagnetic field hits a biologically altered tissue, a phenomenon of interference with the analysed structure takes place.

This phenomenon is interpreted by specially-developed algorithms, and allows the detection of cancer and other pathologies: vascular disorders, joint and bone diseases, sinew and muscle injuries, inflammatory conditions, fibromas," claimed Galileo.

TRIMprob is battery-powered and about 30cm long. Working with a nearby receiver, it analyses the patient fully dressed and with no discomfort.

Medical trials are underway and a probe for prostate cancer is expected this summer.

www.galileoavionica.it

Single photon transmission reaches 100km

Scientists at Toshiba Research Europe and Cambridge University have transmitted quantum cryptography keys using single photons of light over 100km of fibre optic cable.

"As far as we are aware, this is the first demonstration of quantum cryptography over fibres longer than 100km," said Dr Andrew Shields, leader of the Toshiba group developing the system.

Quantum cryptography uses the rules of quantum mechanics to gives the highest level of secrecy yet found in a communications system.

Shields says it offers "unconditional secrecy", which is "independent of the computing power, fancy gadgetry or guile of an adversary".

Toshiba creates single photons using an attenuated laser and encodes data using the photon's phase. At the other end of standard fibre optic cable, avalanche photodiodes are used to detect the incoming photons.

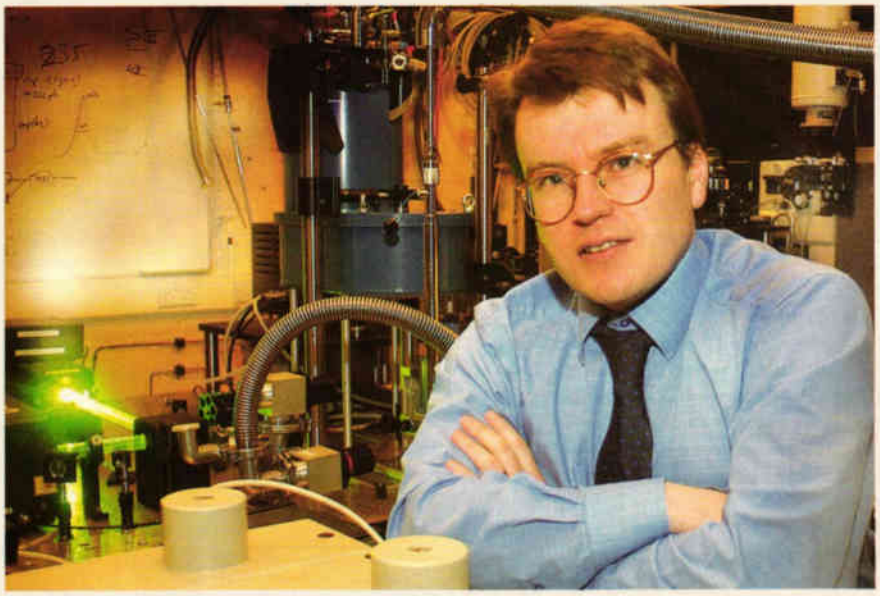
Due to the rules of quantum mechanics, any interception of the photon by an eavesdropper has modify the phase (Heisenberg's uncertainty principle), so the receiver will be aware of tampering.

An eavesdropper "cannot gain any information about the encoded single photons without causing a detectable disturbance", said Shields.

The quantum system is only used to send the key, which is then used in a standard 3DES or AES encryption system, or perhaps a one-time-Pad system. "That extends the security, but is only suitable for small amounts of data," added Shields.

The group's success has led to Government funding for a commercial system on unhackable communications.

"They're funding part of the future programme, to integrate a single photon source," said Shields. This quantum LED project has a budget of £1m, he said.



Japan leads supercomputer race

The world's most powerful computer is still the Earth Simulator - according to the annual top 500 supercomputer list compiled by research labs in Germany and the US.

The Earth Simulator, built by NEC and installed in Yokohama, is rated at 35.86Tflop/s (teraflops or trillions of calculations per second) using the Linpack performance measure.

Number two is Hewlett-Packard's ASCI Q at Los Alamos with 13.88Tflop/s followed by the Intel Xeon-based MCR cluster at Lawrence Livermore Laboratory. This is the highest ever place for a cluster, which uses a Quadrics interconnect and was manufactured by Linux Networx.

Former world-fastest ASCI White came fourth, and would probably have come third with this years slightly modified Linpack if the computer had been available to be re-tested.

The upgraded 6,656-processor IBM SP system at the US National Energy Research Scientific Computing Center, which is almost identical to 8,192 processor ASCI White, came fifth with 7.3Tflop/s.

Away from Japan and the US, France gets tenth spot with 3.98Tflop/s for its nuclear research HP AlphaServer SC, followed by Germany, and the UK at 12 with its 3.241Tflop/s HPCx - an IBM pSeries 690 based Oxforahire (see picture).

The number of systems in the top 500 list using Intel processors grew from 56 to 119 in the six months before the list was compiled, so Intel can at last join IBM (Power architecture) and HP (PA-RISC) as a big chip contributor.

Two notable newcomers among the top ten are Fujitsu's PrimePower HPC2500 system at the National Aerospace Laboratory of Japan, at seven the largest new Japanese system; and at eight, the highest ranked Itanium-based system, produced by Hewlett-Packard and installed at Pacific Northwest National Laboratory.

Almost 4Tflop/s are now required for a top ten position and 59 systems exceed 1Tflop/s.

If you add the performance of all 500 computers, IBM is producing 34.9 per cent of the power, HP 24.1 per cent and NEC 11.7 per cent.

The number of clusters grew again, to 149 systems of which 23 have been made by the organisations which use them.

It has been suggested the US Department of Defense's recent injection of almost $150m into US supercomputer research was prompted by Japan's dominance of the list.

Ranked twelfth in the world, this is the UK's most powerful computer. Called HPXc it is a cluster of IBM SMP nodes containing 1,280 POWER4 processors and delivering 6.6 teraflop/s peak - around 3.5 teraflops/s sustained. It has 1.28Tbyte of memory and 18Tbyte of disk space.

Miniature engine

Ceramic micro-engines just a few millimetres in length have been created by researchers at the University of Birmingham.

"These micro-engines will be much more energy efficient than standard batteries. It takes 2,000 times more energy to manufacture a battery than the battery dispenses while it is being used," said Dr Kyle Jiang, lead investigator at Birmingham's department of mechanical engineering.

However, Jiang's engine is not a fuel cell. "The difference is that a micro-engine gives a displacement, and produces electricity as well," he said.

In fact the micro-engine is an internal combustion engine, with the choice of fuel yet to be finalised. "At the moment the most likely fuel will be propane and a catalyst, platinum," said Jiang.

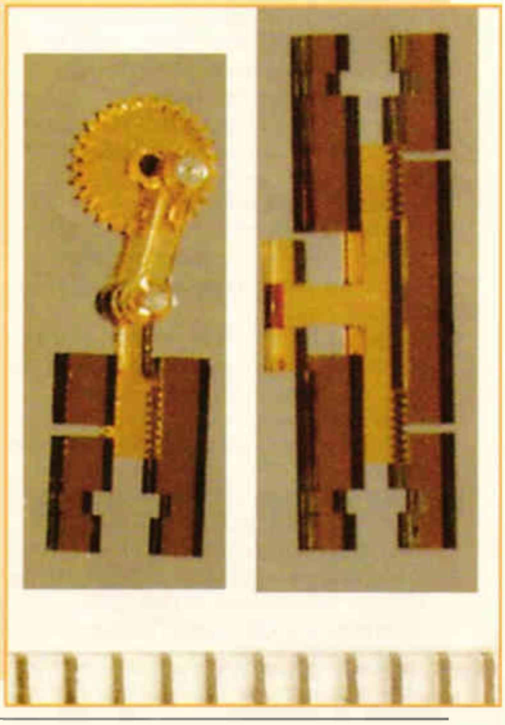
In the presence of platinum the propane will spontaneously combust, avoiding the need for an ignition source, Jiang explained.

While hydrogen might be a better fuel choice, he said, because of its high energy density, it would need an ignition source inside the combustion chamber.

Manufacture of the engines is the University's main achievement. "We use UV lithography. The construction material is a kind of polymer," said Jiang. This is then converted to ceramic.

With conventional combustion techniques there is a minimum size to the device. If the combustion chamber drops below 1mm on a side, the gas will not burn, claimed Jiang.

Micro-engines could be used to drive micro air vehicles and micro-robots for reconnaissance purposes, communications relays, micro-cameras and other sensor carriers.



Mobile radar for the troops

UK design consultancy Plextek has developed a mobile radar system that makes use of programmable logic and a handheld computer for its display.

The radar is called BLightER, and is designed to be set up in a battlefield to provide up to date information to troops. It can be set on a tripod or fixed to a building.

"It's at the concept stage at the moment," said Mark Radford, senior project consultant at Plextek. "It's a very lightweight unit."

BLightER is a frequency modulated, continuous wave radar operating at around 15GHz. The electronically formed beam has a width of up to 5 degrees and a range of 10km. Using e-beam allows different users to focus on different areas of interest.

It can resolve down to 10m with doppler resolution of 1mph, claimed Plextek.

Data is sent to one or more handheld iPAQs, with the option of using a wireless link.

"You could use wireless LAN, or extend the range by upping power or using some kind of directional antenna," said Radford.

Power could come from a car or lorry, battery pack or even a solar cell, he said, as power consumption is around 15W.

The signal processing should fit into a low cost FPGA to keep overall costs down, said Radford, hopefully to less than £15,000.

Spotlight uses LEDs

UK-based Publicscreen & Lightsystem has produced spotlights using Luxeon high-intensity LEDs from Lumileds.

Called LEDSpot Randy 48 lamps, after lighting designer Randy German who helped design the lamps, each uses 48 Luxeons in red, green, blue and white.

DMX control, used in stage lighting, "in combination with Lumileds Luxeon LEDs allows a far quicker response of light, special effects and dimming, while providing a choice of over 16 million colours", said Publicscreen. "In addition, colour-fade effects can be created at the same time as strobe effects, forming the basis for more artistic lighting techniques."

A total of 35 LEDSpots were used on a recent concert tour by German musician Herbert Groenemeyer. "This is the first time a concert has been lit with LEDs and it marks a breakthrough in the acceptance of solid state technology as a major light source for the entertainment industry," said Ingo Teztlaff of Publicscreen.

■ Lumileds has released details of the next Luxeons to be added to its portfolio.

Having previously made 1.2W single-chip and 5W quad-chip devices, it will now introduce 2 and 3W single-chip LEDs.

These will operate at 700mA and 1A, and white versions will deliver 50 and 70 lumens, respectively.

Voltage drop in both is 3.5V, meaning efficiency is 20lm/W, slightly under that of the company's 1.2W chips.

The higher-power LEDs are thought to use a 1mm^2 die similar to that used in Lumileds' 1.2W devices, mounted in a similar package to that used for its 5W LEDs, which has better thermal characteristics.

Lumileds is also now shipping 'warm white' 1W leds with, typically, a colour temperature near 3,200k, colour rendering index over 85 and an average light output of 22 lumens.

www.lumileds.com

Power to the peripheral

A standard for delivering power through Ethernet cable has been ratified by the IEEE.

Devices that are expected to make use of the standard include digital security cameras, wireless access nodes and Webcams. The technology could also be used to help power a laptop PC, increasing battery life when the laptop is connected to a network.

The IEEE802.3af standard specifies that –48V DC is available on the four wires not normally used in Ethernet cabling. Up to 15.4W can be injected into each port, giving each peripheral around 13W to play with.

Using the system will have implications for power supply makers, however, as power fed into the network must meet 100mV noise and ripple specifications. An isolation of 2,250V DC is specified between wires.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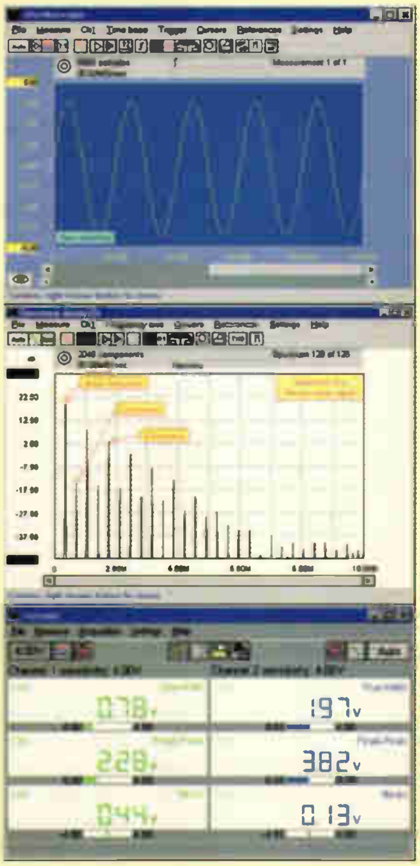

The cathode

Throughout the history of thermionic valve manufacture there has been considerable impetus to develop improved cathodes, as it is the cathode that chiefly dictates a valve's power handling capacity and efficiency. Patrick Mitchell elucidates

Since the rise of semiconductors, thermionic cathodes have been relegated to a few specialised areas such as cathode ray tubes (CRT), high power microwave frequency circuits and high end audio amplifiers but much of the early development of electronics was intimately bound to cathode technology. After being sidelined for several decades, cathodes have again come to prominence with the accelerating development of cold field emission technology.

During the valve era extensive research was dedicated to devising cathodes with lower operating temperatures while maintaining or increasing their electron emissions. High cathode temperatures bring several drawbacks. One index of merit of a thermionic cathode is high emission current to required heating power ratio, which is a function of emissions per unit area, and operating temperature (**Fig. 1 & 2**). This is far lower for cathode types with cooler operating temperatures. High temperature filaments have a limited life because of increased vaporisation of atoms from their surface, and impose considerable constraints on the design of cathodes and their surrounding elements, requiring wide spacing to control the temperature of close electrodes.[1] A wide gap between anode and cathode means that a large anode voltage is necessary to create the necessary field in the immediate vicinity of the cathode to draw away the cloud of emitted electrons. **Fig. 4.** These electrons are then considerably accelerated as they pass to the anode. The energy they thus acquire is transferred to the anode on impact, heating it. Consequently high power valves often have hotter anodes than cathodes! The dividends from reducing cathode temperature are substantial.

The history of thermionic cathodes can be conveniently divided into two phases. From the discovery of thermionic emission in the 1870s until around 1912, thermionic devices were one class of many under investigation by scientists and engineers but did not show outstanding potential. During this period development was driven by curiosity and isolated individuals and was consequently haphazard. This situation then changed to one where thermionic devices assumed great economic importance.

Up to 1912 - scientific curiosity

The British physicist Frederick Guthrie advanced his theory of thermionic emission in 1873 following a series of experiments on hot charged bodies. When he placed a red-hot negatively charged metal sphere in a vacuum it discharged but a positively charged sphere did not. He thus concluded that hot metal bodies emit negatively charged particles. His hot spheres were the first thermionic emitters.

In the 1880s, three researchers: Goldstein, Hittorf, and Edison independently found that a current would flow between the heated filament of an incandescent light bulb and an extra electrode placed in the bulb. The light bulbs of the time (Swan and Edison types) used carbon filaments which formed the first thermionic filament cathodes. The first public description and demonstration of the effect was given on behalf of Edison by Edwin Houston in 1884 at the Philadelphia International Electrical Exhibition. William Preece, chief engineer of the British Post Office was present. He approached Edison for some sample valves and was generously given several. On his return to England he conducted a series of experiments into the phenomenon and published his results in 1885. He used the term "Edison effect" for the current flow between the filament and electrode in his paper and the name stuck. The nature of the current was not understood at the time. The discovery had been made in the course of investigating the blackening of bulbs due to the evaporation of carbon from the filament and condensation on the inside of the bulb. Early theories thus involved charged carbon vapour as the current carrier.

In 1897 JJ Thompson measured the charge to mass ratio of electrons establishing that they have –ve charge and mass. Electrons then became leading contenders for the thermionic charge carrier. Early valves had modest degrees of vacuum and ionised gas molecules as well as electrons carried appreciable current. Later when valves with high or 'hard' vacuums were produced electrons carried effectively all of the current.

A major early contribution was made by Owen Richardson who studied the behaviour of hot metal filaments in gases and vacuum. He published on the platinum filament in 1901 and further results from platinum as well as carbon and sodium in 1903. He formulated an equation to model the emission current per unit area: $i = QT\text{-}e^{(-\phi\varepsilon/kT)}$ A/m². A more accurate equation was provided by Saul Dushman from a quantum based derivation in 1920:

$i = QT^2 e^{-\phi\varepsilon/kT}$ A/m²

where i = saturation emission current from a hot cathode in A/m²

ε = the electronic charge (1.6022×10^{-19} coulombs)

k = Boltzman's constant (1.3807×10^{-23} J/K)

T = Kelvin temperature

ϕ = the work function of the cathode surface (see table 1)

Q = a constant specific to the cathode surface (see table 1).

This is now know as the Richardson Dushman equation.

In this period cathodes were directly heated filaments first made of carbon and then platinum, tantalum or tungsten and operated at around 2500 to 3000K. Tantalum was in use until around 1913 as a filament material but it tended to warp in service. It was replaced by tungsten but tungsten has lower emission than tantalum. Filaments made from tungsten wire with tantalum wrap known as Hudson filaments were briefly popular as was tungsten coated in a tantalum paste.

Such cathodes were superseded for most applications by thoriated tungsten in the 1920s and oxide cathodes in the late 1920s and 1930s. This chronology reflects the manufacturing difficulties associated with the types rather than the sequence of their discovery.[3]

Oxide cathodes that were later to dominate the field originated serendipitously in the pre 1912 period. The German scientist Arthur Wehnelt, while working with platinum wire heated to comparatively modest temperatures in gases, noted luminous spots on the wire. He traced this to contaminants deposited on the surface of the wires during preparation that gave localised areas of high electron emission, exciting gas molecules that emitted light on relaxation. This led to a series of experiments on oxide-coated cathodes, the results being published from 1903-1905.

Histories of the valve highlight de Forest, Fleming, and Langmuir; Wehnelt usually gets less attention. He has nevertheless a persuasive claim to each of the three main developments in valve technology. He used his alkali earth oxide coated cathode to make a diode valve that predated Fleming's (detailed in a 1906 patent application). It was for charging accumulators for x-ray equipment and was not applied to radio reception and so was of little interest

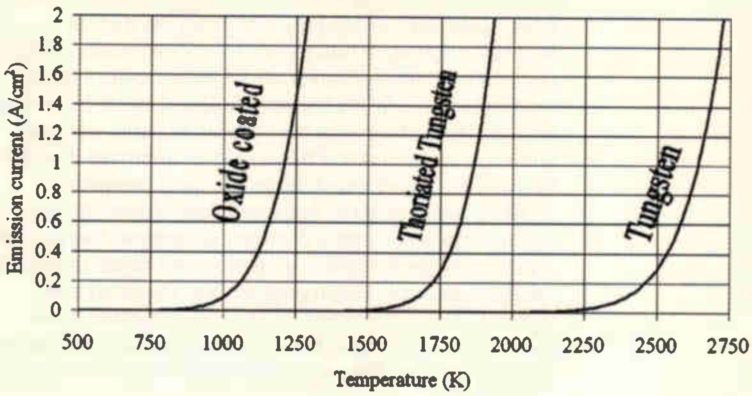

Fig. 1. Plots of emission current per cm² against temperature for the three main thermionic cathode types.

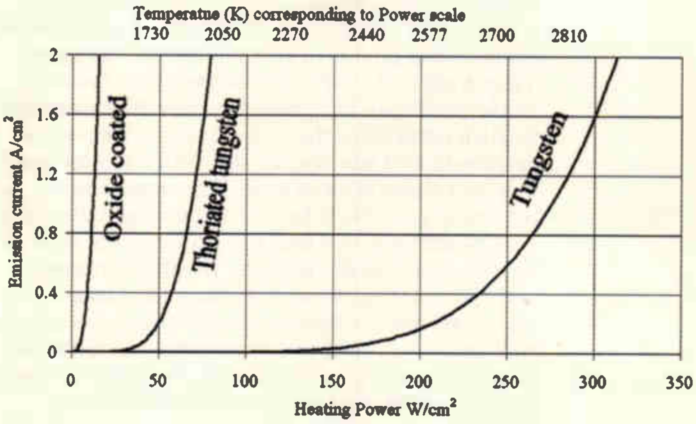

Fig. 2. Emission per watt of heating current for three thermionic cathode types.

to radio historians. He invented a telephone repeater (amplifier) that worked by using a variable electric field to deflect a cathode ray on and off a target thus varying the cathode current. This predated de Forest's Audion (the first triode) and was conceived and designed for, built for and apparently fulfilled the purpose. Compare this with de Forest's triode which he happened on as one of numerous devices he investigated. He did not perform a detailed and accurate characterisation of its behaviour and exploited it after its potential had been recognised by others. Finally Wehnelt's oxide cathode predated the thoriated cathode by at least 10 years.[3]

1912 on - commercial development

Although de Forest introduced his 'Audion' triode in 1906, its potential as an amplifier was not appreciated at first. An urgent need for a means of amplification had meanwhile arisen from the demands of long distance telephone and radio communications. Various devices had

Table 1. Some values for the Richardson Dushman equation

Material	ϕ Volts	Q
Oxide coated cathode	1	0.01
Thoriated tungsten	2.86	15.5
Tungsten	4.53	60.2
Tantalum	4.07	60.2
Thorium	3.35	60.2
Platinum	6.26	.00017

emerged to fill this need including magnetic amplifiers, relay based devices and repeaters along the lines of Wehnelt's, but none was satisfactory. Lowenstein publicly demonstrated unambiguous amplification using a triode for the first time in 1912 shortly followed by de Forrest. At the time the performance of triodes in this role was poor but it was realised that if they could be improved they had the potential to get round the problems of competing systems: low maximum frequency, low sensitivity and high distortion. Powerful commercial interests hungry for a solution to their amplification problems began to finance intensive research. Rapid progress was the result and within 15 years the pattern of valve manufacture to the present day had been defined. This process was not sudden but the year 1912 has as good a claim as any to being the watershed.[4, 5]

As far as the cathode is concerned, this second period in valve history saw the replacement of the earlier high temperature cathodes with the more energy efficient oxide coated and thoriated types. Oxide coated cathodes had been in use for a decade by 1912 but the thoriated tungsten cathode was a product of General Electric's increased research effort. As with oxide cathodes their discovery was serendipitous. Early manufacturers of incandescent tungsten lamps found that at the operating temperature, tungsten formed into large crystals with correspondingly large boundaries between them. When used with AC, such boundaries gave rise to faults, hot spots, and early failure. Various additives were tried to keep the crystal structure fine and overcome this problem. Thorium nitrate and oxide proved to be effective. Thorium has a long association with the lighting industry as its oxide was the principal active component of gas lamp mantles! It has now been replaced in this role because thorium is weakly radioactive. General Electric used one of their lamp factories as a research base for thermionics. Valves under investigation used tungsten cathodes and by accident some thoriated tungsten was used for one batch. When tested, valves from this batch had greater than normal cathode currents. Sources differ[3,4] on the date but this probably happened in 1913. GE's Dr. Irving Langmuir spotted the potential of this observation and began investigation. In 1914 he filed a patent containing all the elements of thoriated cathode preparation. This included 'flashing' at 2900K for 1 minute, 'forming' at 2250K for a few minutes, operating at 17-1800K and the reversion of emissions to the level of pure tungsten at 2800K and the restoration by repeating the flash/form process. Langmuir's is a recurring name in electronic and chemical research of the first half of the 20th century. He was awarded the Nobel Prize for chemistry in 1932.

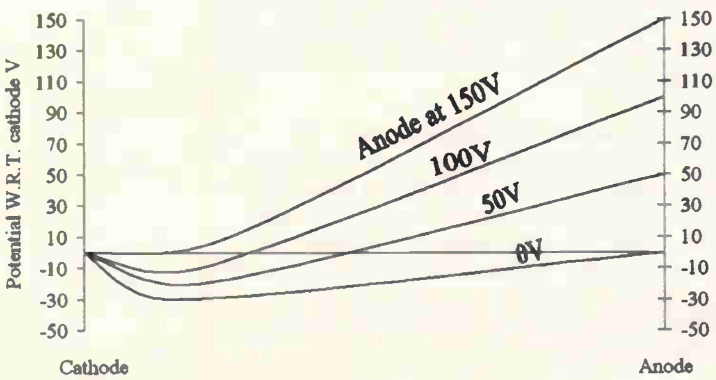

Fig. 3. Plot of the changes in potential with distance in the space between a cathode and anode[7]. With anode and cathode potentials equal, the emitted electrons form a cloud or space charge around the cathode and consequently a potential minimum. Increasing the anode potential reduceds this minimum and increases cathode current until a point where the minimum is abolished (150V in this example) and all emitted electrons pass to the anode and the cathode is 'saturated'. The high voltage necessary to abolish this minimum means that electrons are subsequently substantially accelerated towards the anode which absorbs their energy and gets hot.

GE announced their thoriated filament valves in 1922 and they became generally available in 1923. A curious twist to the history of thoriated cathodes is that the British MOV (previously Marconi-Osram Valve) Company prototyped a thoriated filament valve in 1920 and marketed a production version in 1921. Considering the intensive efforts at GE, how was it that they were beaten to the product? Few details of the MOV valve and its development have survived.[5]

Thoriated tungsten cathodes were denoted 'dull emitter' because at their operating temperatures they glow dull red as opposed to bright emitter plane tungsten, tantalum and Hudsen types that glowed bright white. Like their predecessors they are directly heated filaments. Their operating temperature is around 1700-1900K. A small amount of thorium oxide is added to tungsten to form the cathode filament. In later types the filament was often blasted with steel grit to increase the surface area. Such filaments have emissions only slightly better than pure tungsten until they are heat treated as described by Langmuir. The successful configuration is a tungsten wire with a layer of metallic thorium one atom thick on the surface. The first step in production of this layer is to reduce some of the thorium oxide to thorium metal. At high temperatures an equilibrium exists between tungsten and thorium oxides. Although the equilibrium favours thorium oxide, tungsten metal is in vast excess in the filament so at suitable temperatures (above 2750K) some oxygen passes to tungsten releasing thorium metal atoms. This is the basis of flashing, the first step in the heat treatment.

Flashing is done at 2800K for 1-3 minutes and results in the production of thorium throughout the volume of the wire. At this temperature, metallic thorium diffuses through solid tungsten to the surface where a layer would form if it stayed there but at 2800K the rate of thorium evaporation from the surface exceeds that of arrival at the surface by diffusion. A second step in the heat treatment is hence necessary to form the surface layer and this is done at a temperature where appreciable diffusion of thorium takes place but evaporation does not exceed accumulation on the surface. Such temperatures are in the 'activating range' of 2200-2600K. At this lower temperature thorium oxide is not reduced to thorium to any significant degree, hence the need for two steps. Activation is done over about 20 minutes and the cathode emissions rise over this time. The effect is impressive, testing at 1500°K, activation raises the output from that of clean tungsten (91nA/cm^2) to 8.5 mA/cm^2; a 93,000 fold increase. Emissions per heating watt are around 5 times greater (Figure 2). Interestingly, the emissions from thoriated tungsten are considerably higher than those of pure thorium wire (740μA/cm^2 at 1500K) and the rate of evaporation of thorium atoms from the surface is much smaller.

Damage to the thorium layer reduces emissions drastically. A 50% loss of thorium coverage reduces emission by 99%. With extended use the emission current of a thoriated cathode declines because of thorium loss through vaporisation and two processes involving stray gas molecules within the valve: poisoning and sputtering.[1]

Stray gas molecules within the glass envelope are easily ionised by electrons passing between the cathode and anode. Such ions are positive and are thus accelerated towards, and collide with the cathode. Such collisions knock active surface atoms out of the cathode. This process is known as sputtering. Neon, argon, caesium and mercury are the chief offenders.

Cathode poisoning is due to chemical contamination of the cathode by gases, principally oxygen, which find their way into valves. Nitrogen actually temporarily enhances emissions from thoriated tungsten.

A feature of thoriated filaments is that they can be rejuvenated when emissions drop by repeat flashing and activating because the thorium oxide they contain is not expended by the first process.

The other major development in cathodes of the post 1912 era was the oxide-coated cathode, or rather the reliable deployment of the oxide-coated cathode as the cathode itself dates from 1903. The delay was because of the difficulties in producing a consistent and durable cathode and in producing and maintaining a sufficiently hard vacuum. Once again the principle benefit was to bring down the operating temperature, this time to about 1050°K. Western Electric took an interest in oxide-coated cathodes and had successful valves in production by 1919. Early examples were expensive to make because platinum was used as the filament metal. This was soon changed to nickel alloy or tungsten.[5]

The chemistry of the oxide coating (usually barium, strontium, calcium or a combination of these oxides) is complex. They are manufactured with an oxide coating and are then activated or 'formed' by simultaneously heating the cathode above its normal working temperature and drawing a large cathode current. The duration of forming varies from minutes to days depending on the temperature and thickness of the coating. This denudes the coating of oxygen, leaving an excess of barium, which is required to maximise emissions. Contamination with oxygen will reduce emissions so paradoxically oxide cathodes are poisoned by oxygen.

The oxide cathode made indirect heating feasible and consequently engineers had much more control over the design of the emitting surface. Hotter cathodes are more difficult to heat indirectly because of the high filament temperatures required and severe constraints are imposed on the materials used for the cathodes as well as the proximity of other electrodes. With oxide coating, operating temperatures fell below 1200K and this was achievable in an indirectly heated cathode. A tungsten or NiChrome filament could be coated in an insulating layer of aluminium oxide and located in a casing bearing the coating. Oxide cathodes improve the emission current: heater power ratio of cathodes by an order of magnitude over thoriated tungsten.

Another advantage that was particularly important at the time when oxide-coated cathodes were introduced concerned hum. Early electronic equipment was designed to be powered by batteries because mains electricity was not widely available. Large and expensive batteries were thus needed. AC mains became increasingly available during the first quarter of the twentieth century and was a far more attractive means of cathode heating than batteries but brought a problem with thoriated cathodes. The small mass and high temperature of thoriated cathodes means that they cool very quickly, quickly enough to suffer an appreciable temperature drop between peaks of the AC heating current at 50 to 60Hz. Thus the temperature and emission current, fluctuates with heating current giving rise to hum. Radiant heat loss of a 'black body' (to which a hot filament is a good approximation) is given by $P = \sigma T^4$ W/m^2 where σ (Stephan's constant) = 5.67×10^{-8} Wm^{-2}K^{-4}, so oxide cathodes with their lower temperature and larger mass are far less prone to this problem.[5]

These improvements come at a price. Oxide cathodes saturate poorly, i.e. they have a pronounced Schottky effect. **Fig. 3.**

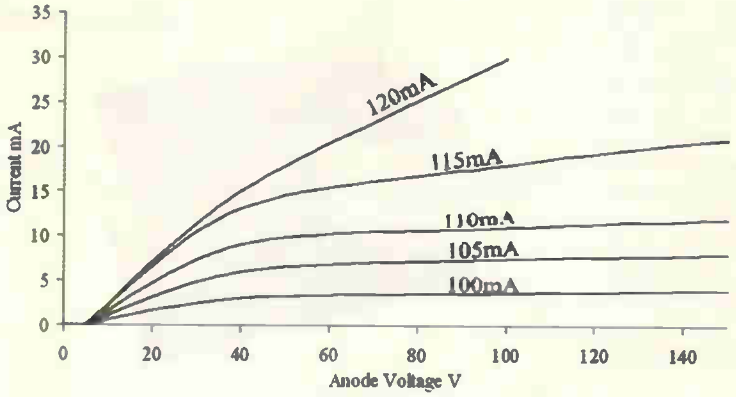

Fig. 4. Characteristic curves of a diode valve to illustrate emission behaviour6. Saturation currents are dependent on anode voltage. This is particularly pronounced with oxide cathodes.[6]

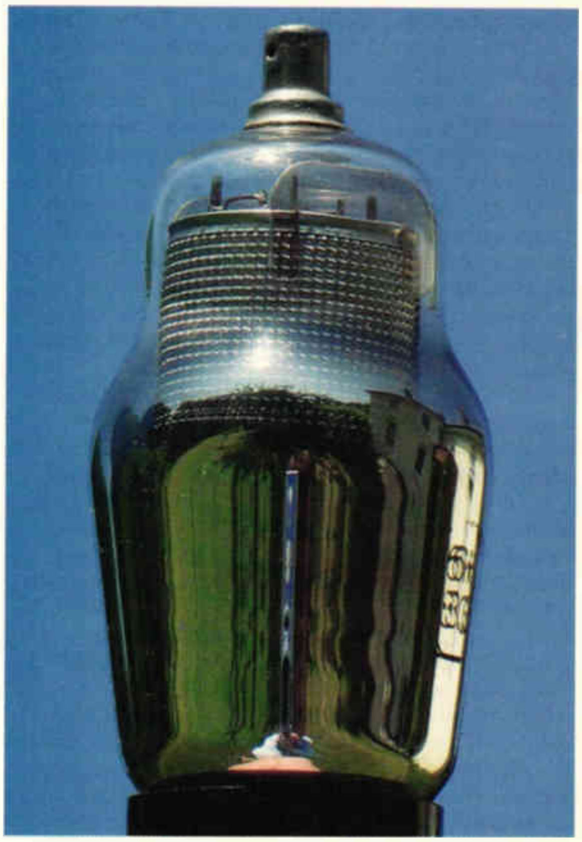

Fig. 5. Valves using oxide coated or thoriated tungsten cathodes appear silvery because of the use of a getter. This is a small amount of reactive metal that is vaporised during the valve manufacture and precipitates on the inside of the glass. Its function is to bind free gas molecules within the valve. It is called a getter because it 'gets' free gas molecules. For a similar reason it is sometimes referred to a 'keeper'.

They also display a degree of instability of emissions which can rise or fall after a large current has been drawn because current electrolyses the coating, liberating oxygen. Further, the thickness of the coating can give it a significant resistance and produce noise. They are best suited to applications where a high output is required and where these failings can be tolerated such as in CRTs. Before the semiconductor age, oxide cathode valves were widespread in domestic equipment but their place has been taken by transistors. Today if you buy a valve amplifier you will be paying for high-end audio technology where fidelity outweighs efficiency and consequently thoriated tungsten cathodes dominate.

Oxide cathodes are fragile. Specifically they are highly susceptible to damage by bombardment by the heavy

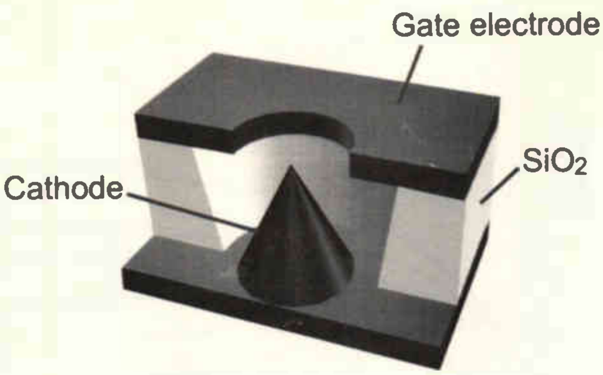

Fig. 6. A cutaway view of a single element of a Spindt cathode or FEC. Electron emissions are controlled by the gate to cathode voltage. +50 to +100 volts on the gate turns the cathode on in this example. No heater is required.

anions that result from ionisation of gas molecules in the valve. This is why practical oxide cathode valves could not be made until the technology to produce and maintain a hard vacuum had been developed. Even hard vacuums are not perfect and heavy ion bombardment remains an issue to this day. Oxide valves last routinely 1,500 – 2,000 hours compared to 5,000 – 10,000 for thoriated. The problem is greatly exaggerated if the heavy ions are accelerated to high energies before impacting the cathode. This places a constraint on the anode voltages that oxide valves can tolerate. For Vaa >1000 volts or so cathode deterioration is excessive. This problem also affects thoriated cathodes though a process of carbonisation can limit the effect. This involves heating the cathode in a hydrocarbon atmosphere. Tungsten carbide is formed on the surface. This reduces the rate of degradation from sputtering by about 85%.[2] The most resilient cathodes are of pure tungsten which is why they continued in use in high power, high anode voltage applications long after they had been superseded in other areas.

A further advantage of thoriated cathodes is that they have a small emitting surface area and so a low capacitance which is particularly important for high power high frequency applications. Where valves are operated with anode voltages of thousands of volts, powers of kW are handled with only a few amps of cathode current. The cathode heating power thus becomes rather immaterial. Such valves made to handle tens to hundreds of kilowatts for radio and TV broadcasting use thoriated cathodes. The EBAC XXX250000 is such a valve. It has a plate dissipation of 250kW, and the filament dissipates 8kW. It weighs 98lb and measures 70 by 33cm.

Both thoriated and oxide cathodes are very sensitive to stray gas in the valve so the vacuum must be 'hard' and this places considerable demands on the initial pumping and long term impermeability of valves. The seals between the glass envelope and the contact pins of valves have always posed a tricky manufacturing problem and these seals are never perfect, allowing the influx of small amounts of atmospheric gas over time. The surfaces of the valve's components also give off dissolved gas molecules over the lifetime of the valve. To minimise the effects of gases a 'getter' is used. This consists of a piece of a reactive metal placed inside the glass envelope and vaporised by an induction furnace or by direct electric heating during evacuation of the valve. Magnesium, titanium (thoriated cathodes) or barium (oxide cathodes) are commonly used for this purpose. The metal then precipitates on the inner surface of the valve and absorbs oxygen and other gases. This is the reason valves appear silvery (**Fig. 5**).

Filament heater voltages deserve a brief note. Most early cathodes used between 1 and 5 volts. In an indirectly heated cathode, the heater voltage has a slight effect on valve operation as the cathode surface potential varies from one end to the other. This tends to blunt the onset of saturation particularly at low anode voltages. This was not a particularly significant problem and does not apply to the indirectly heated oxide cathodes that had become dominant by the 1930s. Eventually by the mid 1930s 6.3V was settled on as the standard heater voltage for directly and indirectly heated cathodes. This came about because of the demand in the USA for car radios. Valves were made for this purpose with the heater voltage chosen to match the car battery voltage that was universally 6.3V at the time.[5]

Recent Progress - Cold Cathodes

Electron emission is divided into thermionic, photoelectric, secondary (electrons scattered from the surface by high energy impacting electrons) and field. Field emissions are induced by a strong electric field such as that occuring at the tip of a lightning conductor during a strike. It is the field emission cathode that brings the technology up to date. Field emission cathode (FEC) technologies today fall into two broad groups: Spindt and carbon based cathodes.

In 1976 by Dr. Charles A. Spindt of the Stanford Research Institute developed the first field or 'Spindt' cathode. It consists of an array of microscopic metal points beneath a perforated metal 'gate'. The Spindt cathode operates cold with a mode of action quite different from that of its thermionic counterpart. Electron emissions depend on electron tunnelling. In a conductor, free electrons are constrained by its surface potential barrier. The height of this barrier corresponds to the work function of the conductor. Thermionic and photoelectric emission work by giving a few electrons enough energy to pass over the potential barrier. Field emission cathodes work by modifying the barrier to maximise tunnelling of electrons which have insufficient energy to pass over the barrier, through it. To modify the barrier in this way field strengths of the order of $10^{16}Vm^{-1}$ are induced over very short distances adjacent to the emitting surface. This is achieved with modest voltages (under 100V) by the geometry of the emitters. Because of their small dimensions, field strengths between the points and gate are large. Field strength is greatest near conductor surfaces which curve with minimum radius as in the well known electrostatic windmill demonstration of school physics labs. Hence emissions are maximised with small sharp points. Spindt used semiconductor manufacturing techniques to produce molybdenum cones beneath holes in a molybdenum layer separated by SiO_2 on a heavily doped Si wafer. He ended up with an array of conical electrodes 1.5μm high and wide at the base below 1.5μm diameter holes as illustrated in **Fig. 6**. More recent elements are of the order of 1 micron across. Spindt's invention began the study of vacuum microelectronics. Spindt cathodes are made on semiconductor wafers so they have the potential to be deployed in integrated circuits. The size achievable is limited to that of wafers of about 20cm diameter. This limits their use in display applications.

Carbon films have been under investigation because of their field emitting properties since the mid-1970s when it was discovered that hydrogenated faces of diamond crystals have a particularly low electron affinity. Diamond based films display emission via two mechanisms. As well as the above noted low affinity for electrons, high aspect ratio geometry associated with diamond crystals facilitates emission from areas with higher electron affinity. A difficulty with this technology is that diamond is not a conductor and thus injecting electrons into the conducting band is difficult. Another approach using carbon that also resulted in good field emission used graphite type carbon materials in the form of nanostructures with high aspect ratios leading to high values of electric field enhancement rather low electron affinity.

The discovery in 1991 by Japanese electron microscopist Sumio Iijima of carbon nanotubes began a worldwide research effort that has revealed extraordinary physical characteristics making them not only structures of inherent fascination but also giving them numerous potentially revolutionary applications. From the point of view of electronics, double wall nanotubes have the potential to form 'ultracapacitors' able to store 50 joules per centimetre cube. Extremely high thermal conductivity along the major axis raises the possibility of heat sinking. They have the potential to act as superconductors and at room temperatures metallic conductivity is achievable. This last property coupled with their extremely large aspect ratio makes them ideal for field emission applications. Current densities of over 1A/cm^2 have been achieved with fields of 7V per µm in a cathode that shows less than 10% degradation after 2000 hours of continuous operation. This figure compares favourably with thermionic cathodes whose emissions range from around 0.1 to 3 amps per cm square depending on the type and the temperature. Unlike Spindt cathodes, carbon based field emission cathodes are made by coating substrates such as glass or metal sheets. They thus have the potential to be made to virtually any size. This feature is highly attractive in display technology.

Field emission cathodes offer major advantages over existing thermionic technology. One of the main forces driving their development is the large potential market for flat panel display products. Successful flat displays have been demonstrated using gated FECs between 0.2 and 5 millimetres behind a phosphorescent screen, each pixel having its own set of cathodes, the colour and brightness of the pixel being controlled with cathode gate voltages. They are brighter and faster than LCD technology and have a wider viewing angle. Large scale commercial production is awaited.

Another potential use is in the manufacture of valves. Durability will have to be improved before commercial exploitation but practical valves have been demonstrated, for example a 10GHz 27W travelling wave tube by Makishima et al of NEC, Japan.

Other diverse applications have been announced including electric thrusters for spacecraft, miniature X-ray tubes for medical robots, indicator and illuminator lights, and microwave devices. Cold cathodes look set to largely replace thermionic cathodes in the future. They also have the potential to make inroads into applications that are currently the domain of semiconductors and most significantly to extend the scope of electronics in general beyond what is now possible. ■

References and further reading

1. Fred Rosebury, Handbook of electron tube and vacuum techniques. ISBN 1563961210
2. A V. Eastman, Fundamentals of Vacuum Tubes. McGraw-Hill, New York, 1941
3. History of Thermionic devices. Conference proceedings of the Newcomen Society, 23/4/1994, ISBN:0-904685-05-5
4. GFJ Tyne, Saga of the Vacuum Tube. ISBN: 0-672-21470-9
5. John W. Stokes, 70 years of radio tubes and valves. ISBN 1-886606-11-0
6. Morgan Jones, Valve Amplifiers. ISBN 0-7506-2337-3
7. Handbook of Wireless Telegraphy 1938 Admiralty HM Stationery Office London 1938.

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Efficient lighting controller

Street and garden lighting controllers usually use timers, which are rather crude as the onset of daylight of dark can vary considerably. Using distributed LDRs, this circuit makes sure that the lights are only turned on when they are needed.

£50 WINNER

In most parts of the world, turning on street and garden lighting is done either manually or on a time basis. Since the number of hours of sunshine in a day varies from day to day and from one place to another, and since a manually controlled system is prone to error, an automatic control system that detects the intensity of light and turns on/off the system is a more efficient solution.

This lighting controller is designed to take care of this. It also provides a manual control feature. Light dependent resistors – LDRs – are placed at different parts of the garden/locality, taking care that shadows from nearby trees of light from nearby buildings does not impair the effectiveness of the LDRs.

In most parts of the world, during summer, the number of hours of sunshine varies from 10 hours to 6 hours and 12-15 hours during winter. The resistance of LDRs changes of the order of thousands of times when daylight turns to darkness and *vice versa*. This change is tapped using a potential divider.

Outputs from all the sensors are ANDed and NORed. These processed outputs are sent to an S-R bistable device shown in the diagram. Final output is sent to the relay via a transistor.

When sunlight fails on any of the sensors, the output of the bistable goes low and the relay is not activated. Lighting is activated only when outputs from all the sensors are low. Multiple sensors are used to make the system foolproof. If a bird sits on a sensor, or there's sudden clouds cover, etc., false triggering will not occur.

Switch S_1 is used to select the type of control to be used. For manual control, a 14-stage ripple counter, 4060B, is used as an *RC* oscillator whose resistance can be varied to get the necessary timeout, detailed in the **Table**.

Pin 3 of the 4060B is ORed with the reset switch S_3 and fed into another SR bistable. Switch S_2 is used trigger the oscillator. The output of this bistable triggers the relay.

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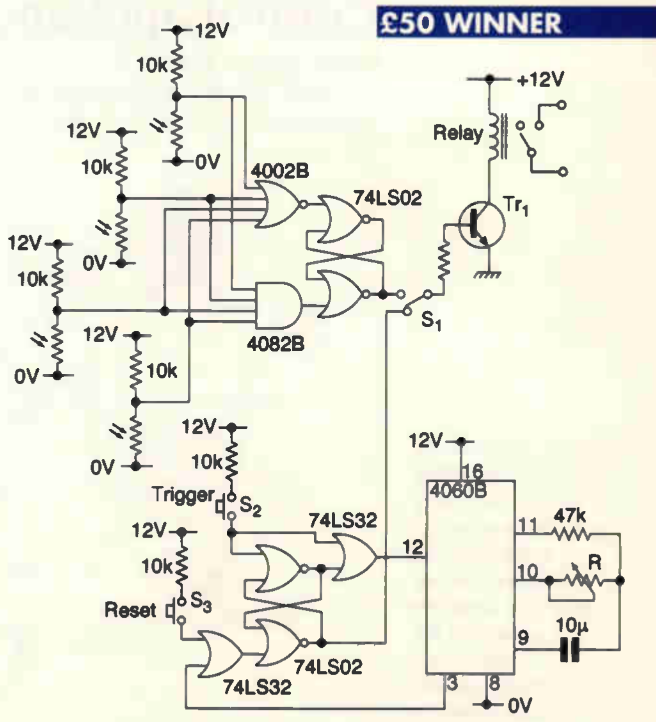
Table. One resistor sets the 'on' period in 'manual' mode.

No of hours	Resistance (kΩ)
6	105
8	140
10	175
12	210
14	245
16	281



Porch light control

Having once again found our porch light left on all night, it was time to try and design a circuit which would allow the lamp to be manually turned on but would automatically turn it off after a few minutes. For convenience, it should also fit safely into a standard mains patress box.

It seems that the only practical switch available which provides this facility is mechanical. You press a sprung plunger which closes the switch. On release, air returns to the cylinder through a very small hole and so the switch opens some time later. The time delay is very variable and uncontrollable. Surely there must be an *electronic* solution?

The problem is that behind every single switch in normal house wiring are only two wires: live in and switched live out. You cannot get directly at the neutral. So producing a small DC voltage to run an electronic switch is a problem extending beyond squeezing into a standard switch box a mains transformer (or even a voltage-dropping capacitor), rectification and smoothing.

The circuit shown in the figure is a solution.

Pressing S1 results in the lamp being switched on via two diodes in the bridge and the 6.8V Zener. Across the Zener is full wave rectified 6.8 volts which is smoothed by C1. IC1 is a frequency divider whose reset at pin 11 is briefly held high until C3 is charged. when the counter starts from zero to count the 50Hz pulses at its clock input, pin 10. C2 ensures that any spurious spikes appearing on the mains are not counted. The used output on IC1 is pin 3 where the resultant frequency is the clock divided by 2^{13}. This results in a wavelength of approximately 5_ minutes.

The counting always starts from zero and so the first half of this output wavelength results in pin 3 being low. Hence Q1 is off and the LED in the MOC3041 optoisolator is lit via R5. At a zero-crossing point this switches on the triac in the isolator. In turn this provides gate current to the 400V triac and hence the circuit remains latched on with the lamp lit even when push-button S1 is released.

However, after approximately 2_ minutes the half wavelength ends, taking IC1 pin 3 high. This switches on Q1 which shorts out the internal LED in MOC3041, switching both triacs off, together with the lamp.

This circuit runs directly from the mains and the utmost care must be exercised in building, testing and fitting the circuit board into its switch box. Once the circuit board is fitted, it is potentially no more dangerous than the mechanical switch it replaces.

Note that S1 switches mains and therefore should be designed for 230 volts at no less than 1 amp. Further the Zener diode ZD1 carries all the current of the lamp, which means that it should be at least 5 watts and, for a good safety margin, only bulbs up to 100 watts should be used.

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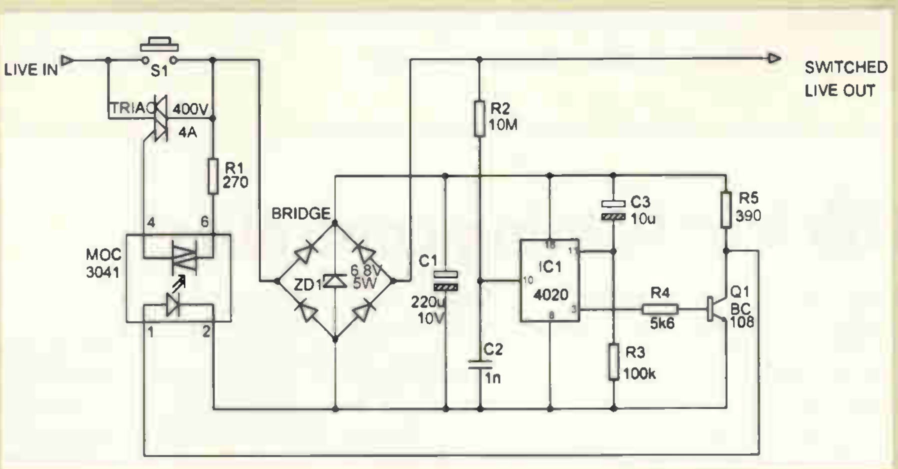


Control appliances remotely via the telephone

Remote control of selected electrically-operated home appliances by switching on and off for a chosen duration is desirable in many circumstances.

It may be useful, for instance, to switch on a pump for watering the garden when you're away from home for a long period. While the house is empty, for security purposes, it is also wise to switch on a couple of lamps for a short time to give the impression that there's someone inside the house.

This note describes a circuit that exploits the home telephone to control appliances by switching them on or off using a digit dialled through the telephone.

Figure 1 shows the schematic block diagram of the circuit. When the caller dials the number of the telephone of his/her house from a remote place, the ringing signal is received at the home.

The ring signal is 75V AC riding on 48V DC. When it arrives, the opto-coupler connected in one arm of the telephone cable produces impulses. The 555 re-triggerable monostable multivibrator produces the 'count' output to the counter chain, comprising two 7493s, and it

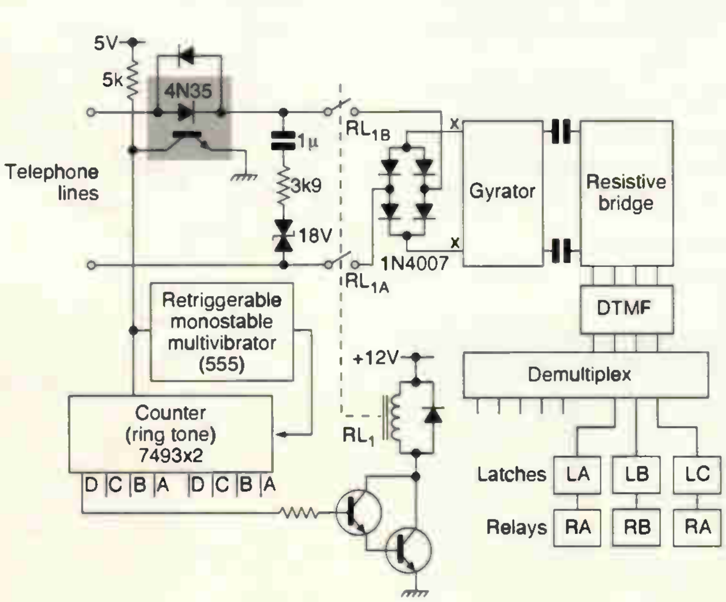


Fig. 1. Detail of the first part of the remote switching circuit and outline of the decoders and relay drivers. Relay RL_1 keeps the phone 'off the cradle' for a predetermined period when the phone rings.

starts counting the ringing pulses.

When 128 pulses are counted, the most significant bit of the second counter, D, becomes 'high' and this operates the relay RL_1 which closes the contacts $RL_{1A,B}$ connecting the telephone lines to the rest of the circuit comprising the diode bridge, gyrator, resistive bridge, DTMF, demultiplexer, latches and relay circuits, to simulate the conditions of taking the telephone transceiver from its cradle. Ringing stops at this moment.

When the telephone is taken from the cradle, normally 40mA current flows through the loop and this is a requirement to stop the ringing tone. In order to get a more or less constant current of 40mA flowing in the loop, a gyrator circuit is employed.

The equivalent resistance of the gyrator circuit varies in accordance with the changes in the line voltage, drawing 40mA of current in the loop. As soon as the ringing stops, the caller dials the control digit assigned for an appliance.

Figure 2 shows the detailed circuit, starting with the gyrator. The control digit is picked up and fed to a DTMF (KT3170) receiver which in turn produces the digit in binary form at its output.

The DSO output of the DTMF also becomes high whenever a valid tone is received. This state enables the accompanying decoder (74LS138). The decoder and the associated logic gates demultiplex the bit Q1 of the DTMF to the latches in accordance with the code obtained in Q4, Q3 and Q2 and the latched outputs drive the relay circuits accordingly. The information in **Table 1** is given to each relay circuit as per the code obtained.

Only three appliances are considered here. If needed, two or three more appliances could be included in the system by using the remaining digits and special characters available in the keyboard of the phone.

The de-multiplexed bit is latched (7474) in L_2, L_3 and L_4 and driven to the relay drivers operating relays RL_2, RL_3 and RL_4 respectively. Switching is arranged so that appliances can be turned on or off manually. The trigger logic for the latches is shown in **Table 2**.

The control action is sustained for half a minute, after which the control operation comes to an end. The re-triggerable monostable multivibrator set for this half a minute delay clears the counter to open the contacts $RL_{1A,B}$, simulating the condition of replacing the telephone on the cradle.

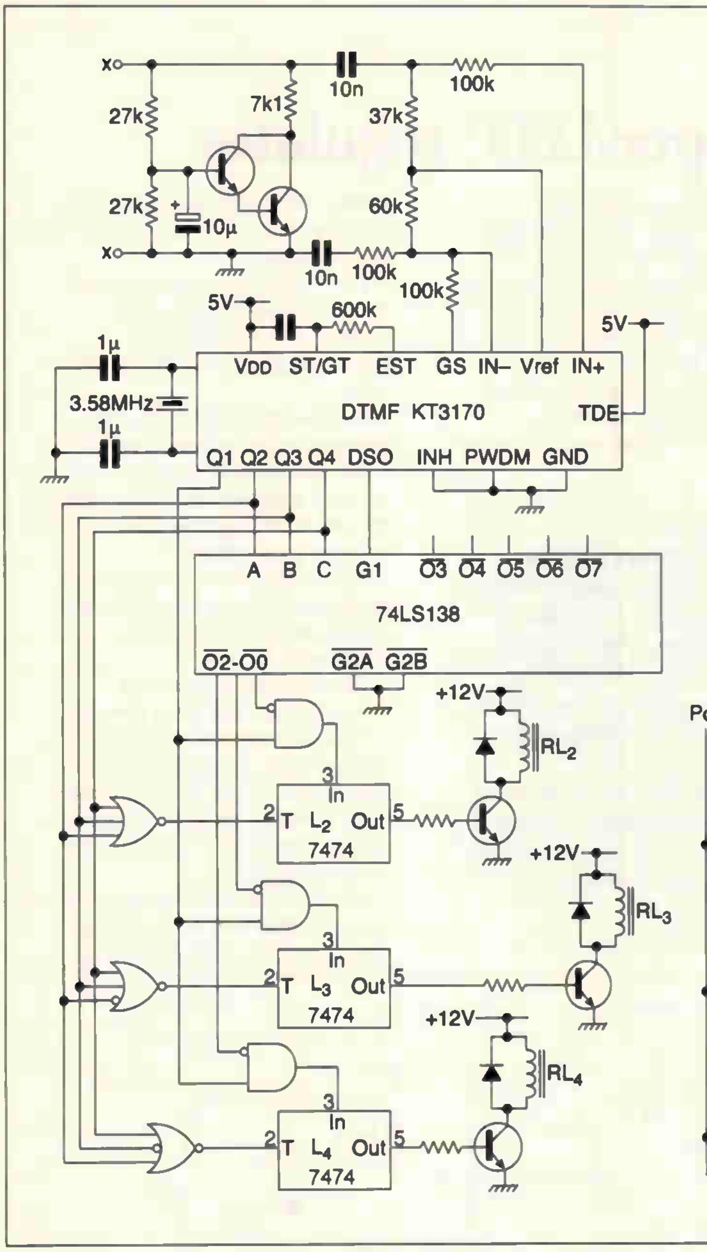


Fig. 2. DTMF decoding, latching and relay driving circuitry. With switching arranged as per the inset, it is possible to override the relay contacts manually if necessary

K. Balasubramanian
Mersin
Turkish Republic of Northern Cyprus

Table 1. Dialling a number causes one of three appliances to be turned on or off, depending on the dialled number.

No dialled	DTMF output Q4	Q3	Q2	Q1	Control action
0	0	0	0	0	Lamp off
1	0	0	0	1	Lamp on
2	0	0	1	0	Pump off
3	0	0	1	1	Pump on
4	0	1	0	0	Fridge off
5	0	1	0	1	Fridge on

Table 2. Number dialled versus the relay latch switched.

Digit dialled	Q4	Q3	Q2	Latch
0,1	0	0	0	L_2
2,3	0	0	1	L_3
4,5	0	1	0	L_4

'Super-LED' regulator

This circuit was made out of oddments from my parts bin after someone gave me a Luxeon Star super LED as a present. It supplies the Luxeon with a variable regulated current enabling brightness to be set from 'off to on'.

An LM10 op-amp plus voltage reference is the main active component. Component IC_{1a} is the 200mV reference buffer part of the LM10 which wired like this provides 200mV at pin 1.

The 4.7kΩ resistor and 1kΩ pot divide this down to a variable 0-35mV which is fed to the non-inverting input of the op-amp IC_{1b}.

Feedback around the op-amp is arranged so the voltage across the 0.1Ω resistor matches the 0-35mV from the reference section by varying the current through the 0.1Ω resistor between 0 and 350mA.

As all this current, except for the small transistor base current, comes though the LED, it receives a regulated 0-350mA.

The transistor must have a low-saturation voltage at low base current as pin 6 cannot supply much current. Also, there is only 200mV headroom between the 3.6V NiMH battery voltage and the 3.4V Luxeon voltage – and 35mV of this is eaten by the 0.1Ω resistor.

I used a ZTX692B which was given free with *Electronics World* some years ago. This saturates to under 100mV at 350mA with 2mA base drive.

As the battery flattens, the voltage at pin 6 rises as the op-amp works harder to maintain Luxeon brightness. This is indicated by the 'battery low' led.

Run on three NiMH cells, this circuit is over 90% efficient at full power and tops 80% for most of the rest of its range.

Although current is under 1mA at minimum brightness, the circuit will still needs an on-off switch.

Luxeon LEDs

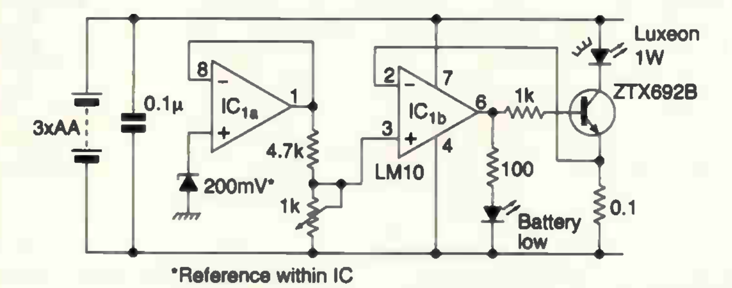
Luxeon is a range of high-brightness leds from Lumileds in California. Available in many colours, the white Star/O variant also includes optics to give an approximately 10° beam which is just about perfect for a camping torch. Max device current is 350mA and dimming allows battery-life to be extended when less light is needed – when reading for instance.

The heat sink built in to the LED needs plenty of fresh air or conductive cooling if damage through overheating is to be avoided. www.futureelectronics.com will sell small quantities in the UK.

See also www.luxeonstar.com

The LM10

National Semiconductor's LM10 was designed by Bob Widlar, originator of many analogue building blocks including the bandgap reference, three-terminal regulator and two-stage op-amp. To me the LM10 is like a symphony, with all the components playing in perfect harmony. We probably won't see anything like that again: it took Widlar five years to design it," said Hans Camenzind, designer of the famous 555 timer.



This regulator keeps the Luxeon super LED bright as the battery voltage falls. At full power, it's over 90% efficient.

Correction

I would like to advise you that tracking transmitter circuit published in the June issue has an error: The 22µF capacitor connects between the base of TR1 and the collector of TR2. The 2.2K Resistor also connects to the collector of TR2.

Amrith Ramjewan

Battery-operated lamp timer

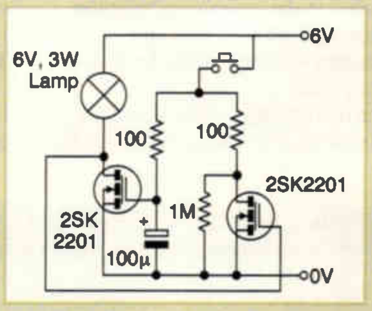
Operation of this lamp timer is fairly self-explanatory. The circuit turns off by virtue of the rise in drain voltage across the left-hand MOSFET as the capacitor discharges. This in turn switches on the right-hand MOSFET to completely discharge the capacitor. The 100Ω resistors limit initial currents in the right-hand MOSFET and capacitor.

Cheap battery-operated globe-style lamps are readily available from market stalls. Used for short term illumination, such as stairway cupboards, they are prone to be left on and the four AA cells employed discharge very quickly.

The circuit shown is a minimal component timer that can be fitted inside the existing casing. A similar non-latching type can either replace the original latching push button, or the latching mechanism removed from within the existing button.

The circuit has many applications for battery operated equipment.

Henry Maidment
Salisbury
Wiltshire
U K



Battery-operated lamps are popular for applications where it's difficult, or just not worth it, to run mains lighting. Intended to prevent discharge of the batteries if the lamp is left on accidentally, this circuit turns the lamp off after a preset period.

NEWPRODUCTS

Please quote *Electronics World* when seeking further information

Power module's three-phase inverter has gate drivers

International Rectifier has launched the IRAMS10UP60A PlugNDrive power module which is designed for electronic motor control circuits in home appliances and light industrial applications. The module incorporates a three-phase inverter power stage with gate drivers and auxiliary circuitry in an isolated package. Rated at

10A, the module is designed for 400W to 750W motor drives found in washing machines, in-room air conditioners and commercial refrigerators. According to the supplier, the module will support the design of multi-shunt current feedback for a vector control loop, in V/Hz control loop, with no circuit layout limitation.

International Rectifier
www.irf.com
Tel: +44(0) 208 645 8003

GPS without seeing satellite

U-blox, a Swiss supplier of GPS-based positioning technology, is offering a sensor-based GPS receiver with a proprietary dead reckoning algorithm which the company says can provide accurate

navigation regardless of whether satellites are visible or not. The SBR-LS includes a GPS positioning engine with a dead reckoning algorithm to use information from a gyroscope and vehicle odometer for accurate navigation without GPS for extended time periods. Once the satellites are visible again, the GPS receiver with its fast reacquisition time of less than 1 second resumes to GPS navigation immediately. It will also carry out automatic calibration and temperature compensation. The receiver provides an MCX type RF connector and a 2mm pitch connector with two serial inputs.

U-blox
www.u-blox.com

PWM controller has quasi-resonant switch

On Semiconductor has introduced a pulse width modulated (PWM) current-mode controller with quasi-resonant (QR) switching capability that is designed to reduce power consumption and component count. Intended for switch-mode power supply designs, the NCP1207's QR design allows better efficiency compared to existing fixed frequency controllers, says the supplier. The QR design minimises EMI and reduces switching losses. An adjustable skipmode capability under light loads minimises audible noise generation. The high-voltage start-up-current source offers a clean loss less start-up sequence. The device is self-supplied from a 40V to 500V DC rail, so it requires no transformer auxiliary winding or associated passive components. It is offered in two packages - the 7.62 x 10mm PDIP-8 package and the 5 x 6.2mm SO-8 package.

ON Semiconductor
www.onsemi.com
Tel: +44(0) 033 5346 11388

Amplifier draws just 120µA at 2.7V

Fairchild Semiconductor is offering CMOS amplifiers for lower power applications. The LMV321 (single), LMV358 (dual), and LMV324 (quad) amplifiers consume a supply current of 120µA maximum at 2.7V and typically 100µA at 5V. The amplifiers also provide rail-to-rail output and offer a supply voltage range of 2.5 to 5.5V (±1.25V to ±2.75V). With a gain bandwidth product of 1.4MHz at 5V and slew rate of 1.5V/µs at 5V, each amplifier is available in different package types. The single LMV321 is available in a SOT23-5 or SC70-5, the dual LMV358 in an SOIC-8 or MSOP-8, and the quad LMV324 is available in a SOIC-14 or TSSOP-14 package.

Fairchild Semiconductor
www.fairchildsemi.com

Remote sensing telemetry modules

Adcon Telemetry's latest remote telemetry units (RTUs) include solar-powered devices for unattended and permanent monitoring of sensor

Serdes for 6Gbit/s access routers

National Semiconductor has introduced a serialiser/deserialiser (serdes) chipset exceeding 6Gbit/s performance. Typical system applications for this chipset include terabit core routers, multi-service access routers, optical switches, high performance colour printers and copiers, and storage area network fault tolerant servers. The DS90CR485 and DS90CR486 serdes chipset supports a full 48-bit parallel bus interface. Instead of serialising 32 bits of data onto four differential pairs, the D590CR485/6 serialises as many as 48 data bits (between 66-133MHz) onto eight differential LVDS pairs. The clock is sent over

an additional 9th LVDS pair. This requires more serial data lines, but the lower data rates per line ease differential design requirements. In addition, the extra-wide 48-bit parallel bus not only serialises 32 data bits, but also extra data, control, and address signals. The devices are offered in a 100-pin TQFP package.

National Semiconductor
www.national.com
Tel: +44(0) 870 242171

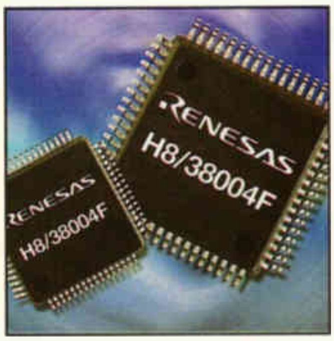
Please quote *Electronics World* when seeking further information

information from remote or isolated locations. Applications include water management, irrigation and environmental monitoring. these units can be supplied with low-power, licence-free communications capabilities, or with GSM function for communication over longer distances. Digital and analogue inputs and interface adapters for SD1-12 and standard 4-20mA inputs are available. the company has also developed a range of modem units and OEM modules for end users looking to add radios to their own sensor and monitoring applications. M868-500 PowerLink, for example, is a single-channel wireless modem that operates licence-free at the 868MHz ISM frequency band, and offers 4km line-of-site range. A board-level version is available for OEMs. In addition, addLINK is a low-power 'wireless connector' for licence-free use at data rates up to 10kbit/s. It includes a 868MHz transceiver, an 8-bit microcontroller and an antenna in a 21x38x7mm surface mount module.

Adcon Telemetry
+44(0) 1442 263716

Flash micro draws 1μA

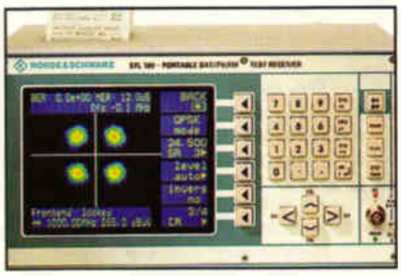
Renesas Technology Europe has announced its lowest cost flash microcontroller to date. The H8/38004F offers low power consumption of 1μA with 32kbyte of on-chip flash memory and is the first in the series that is available in a 64-pin QFP (quad flat pack) package. The device is ideal for many battery-powered, line-powered and metering applications. Operating voltage is 2.2 to 3.6V, with a fast oscillator start-up, typically about 20μs using an external resonator. This makes it ideal for applications that spend the majority of time in the low power modes. The device has an eight channel 10-bit A/D converter. A peripheral set includes a 10MHz clock oscillator, a 16-bit timer and three 8-bit timers, a USART, and a 25 x 4 LCD display drive.



Renesas
www.renesas.com
+44(0) 1628 585161

Digital broadcast tester offers on-screen TV picture

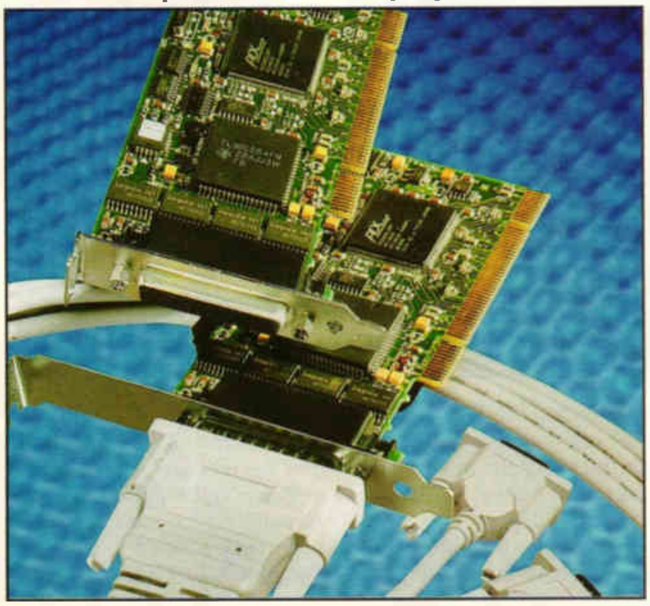
Rohde & Schwarz has introduced a first broadcast instrument in its recently announced lower price bench-top test system range. The EFL100 provides measurement functions for broadcast standards encountered in analogue and digital TV and FM radio. The portable instrument includes an on-screen TV picture and built-in printer. In addition the instrument can receive and measure digital TV signals (DVB-Sat, cable, terrestrial) as well as analogue TV and FM radio signals. The on-screen TV picture, the built-in printer for measurement results and diagrams plus the integrated loudspeakers facilitate the operation of the EFL 100.



Rohde & Schwarz
www.rohde-schwarz.com
+44(0) 1252 811377

Universal PCI cards for 3.3 and 5V buses

Brainboxes has launched a range of two-port and four-port serial card products for the universal PCI standard which supports either 3.3V or 5V PCI buses. They are available in standard or low profile PCI form factor and are intended for applications in point of sale, banking, kiosk, and test and measurement. Universal PCI is a relatively new standard for PCI cards that can accept signals at either 3.3V or 5V, and can therefore connect to any PCI slot. PCI cards have traditionally been powered by 5V but the 3.3V PCI standard has been adopted primarily by the server market. This 3.3V PCI bus is likely to move into, and become the standard for, all desktop PCs over the next two years, according to the company. 16550 UART provides a 16-byte input and 16 -byte output FIFO hardware buffer for each of the serial ports to permit high data rates without data loss or overrun errors, CC-701, CC-734, CC-712 and CC-260 half size cards (6.5cm x 12cm) all come with fully moulded cables using standard 9-pin male 'D' type connectors (25-pin versions of all are available) which provide connection using 4 of the four-port CC-701 or CC-712 cards installed in one.



Brainboxes
www.brainboxes.com
+44(0) 151 2202500

Power supply has less than a watt standby power

FSE Group, a Taiwanese power supply manufacturer, has a range of what it calls Green Power products which are designed to work with less than one watt stand-by. Four models will be available. The input power is less than 1W at PS-OFF (main power shut down) and Vsb 0.1A load (0.5W load) when input line is at AC 230V. It is a switching power supply with a passive PFC circuit (optional) to meet EN61000-3-2/1995 +A1/1998 +A2/1998 +A14/2000. The supplies incorporate a vacuum-impregnated transformer and include line input fuse protection. The power supplies operate up to 40deg C. It will exceed 70 per cent efficiency when power is at full load. Additionally they feature over voltage and short circuit protection for high system security and increased stability.

FSP Group
www.fspgroup.com
+44(0) 1721 873668

Please quote *Electronics World* when seeking further information

Stepdown converter goes to 0.75V

An 800mA stepdown converter from Maxim Integrated Products can output voltages down to 0.75V. The MAX1572 includes a built-in 170ms DC-DC reset output with preset outputs for 0.75V to 2.5V, stepped in 50mV increments. Maxim says the part is ideal for smartphone and PDA applications. Switching frequency is 2MHz using a 2.2μH inductor and ceramic capacitors. Input voltage range is 2.6V to 5.5V for use with single lithium ion battery. Other features include analogue soft-start with zero inrush current. To maximise battery life for hand-held equipment, the quiescent current is 48μA in logic-controlled shutdown. The MAX1572 comes in a 12-pin QFN package and is screened for the extended-industrial temperature range (–40°C to + 85°C). An evaluation kit is available to speed designs.
Maxim
www.maxim.com
+44(0) 800 585048

SoC verification tools have API for profiling

AXYS Design Automation has a new release of the MaxSim and MaxCore Developer Suites for multi-core system on chip (SoC) simulation, debugging and verification. The v4.0 of MaxSim Developer Suite features efficient collection of simulation data for profiling purposes enabling designers to meet product requirements with the optimal architecture. An API (application programming interface) for profiling information has been introduced, which works with standard SystemC components as well. The MaxSim Developer Suite also offers visualisation for the performance impact of caches, memories, bus-systems and user-defined statistics. Compared with v.30 the v.40 of maxCore Developer Suite features performance improvements of up to 60 per cent for instruction accurate models.
AXYS Design Automation
www.axysdesign.com

First DC-DC converter in sixteenth-brick sized module

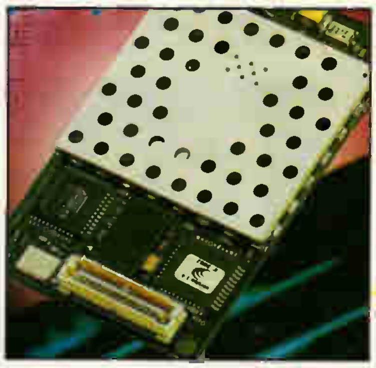
Astec Power has introduced its first industry standard sixteenth-brick isolated converter. Measuring 41.9 x 20.3mm with a 8.3mm profile, the 50W ALX series preserves the same quarter-brick pin location assignments. The ALX series operates from a 36V to 75V input bus voltage and delivers up to 20A of current from the 1.8V and 1.2V models, 18A from the 2.5V and 15A from the 3.3V units. According to the supplier, the power density is 114W per cubic inch. Power efficiencies can be up to 88 per cent for the 1.8V model.
Astec Power
www.astec-europe.com
+44(0) 1384 842211

Analytical software adds MATLAB and Visual Basic

The latest version of Maple, the analytical computation software from Canadian firm Maplesoft, is available from Adept Scientific. Maple 9 has added MATLAB and Visual Basic to the set of target languages in its code generation function, which already includes C, Fortran and Java. The function takes computational results and translates them into programming code for other languages. Other improvements include an API which enables users to harness the Maple maths engine from external programs. For example, a database program written in C or Visual Basic could invoke Maple 9 algorithms for data analysis. Algorithms are available for FFT, integration and solving differential equations. Maple 9 has also integrated the GMP libraries that enable computations with up to millions of digits accuracy. The system is available for Windows, Macintosh (including Mac OS X), Linux and various UNIX platforms.
Maple
http//maple.adeptscience.co.uk
+44(0) 1462 480055

2.4GHz radio module ready for the freezer

Frequency hopping RF module supplier Aerocomm has upgraded its AC5124 module with improved operating temperature performance, and improved range. The module is a digital RF transceiver employing frequency hopping, spread spectrum (FHSS) technology.



Operating in the 2.4GHz band, the module's operating temperature range now covers –40 to +80 deg C. The module contains temperature compensating hardware and software to adapt across the entire industrial temp range. The device's sensitivity has been improved from –90dB to –93dB to detect lower signal le vels.
Aerocomm
www.aerocomm.com
Tel: +44(0) 1908 326342

Boost converter IC for batteries

Zetex is offering a boost converter IC which, with an external switching transistor and diode, can be used in power supplies with 85 per cent efficiency. ZXSC410 and 420 are voltage mode, operate from 1.65 to 8V, and aimed at portable equipment. Load and line regulation means, for the full supply range of Lithium Ion cells said the supplier, output voltage typically changes by less than 1 per cent. Maximum output voltage depends on the V_{CE} of the external transistor. Output current up to 300mA is available. The ZXSC420 swaps shut down for an end - of-regulation flag to indicate when the battery is approaching full discharge. Package is SOT23-6 and the company offers a companion transistor and Schottky device in a 3x2mm micro leaded package.
Zetex
www.zetex.com
Tel: +44(0) 161 622 4444

Environment simplifies debugging applications

Green Hills Software is offering an integrated development environment for embedded Linux systems. Providing an environment for debugging Linux applications, the Linux

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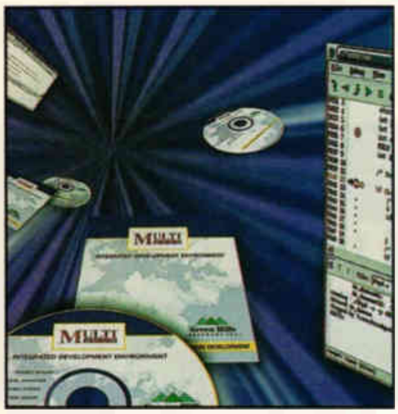
kernel and Linux device drivers, the development system called Multi works with existing GNU development tool chains. These include those used for native Intel/Pentium, embedded MIPS, and embedded PowerPC environments. It is designed to give Linux kernel developers, who are accustomed to debugging their code with primitive print statements and command-line gdb debuggers, an optimised and simplified debugging process. According to the supplier, it will enable users to debug full source code, interrupt service routines, loadable kernel modules, non-ISR kernel code (including kernel threads), and complex device driver code that runs in the Linux kernel. It also provides debugging facilities such as its customisable Register Description Files (RDF), for example. The RDF considerably simplifiers driver development by allowing designers to create datablock-like views of on- and off-chip (e.g. PCI) device registers. The environment also provides full support for kernel breakpoints, enabling developers to save and restore breakpoints across debug sessions on a per-kernel-module basis. The debugger, hosted on a PC or Unix system, communicates with the Linux kernel on the target system through a high-speed probe (Green Hills Probe) attached to the target board's on-chip JTAG or BDM connector.

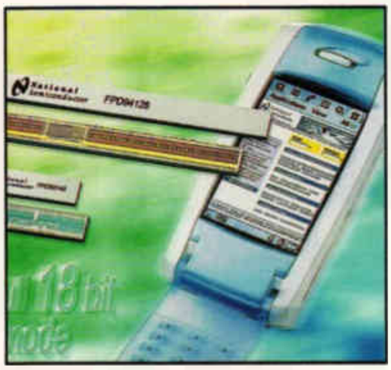


Green Hills Software
www.ghs.com
+44(0) 1844 267950

N-channel Mosfets take 1.8W power dissipation

Fairchild Semiconductor has introduced the 30V, 9mW and the 100V, 70mW N-channel Mosfets which are designed to handle 1.8W of power dissipation. Intended for small form factor DC-DC power supplies, the FDC796N and FDC3616N offer low R^{DS}(on) ratings and low gate charge, typically 14nC and 23nC, respectively, in a package occupying 9mm^2 of PCB area, a third the area of the SO-8 package, said the company. The devices incorporate the firm's patented FLMP packaging.
Fairchild Semiconductor
www.fairchildsemi.com
+44(0) 1793 856831

Driver IC for colour LCDs in handsets



National Semiconductor has introduced an active matrix LCD driver chipset for mobile phone colour displays, Comprised of two ICs, the FPD94128 controller/column driver and the FPD93140 power supply/gate driver, the chipset intended to core of a design for driving amorphous silicon active matrix LCD (AMLCD) panels used in mobile phones that support full colour graphics, video and still images. The chipset features an image dependent backlight controller for the reduction of backlight intensity.
National Semiconductor
www.national.com
+44(0) 870 242171

STB Platform uncovered

IBM Microelectronics has teamed with Sony Semiconductor to offer a set-top box reference design platform for terrestrial and satellite digital TV standards. The firms said they aim to reduce time-to-market cycles for set-top designs to three months. Sony supplies the terrestrial and satellite tuner/demodulators, and interface elements including the

Monitor for multiplexed 3G infrastructure

Tektronix has a passive network monitoring software which supports the use of inverse multiplexing for ATM (IMA) techniques on transitional next generation mobile phone networks. IMA is a technology that bundles present lower bandwidth (EI/DSI) network links to gain higher bandwidth (3G) backhaul capabilities on existing GSM network infrastructure. To employ IMA operators must have a non-intrusive monitoring tool that examines all lines without utilising additional test equipment. By combining innate protocol monitoring for specific interfaces with access to IMA links, this monitoring software enables users to perform upper-layer protocol analysis in addition to retrieving information (statistics, alarms, etc.) from the lower-layer IMA links. GSM network operators own a vast infrastructure of EI/DSI hardware links connecting transceivers to the basestation controllers. These individual links lack the bandwidth to handle 3G UMTS traffic. IMA technology works by binding groups of these lower-bandwidth EI/DSI links to form "virtual" high-bandwidth. The non-intrusive monitoring tool can be connected to the EI/DSI lines with IMA at any time without affecting live traffic, and there is no need to disconnect or re-start the links being monitored.
Tektronix
www.tektronix.com
Tel: +44(0) 1344 392241

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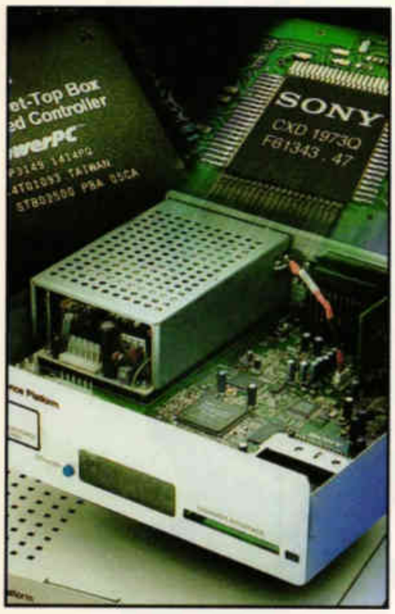


AV SCART switch and common interfaces. IBM provides PowerPC 405 microcontrollers and MPEG-2 compression subsystems. Sony and IBM selected Wind River's VxWORKS operating system, embedded software platform and Tornado cross-development tools for the reference design.

There are two platform variant, DVB-Terrestrial and DVB-Satellite, enabling entry level to mid-range designs targeted at both free-to-air services, such as UK Freeview, and retail satellite, where external conditional access is realised via the DVB Common Interface standard. Sony is supplying the CXD1973 and CXM3002 COFDM demodulator and single package silicon QPSK tuner and demodulator. Audio video switching for up to two SCART sockets is supported with minimal need for external components using the CXA7002.

IBM Microelectronics
www.chips.ibm.com
www.sony.net

Direct tyre pressure sensor circuit has RF controller

A pressure sensor from Motorola is designed to allow drivers to maintain proper tyre pressure by notifying them when pressure is not optimal.

Supporting direct tyre pressure by monitoring, the MPXY8020A sensor is available with microcontrollers and an RF comms device. It is intended to be used in remote sensing modules mounted onto valve stems or wheel wells. It is available as a chipset which features a remote sensing module housing the MPXY8020A sensor and an MC68HC908RF2 8-bit flash microcontroller. The MCU package also contains an RF transmitter.

Motorola
www.motorola.com
Tel: +44(0) 1355 565000

Analogue scopes start from £119

A range of analogue oscilloscopes from Vann Draper now includes a single channel 10MHz bandwidth unit, a dual channel 20MHz unit, a dual channel 40MHz unit and a dual channel 60MHz unit. Triggering modes are Auto, Norm and TV, with the 40MHz and 60MHz versions also including PP Auto triggering for automatic triggering without the need for level adjustment. The CRT accelerating voltages are 1.3kV for the MO10, 2kV for the MO20 and 14kV for the MO40 and MO60. Signal delay lines and Z modulation inputs are provided as standard on the 20MHz, 40MHz and 60MHz models. All units include X1/X10 probes.

Vann Draper
www.vanndraper.co.uk
Tel: +44(0) 1283 704706

Motor drive chips minimise noise

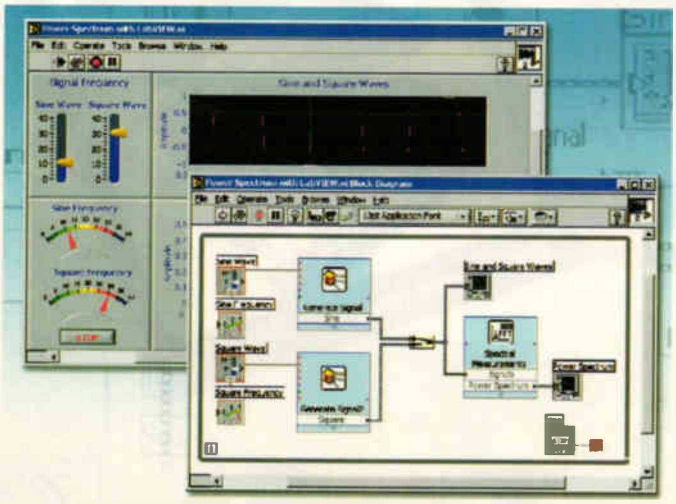
Toshiba's three-phase brushless motor drive ICs offer full sine wave pulse width modulation (PWM) outputs, which are designed to minimise levels of acoustic and electrical noise

without the need for external micro microcontrollers. According to the supplier, the built-in lead angle control function senses motor current and automatically varies the lead angle to ensure optimum efficiency for varying speed and load conditions. With previous generations of motor controller devices lead angle could only be adjusted for a fixed motor load and speed. The ICs operate with supply voltages of between 6V and 10V and feature a built-in triangular wave generation. Designed to operate with external IGBT modules, devices in the TB65xx family support bootstrap circuit configurations and feature a built-in deadtime function to ensure safe IGBT operation in a push-pull configuration.

Toshiba
www.toshiba-europe.com
Tel: +44(0) 049 211 5296254

Latest version of LabVIEW designed to target FPGAs

National Instruments has introduced the latest release of its LabVIEW graphical development and test operating system. The intention with LabVIEW 7 Express is to simplify the process of designing its card-based measurement and automation applications as well as extending its use in a range of targets, from embedded FPGAs to Microsoft Pocket PC PDAs. There is a redesigned NI-DAQ driver framework and two new interactive assistants for data acquisition and instrument control. The DAQ Assistant is designed to help users configure and define data acquisition tasks. For GPIB, serial, VXI and other traditional instruments, users can use the instrument I/O Assistant to prototype instrument control systems, take measurements and develop simple instrument drivers. The Instrument I/O Assistant delivers interactive instrument control, auto parsing of data and automatic LabVIEW code generation. The release of LabVIEW 7 Express product family includes the LabVIEW Base, full and professional development systems and add-on modules including an FPGA module for developing applications to run in FPGAs on NI reconfigurable I/O hardware.



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Calculus is for life – not just for Christmas

In recent interviews of graduate applicants for the position of design engineer, I have been appalled by their lack of understanding of elementary calculus[1]. If you think your calculus is up to scratch, then there are two sets of simple test questions in this article. Do them. If you get any question wrong then your maths is not even close to being acceptable. You need to read the whole article carefully and try again. Leslie Green CEng MIEE, is handing out detentions....

Calculus is not something you should learn at school and then promptly forget; it is a *general way of thinking* that will outlast any technological changes that can happen in your career. This article is to give adequate stress to the subject for those who didn't realise its importance and to act as a primer to those who never studied it in the first place.

You will find all electrical engineering textbooks write equations using calculus notation or simplified forms derived using calculus. It is therefore in your best interests to know the basics of the subject, so that you do not feel and act like a novice.

As a teenager at school you would have done simple problems such as calculating the power in a DC circuit or investigating the acceleration of a mass when a constant force was applied. The equations given were:

$$P=I\times V$$

Power is the product of the current and the voltage.

$$F=m\times A$$

Newton's second law of motion.

These equations are for steady conditions, with no change occurring in the driving forces. This is a nice simple introduction to science and lets the student feel that it is possible to learn about science and make calculations.

Changing Conditions

Given the nice simple equation $F=m\times A$, the student is never asked to think about what would happen if the force were to change with time, or if the mass were to change with time. What would happen to the acceleration in these cases?

As soon as changes occur in these simple situations, more advanced mathematics is called for. This step is not difficult to grasp if you understood the steps leading up to it. If you failed to get the earlier material, however, you get lost and confused. I was introduced to calculus in Advanced level maths classes by the simple statement that if $y=x^n$ the *differential coefficient* is given by,

$$\frac{dy}{dx}=nx^{n-1}$$

It was not even mentioned that we were now dealing with a subject called 'calculus'. With instruction like this, it is hardly surprising that engineers are being 'trained' who don't know what the subject is all about. We need to go right back to basics and start again.

Calculus for Engineers

Once upon a time, charge was moved from one conductor to a nearby conductor. This caused a difference of potential between the two conductors. It was observed that moving twice as much charge created twice the potential difference. Using mathematical terminology it was said that the potential difference, V, was *proportional* to the charge, Q, which had been moved. This was written as, $V\propto Q$. Now all we have done here is to write an experimental observation in a concise mathematical form.

The next step was to put in a constant to replace the proportionality sign. We now say that $Q=C\times V$ where we have a constant, C, for any particular system of two conductors. We call this the capacitance between the two conductors. There is now an equation, and a constant that we can measure. If charge moves with time we say that an electric current is flowing. More specifically we say that the rate of flow of charge past any fixed point is the definition of current. Now saying that "the rate of change of charge with respect to time is the current" is a very longwinded way of expressing the idea. So we use a mathematical notation instead and say:

$$i=\frac{dQ}{dt}$$

This is the notation presented in 1684 by Leibniz, when he published the first paper on calculus[2].

We can apply this notation to the equation $Q=C\times V$ and we get,

$$\frac{dQ}{dt}=\frac{d(C\times V)}{dt}$$

Now we can look at the special case where the conductors are not moving relative to each other. In this case the capacitance is constant and the C can be moved outside of the 'rate of change' expression. This now gives us a very important equation:

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

In words this says that the instantaneous current in a capacitor is equal to the product of the capacitance and the rate of change of voltage across the capacitor. If you have ever looked carefully at capacitor data sheets, you may have seen limiting values of.

$$\frac{dV}{dt}$$

This is nothing mysterious; if the rate of change of voltage across a capacitor is too high, the current through it will be too high and the capacitor will burn out. If you see a calculus expression like this and neglect it because it is 'too hard', then you will be a liability to everyone around you.

Origins

The rate of change of a quantity with respect to time is not a complicated issue. If you draw a graph of the quantity, with time along the bottom axis, then the rate of change is simply the slope of the line, also known as its gradient. If you wanted to know what the slope of any particular function was, then you could just draw a graph and measure the slope with a ruler. Now you may have thought that you should measure a slope with a protractor, an angle measuring device. Well, you can also measure a slope in terms of how far *up* you go compared to how far *along* you go; hence the use of the ruler. See **figure1.**

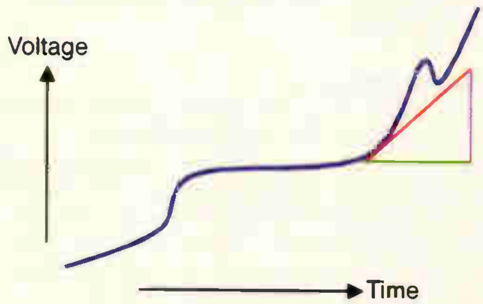


Fig 1: Plot of the voltage across a capacitor against time, as you might expect to see on a chart recorder or a scope.

The blue waveform is a plot of the voltage across a capacitor against time, as you might expect to see on a chart recorder or a scope; it is anything but constant. If we want to measure the slope at any point, we construct a right-angled triangle, where the long side (red = hypotenuse) is in the same direction as the waveform (the tangent to the curve). The slope is then defined as the length of the vertical line in the triangle (purple) divided by the length of the horizontal line in the triangle (green).

This is how one could go about measuring a slope from a graph. The method of calculus gets the slope from the equation of the curve. Rather than using x and y, which seems like a maths lesson, let's take a 'simple' equation for a voltage.

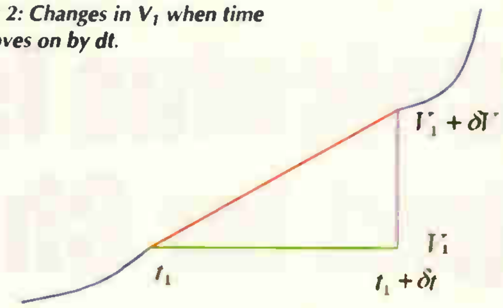
$$V = A \times t^K + B$$

A, B and K are just constant values. We want to know what the slope of this curve is at some point in time, t_1. We know the value of V at this point: it is simply.

$$V_1 = A \times t_1^K + B$$

But that hasn't yet told us the slope of the curve. Now comes the clever part. We can look at the value of V at some very short time later. We know that from the graph drawn previously, the triangle measuring the slope was very large compared to the bend in the waveform. However, if we were to get out a magnifying glass and zoom in on a small part of the waveform, it would look almost straight. The closer in that we looked, the straighter it would appear.

Fig 2: Changes in V_1 when time moves on by dt.



Hence we are going to see what happens to v_1 when time moves on by a very small amount δt, as in **figure 2.** The length of the purple vertical line is δv and the length of the green horizontal line is δt. These sizes are related by two equations:

$$V_1 = A \times t_1^K + B$$

and the one obtained by moving forward in time by a small amount.

$$V_1 + \delta V = A \times (t_1 + \delta t)^K + B$$

All we do now is subtract the first equation from the second.

$$\delta V = A \times \left[(t_1 + \delta t)^K - t_1^K\right]$$

Now comes the difficult part. Expanding the terms inside the square bracket uses another mathematical technique, the binomial expansion (remember Pascal's triangle?)

$$(t_1 + \delta t)^K = t_1^K + K \times \delta t \times t_1^{K-1} \mathrm{K} \quad + \delta t^K$$

There are K+1 individual terms. The first term, t_1^K, is equal but opposite to a similar term inside the square brackets above: it therefore cancels. We are then left with K individual terms, where the power of the term δt is steadily increasing. We now make use of a simple fact. If a number is small, then higher powers of that number are even smaller still. For example, take the number 0.01: when squared it gives 0.0001 and when cubed it gives 0.000001. Thus if we make δt small enough, we can neglect all the higher powers of it. We can then simplify our equation to.

$$\delta V \approx A \times \delta t \times K \times t_1^{K-1}$$

At this point we say that we make δt so small that is almost zero; mathematicians would say it is the limit as δt approaches zero. We then make the approximately equal sign '≈' into an equals sign, because the error is arbitrarily close to zero. The curly δ is replaced by a straight version, a 'd', to show that this limiting value has been used. This gives.

$$dV = dt \times KA \times t_1^{K-1}$$

We now have the slope of the line at the point t_1. It is simply,

$$\frac{dV}{dt} = KA \times t_1^{K-1}$$

This is *differential calculus*, because it deals in small differences. There is considerable complexity involved in applying these techniques to particular mathematical functions, but then mathematicians have been working on these problems for over 300 years. All we have to do is look in a book to find out how to get the slope of any particular function.

There is of course a mathematical name for getting the slope of a function; it is called *differentiating* the function. The result is called the *derivative*, or more specifically the *first derivative*. You can also find the slope of the slope, the second derivative, and so on. For our function $V=A\times t^K+B$ we differentiate with respect to t to get the derivative,

$$\frac{dV}{dt}=KA\times t_1^{K-1}$$

TEST YOURSELF:
What do these fundamental equations mean?

$$E=n\times\frac{d\phi}{dt}$$

$$E=L\times\frac{di}{dt}$$

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

$$r=\frac{dV}{di}$$

Integral Calculus

We have a rule for getting the derivative of a function, for *differentiating* it in other words. This gives the slope of the curve. Another useful operation would be to find the area under the curve as shown in **figure 3.**

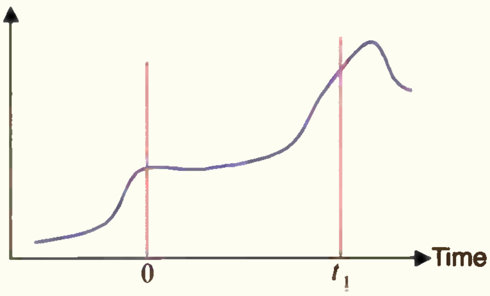


Fig 3: The area under the curve is a product of current and time.

The area under the curve above is the product of current and time, which is actually the total amount of charge that has moved during the interval in question. We could evaluate this area by drawing the graph on paper, cutting it up into little strips and then measuring the area of these strips. This is actually done in some elementary maths classes. The next step is to move on to finding the area by using the trapezium rule; mathematically splitting the graph up into strips and evaluating the area by means of numbers. The next logical step in this sequence is to make the strips really small.

Consider a more general curve described as $f(t)$. This is read "f of t", and simply means that the function f varies in some manner according to the value of t. The beginning of the area of interest has been arbitrarily set to 0. The end of the area has been marked as t_1. If the area is divided into n equal-width vertical strips, then each of these strips is t_1/n wide. For convenience we can call the width of these strips δt. We zoom in on one of these narrow strips so that the curve seems to be straight over the small distance, illustrated in **figure 4.**
This strip has an area of,

$$\delta t\times\left(\frac{f(\delta t)+f(0)}{2}\right)$$

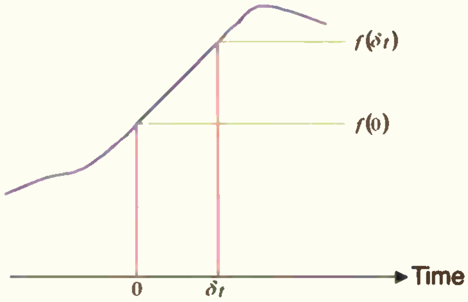


Fig 4: The curve appears straight over the small distance.

The next strip has an area of,

$$\delta t\times\left(\frac{f(2\times\delta t)+f(\delta t)}{2}\right)$$

The total area is given by a summation of all of these little strips. The capital sigma, Σ, means sum the expression which follows, starting from the limit under the sigma symbol (m=0) and ending with the limit above the sigma symbol (m=n−1) in steps of 1.

$$Area=\sum_{m=0}^{m=n-1}\frac{f([m+1]\delta t)+f(m\times\delta t)}{2}\times\delta t$$

Inspection of this summation shows that there are always two halves of each term like $f(m\times\delta t)$, except at the end points.
We can therefore write:

$$Area\approx\sum_{m=0}^{m=n}f(m\times\delta t)\times\delta t$$

We now let n head off to infinity, which makes δt tend towards zero. This reduces the error at the end points to an arbitrarily small value. The approximate equality is replaced by an equality and the summation sign becomes an integral sign.

$$Area=\int_0^{t_1}f(t)\times dt$$

Closer examination of the integral sign shows it to be a large S, suggesting summation. Notice that the limits of integration given at the bottom and top of the symbol are in the same units as the variable of integration; in this case t. We are summing the function f over a range of time values. We can now bring on the *fundamental theorem of calculus* which says that differentiation and integration are an inverse pair of operations. In other words, if you integrate then differentiate, you end up where you started. Let me make this more real with an example. Using time as the reference, the integral of current is charge, and the derivative is charge is current. In symbolic notation:

$$\int_0^T i\times dt=Q;\quad i=\frac{dQ}{dt}$$

Using this notation we can now formulate precise statements about power, energy, equivalent heating effects etc.

Power = rate of change of energy

$$energy=\int_0^T power\times dt$$

In electrical terms the energy could be the heat dissipated in a resistor, for example,

$$energy=\int_0^T \mathrm{v}\times\mathrm{i}\times\mathrm{dt}$$

Measuring current is always more difficult than measuring voltage, so it is more convenient to say that the current is the voltage divided by the resistance.

$$energy = \int_0^T v \times \frac{v}{R} \times dt = \frac{1}{R} \cdot \int_0^T v^2 \times dt$$

Often the waveform is cyclic, with a period of say T. In these cases we are interested in the average (or more specifically the *mean*) power. We then write:

$$\text{mean power,} \quad P = \frac{\text{energy per cycle}}{\text{cycle time}}$$

$$P = \frac{1}{R} \cdot \frac{1}{T} \int_0^T v^2 \times dt$$

It would be nice to use a simplified form of this equation, where there was a voltage which when squared gave the same heating effect as the true calculus expression. It would then be:

$$P = \frac{V_{EQUIV}^2}{R}$$

This is then very similar to the simple DC case. You should be able to see that:

$$V_{EQUIV}^2 = \frac{1}{T} \int_0^T v^2 \times dt$$

By taking the square root of both sides we get:

$$V_{EQUIV} = \sqrt{\frac{1}{T} \int_0^T v^2 \times dt} = V_{RMS}$$

The equivalent voltage is the square Root of the Mean value of the sum of the Squared voltage, or RMS for short. This is the most elementary of electrical engineering topics and yet you still get 'engineers' who are unable to recognise that RMS voltage and RMS current are valid quantities, but that use of the term 'RMS power' is technical illiteracy, as there is no such valid, useful quantity.

This lack of understanding is not assisted by manufacturer's adverts, which talk of "true RMS power" measuring devices. This is tricky. Power measuring devices can measure peak power, assume the signal is sinusoidal, and give a calibration of the actual mean (average) power. A better technique is to measure the RMS voltage across a resistance, which gives the true power. In this case the manufacturer is trying to say that their measurement method uses a true RMS voltage measuring technique, which is more difficult to do but gives a more accurate answer. The adverts truncate this to a "true RMS power" measuring device, which confuses those with inadequate understanding of their basics.

Rules of differentiation and integration

Integration is somewhat harder than differentiation in terms of the mathematical manipulations. Often one has to see what function when differentiated gives the function we are trying to integrate. You almost guess the answer, differentiate it and see if you were correct!

In any case, most of the hard work has been done by our predecessors compiling tables of the difficult functions. What remains is for us to break any particular problem down into a form such that we can look the answer up in such a table. For both differentiation and integration, constant multipliers can be freely moved outside of the calculus part. For example, with a constant K;

$$\frac{d(K \times i)}{dt} = K \times \frac{di}{dt}$$

and,

$$\int K \times V \times dt = K \times \int V \times dt$$

Calculus operations can be split up between simple additions and subtractions. Thus:

$$\frac{d(V_1 + V_2)}{dt} = \frac{dV_1}{dt} + \frac{dV_2}{dt}$$

and,

$$\int (i_1 + i_2) \times dt = \left(\int i_1 \times dt\right) + \left(\int i_2 \times dt\right)$$

A constant has no rate of change with respect to anything. Thus the derivative of a constant is *always* zero, regardless of the variable we are differentiating with respect to.

Using the constant K again:

$$\frac{dK}{dt} = 0$$

The integral of a constant gives the product of the constant and the variable of integration.

$$\int_0^T K \times dt = K \times T$$

This is obvious if you think about the integral as being the area under the curve. If the curve has a constant value, the area is rectangular and is simply the product of the height of the curve above the axis and the distance along the axis that we integrate over.

Limits of integration

So far I have skilfully avoided the subject of the *limits* of the integration. If I were to differentiate a function such as $V = K_1 \times t^n + K_2$, the additive constant would 'disappear'.

$$\frac{dV}{dt} = nK_1 \times t^{n-1}$$

This means that when I integrate some function, I always have to add on an arbitrary (unknown) constant. For example:

$$\int t^n \times dt = \frac{t^{n+1}}{n+1} + K$$

The rule for integration is seen as being the rule for differentiation done 'backwards'. In differentiating I multiplied by the index (n), then reduced the index by one. For integration I increase the index by one (n+1) then divide by this new index.

What I have given here is an integral without limits. This is called an *indefinite integral*. I have asked the question, "What is the area under the curve up to a specified point?" but I have not given the starting point of the summation! This is a graphic explanation of why an indeterminate constant is required.

The last rule required for integration is that the limits can be split into parts. Suppose we have a waveform that is doing one thing up to a time t1, but then does something else up to the time T. We can split the integration up over these two intervals to make the integration easier.

$$\int_0^T i \times dt = \left(\int_0^{t1} i \times dt\right) + \left(\int_{t1}^T i \times dt\right)$$

By splitting the integral up into these intervals, it is possible to look up the individual function pieces in tables.

Table 1: This table uses time as the variable of integration. The derivatives are also done with respect to time.

Differentiate this to get that →	Integrate this to get ← that
K	0
$K \times t^n$	$nK \times t^{n-1}$
$\frac{K \times t^{n+1}}{n+1}$	$K \times t^n$
$\sin(\omega \times t)$	$\omega \times \cos(\omega \times t)$
$\cos(\omega \times t)$	$-\omega \times \sin(\omega \times t)$
$e^{-K \cdot t}$	$-K \times e^{-K \cdot t}$

This table uses time as the variable of integration. The derivatives are also done with respect to time.

Now you are ready for the final test… These are very basic questions actually; if you can't do them or get them wrong, after having read this article carefully, then you definitely need to dust off those text books and put in some extra study.

FINAL TEST

What is the maximum slew rate of a 3V RMS 1MHz sinusoidal signal?

What is the current flowing in a 0.1μF capacitor when a voltage is applied to it which increases linearly from 0V to 100V in the space of 1.5μs?

What is the RMS value of a repetitive 25kHz rectangular voltage waveform which is at 10V for 10μs, then at 1V for the rest of the cycle.

What is the RMS power dissipated in a 1Ω resistor when the voltage of #3 above is applied across it?

Answers on page 51…

References

1. The Latin word *calculus* means 'a small pebble used for counting', as well as 'the subject of reckoning'. The original presentation of this branch of mathematics was written in Latin.
2. "Nova Methodus Pro Maximis et Minimis, …", Acta Eruditorum 1684 by G.Leibniz; pp466-473 of the 1682-1687 volume (1966 reprint). *Unfortunately this is all in Latin.*

Professional SDI router

Known commercially as the 'DVRS-8x8', Emil Vladkov's stackable serial digital interface router provides eight inputs and outputs for digital video signals running at up to 400Mbit/s. This second article covers additional circuits, software and a dedicated keypad for controlling the router.

First I will outline the optional add-on section of the design for those of you who need the reclocking signals from outputs 2 to 8, **Fig. 1**. Although this is add-on circuitry, I have designed the router's main PCB to accommodate it.

The idea is, that if you don't need reclocking at outputs 2-8, the components of this section can be skipped. If they are omitted, it is important that input ports DOxIn are shorted to the output ports DOxOut with wire bridges.

In my prototypes, I have implemented the full-featured version, so I will discuss this section too. The retimer/reclock circuits for outputs 2-8 are $IC_{37\text{-}43}$. They have the same wiring as IC_{10} in Fig. 3 of last month's article with the same component values.

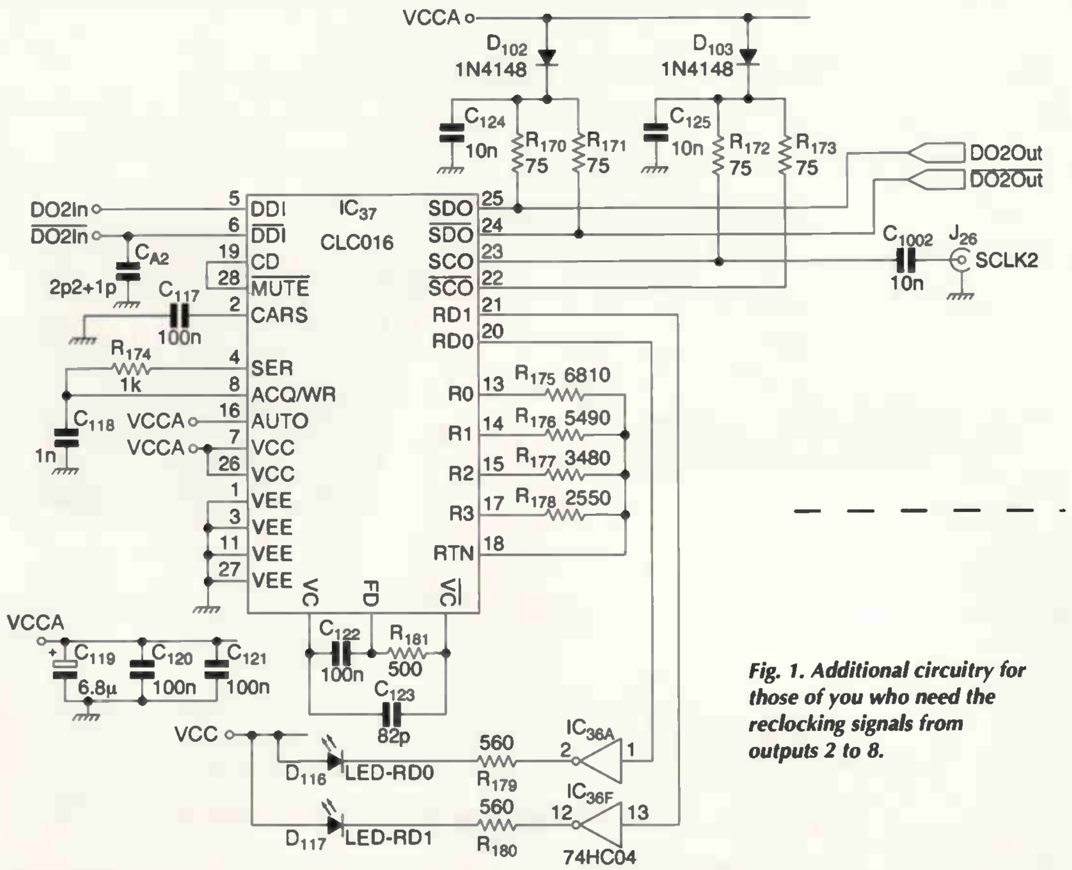


Fig. 1. Additional circuitry for those of you who need the reclocking signals from outputs 2 to 8.

Main features of the router

Full specifications for the router were presented in last month's article. Here's a summary of the router's main features.

8x8 digital cross-point switch capable of operating at data rates exceeding 360Mbit/s per channel;
Non-blocking architecture;
Low channel-to-channel crosstalk;
Channel jitter 200ps pk-pk typ.;
Fast output edge speed: 650ps typ.;
Input type: 800mV, 75Ω, BNC;
Output type: 800mV, 75Ω, BNC (Belden 8281 or equivalent transmission lines);
Conforms to SMPTE 259M serial digital interfaces: NTSC/PAL, 4:2:2 component, 360Mbit/s wide screen, also 540Mbit/s 4:4:4:4 (optional);
Clock and data recovery at all channels at fixed data rates: 143, 177, 270 and 360Mbit/s. The data rate of the reclocked signal is displayed at the front panel;
Carrier detection and output mute for all input channels. The carrier detected signal is displayed at the front panel;
Automatic equalisation of all input channels: up to 300 metres of Belden 8281 cable;
Control via button panel (with indication) or Windows 95/98 graphical user interface;
Visual indication on the local front panel of the routing system (64 channel cross-point LEDs plus 8 input CD LEDs plus data rate indicators for output channels 1-8);
Lock control preventing accidental switching;
Stackable using standard RS-232 cables – up to four devices can be independently controlled via the PC user interface;
Start-up configuration selectable by user;
Mains powered.

The active data rate LEDs are $D_{116\text{-}129}$ and the driving buffers are $IC_{36A,F}$ and $IC_{44,45}$. Power supply decoupling is provided at every chip with two ceramic and one tantalum capacitor.

Microcontroller Firmware

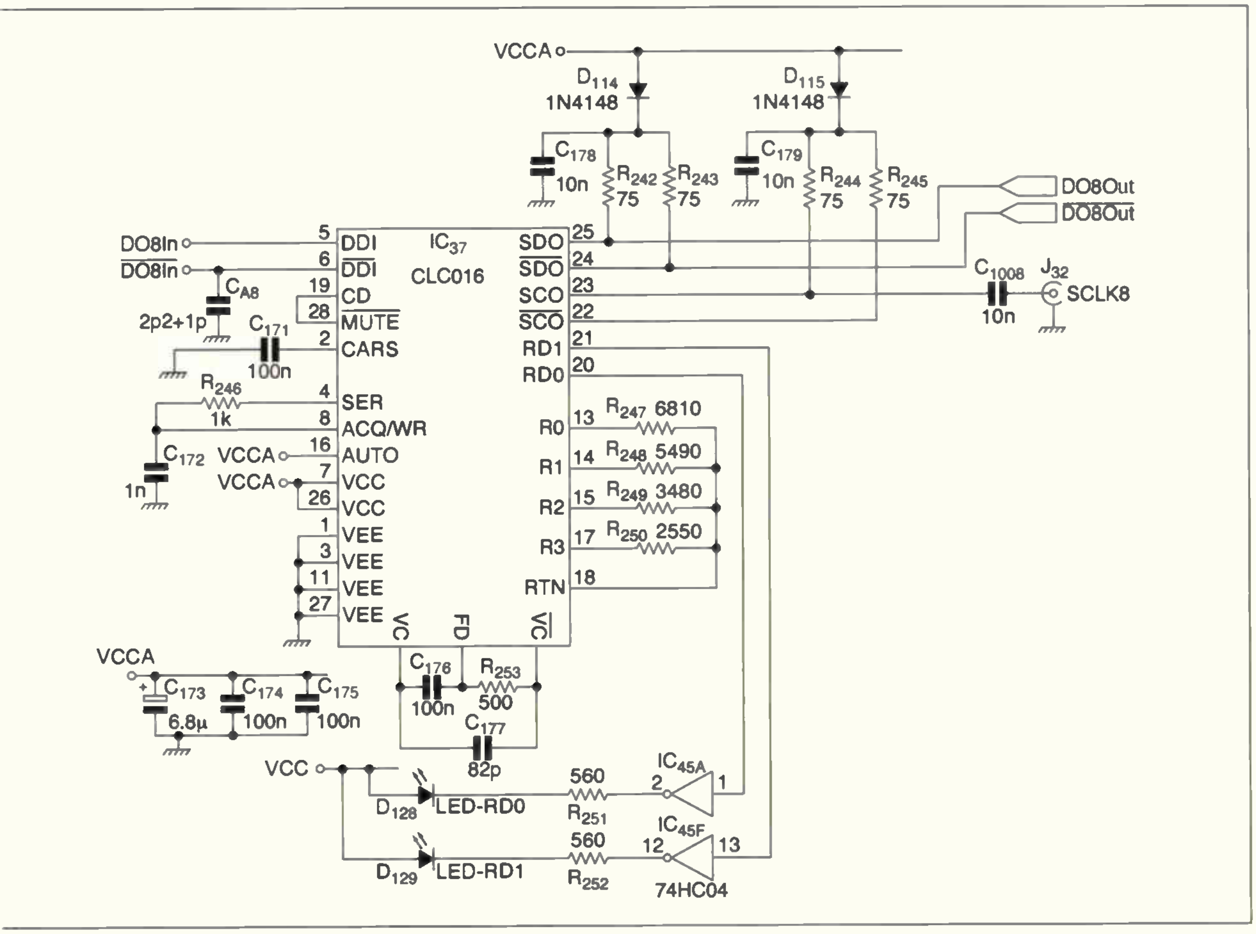
The firmware is code residing in the microcontroller's external PROM. This code is presented in object code form in **Listing 1**. It is responsible for all configuration functions of the crosspoint matrix, for the LED indication at the front panel and for communication with the external keyboard or host PC. It also retransmits commands to any stacked devices connected at the slave port and it loads the start-up configuration.

This is not the place to discuss the assembler source code used to produce the object code shown, but but I should mention that this program is considerably large. I consider it to be well thought through, providing redundancy and preventing lockups. Writing the software took a significant proportion of the system's total design time.

Device implementation and mechanical considerations

The DVRS-8x8 router is housed in a 19in, 1RU metal case. It's front panel with the LED indications and the back panel with the signal connectors and communication ports were shown on page 44 of last month's article.

Good electrical contact should be provided between the case base and the case lid to ensure good screening. A dedicated printed circuit board is available on request from me via the editorial offices of *Electronics World*. The price is dependant on demand email j.lowe@highburybiz.com.



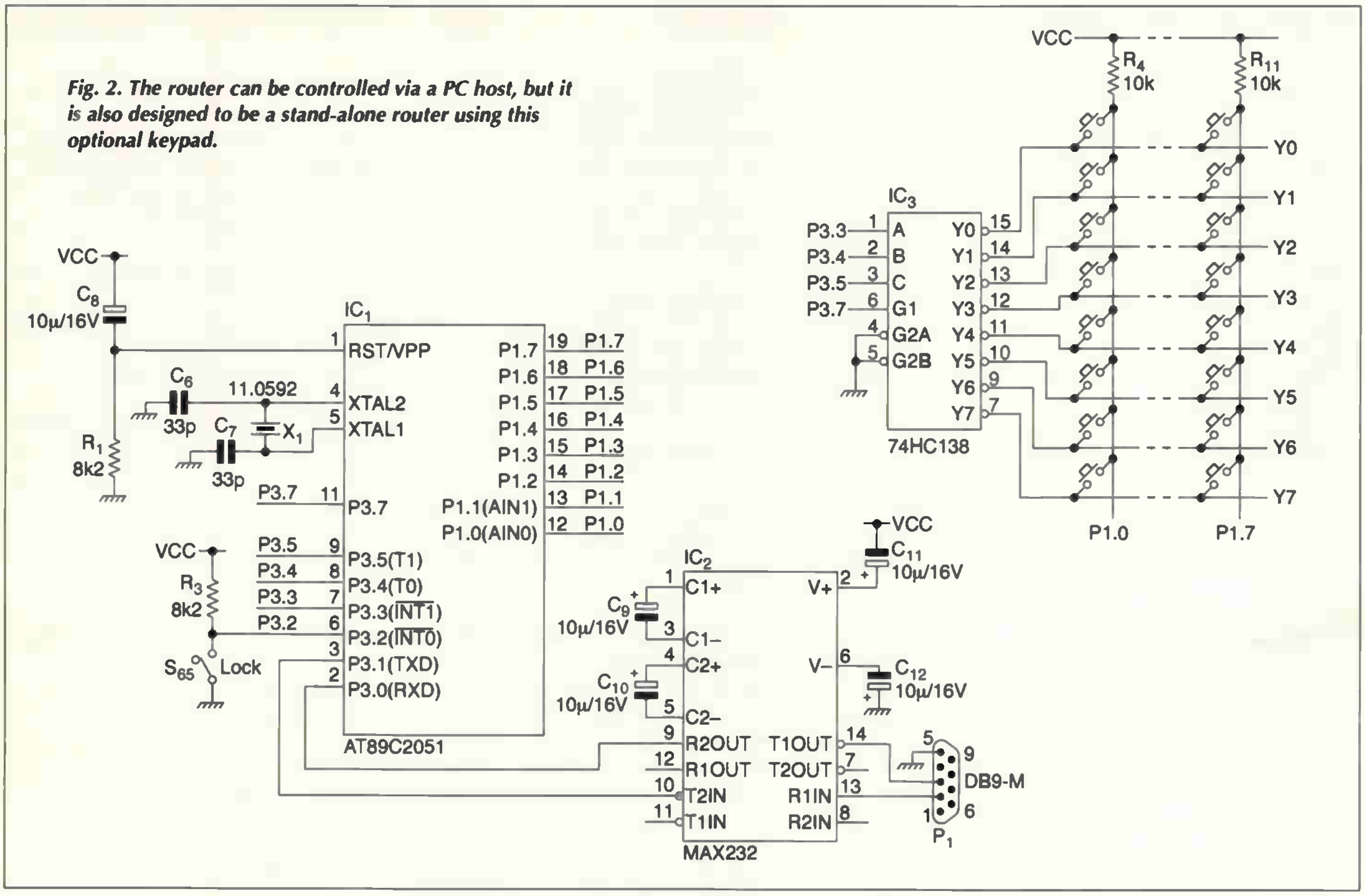


Fig. 2. The router can be controlled via a PC host, but it is also designed to be a stand-alone router using this optional keypad.

The PCB is designed with microwave techniques in mind, although using conventional 1.5mm double-sided material. Connections between the signal ports at the PCB and the panel-mounted BNCs at the rear panel should be implemented with short – but not crossing – coaxial cables without any additional board connectors. Belden type 8281 or equivalent can be used for the connections.

If necessary, the backs of the BNC-connectors and the mounting points at the PCB can be screened with copper plates. Connections to the LEDs and communication ports are made with standard ribbon cable. There's a lot of cabling to fit inside the small 1RU case, so measure the lengths exactly and organise the cable to prevent running out of space.

Linear regulators IC_{25} and IC_{26} from Fig. 4b) in last month's article are mounted on separate heat sinks that are isolated from each other and the case. These are not mounted on the circuit board, but on the bottom of the case.

The mains transformer mounts on the PCB. Mains is fused at the back panel of the device near the mains switch. Don't forget to isolate carefully all wires carrying line voltage.

Controlling the router

There are two of controlling the DVRS-8x8. One is a dedicated keyboard, the other a user interface program running on a host PC.

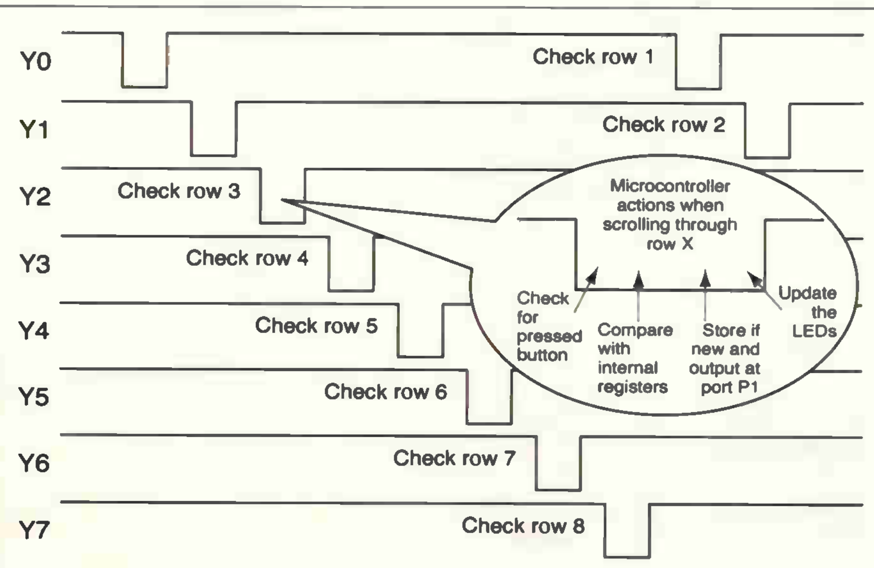


Fig. 3. As the keys of the stand-alone keypad are non-latching, software has to be used to scan them continually and 'remember' which one was pressed most recently. This diagram shows how the controller scans the keypad hardware.

The PVRS-2 8x8 keyboard. The dedicated keyboard has eight rows and eight columns of keys with a lock switch. It connects to the master serial port of the routeing system. Power for the keyboard is derived from the routeing system with a dedicated banana jack.

First I'll discuss the internal working of the PVRS-2 keyboard, **Fig. 2**.

The button matrix is built from eight rows by eight columns of standard non-latching push buttons. Scanning and interpretation of the keyboard is done in the Atmel[1] microcontroller, IC_1.

The response of the keyboard to user actions is blocked – i.e. the keyboard is locked – while switch S_{65} is closed. The 89C2051 looks at the level at this pin. If it sees a low level – i.e. switch closed – it loops, performing no action when a key is pressed.

The lock feature is useful for preventing accidental switching arising from operator error or inattention during live on-air applications of the router.

Scanning the keypad takes place as follows: the microcontroller, IC_1, addresses sequential rows from top to bottom, asserting incrementing addresses through its P3.3, P3.4, P3.5 lines to the decoder, IC_3.

Outputs of the 74HC138 decoder pull down the rows of the keyboard sequentially so only one row is low at a time. As all columns have pull-up resistors, namely R_{4-11}, when no key is pressed, port P1 of the micro connected to the columns of the keypad sees only high levels.

When a key is pressed, one of the port pins P1.7-P1.0 sees low level, and as the micro 'knows' which row is addressed it can identify exactly which button is pressed.

Software latch

As the buttons are not latching, a software latch has to be implemented. This works as follows: when a key is pressed the microcontroller identifies the key and stores the information in its internal registers. Then the microcontroller puts out the key information to its P1-port, which is also connected to all 74HC374 latches IC_{4-11}.

As the micro changes from one row to the next, it pulls the P3.7 line to the IC_3 first low and then high. This forces the formerly asserted row to go high, and after a time the next to go low, as depicted in timing diagram **Fig. 3**.

As the former row goes high, so does the respective Y0 to Y7 line too. This latches the valid key information on P1 into the LED latches IC_{4-11}.

Note that the Y output lines of the decoder connect to the clock-lines of the latches, which are edge triggered. Corresponding LEDs in the active row light to reflect the action on the button, **Fig. 4**.

As the microcontroller scrolls down the rows looking for new keys pressed, it also calls out the stored information

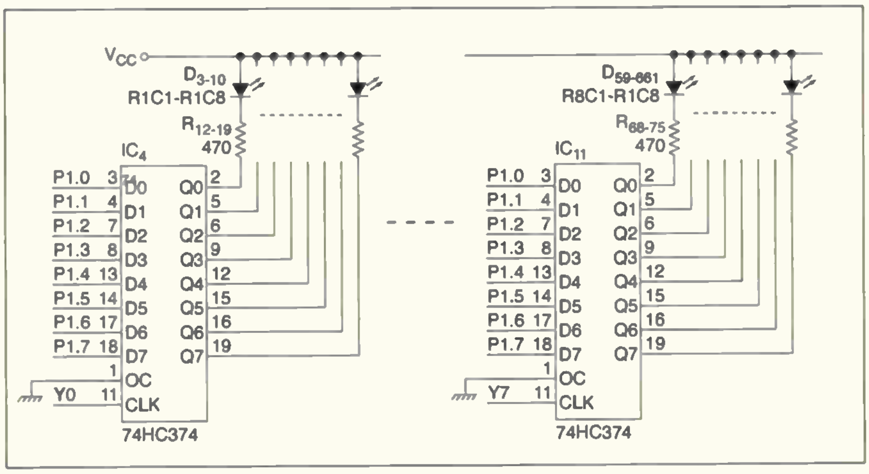


Fig. 4. The router's keyboard's LED display matrix forms a map reflecting which signal's routed where.

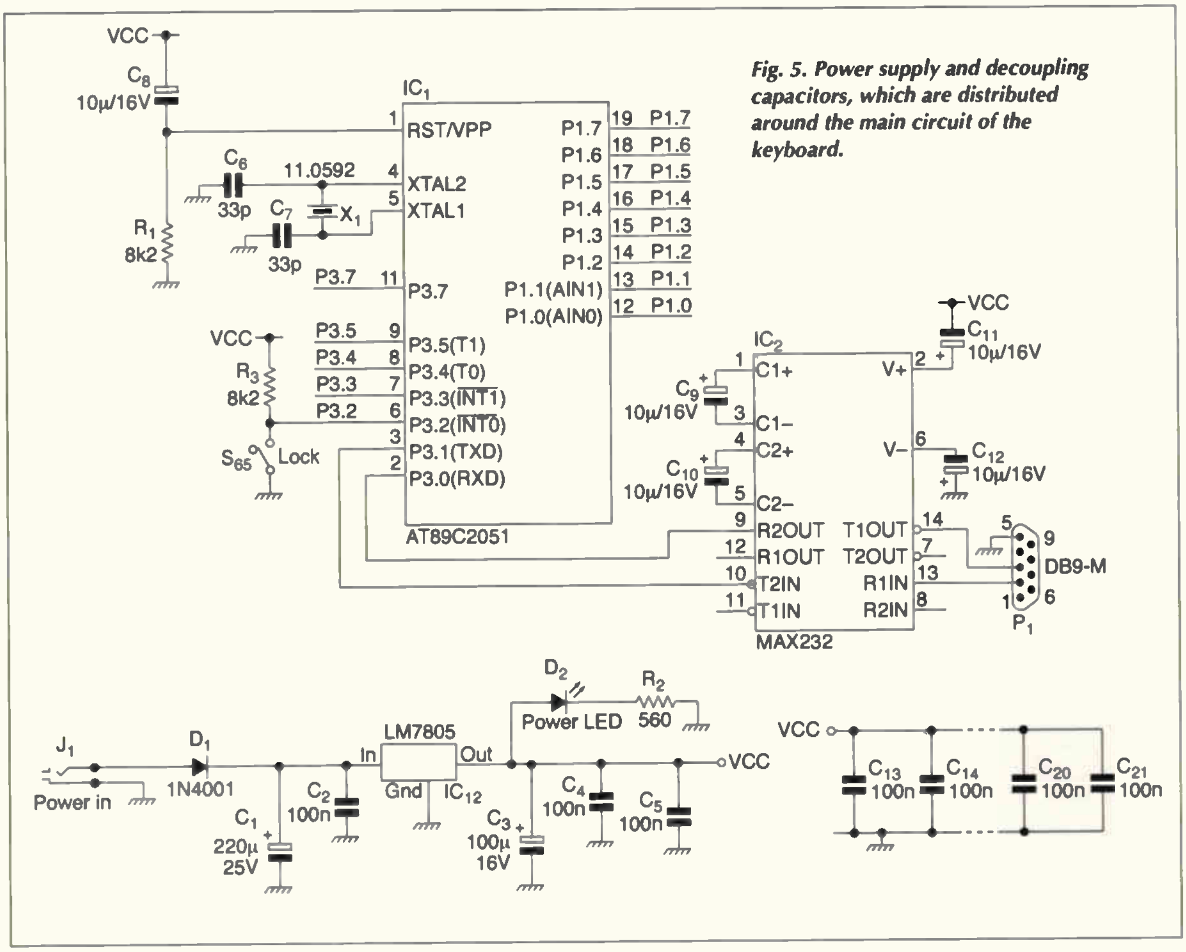


Fig. 5. Power supply and decoupling capacitors, which are distributed around the main circuit of the keyboard.

Table 1. Commands recognised by the router.

All commands end with CR and not with CR+LF. The commands are simple ASCII-characters sets.

Command	Description
OXXXXXXXX + CR	Device configuration for a single device. X can be any number between 1 and 8 (respective input) or D for output disable.
OXXXXXXXXOXXXXXXXX... + CR	Device configuration for stacked devices. X can be any number between 1 and 8 or D for output disable. Maximum 4 stacked devices can be configured in this way in the order: 1-st, 2-nd and so on. The first one is this next to the PC
ODDDDDDDD + CR	All outputs are disabled (but the cable equalisers are active).
SOXXXXXXXX + CR	Save the Start-Up configuration – X can be any number between 1 and 8 or D for output disable. The current configuration is not affected. The configuration selected will be loaded at next device power up.
SOXXXXXXXXNXXXXXXXX... + CR	Save the Start-Up configuration for stacked devices – X can be any number between 1 and 8 or D for output disable. The current configuration is not affected. Maximum 4 stacked devices can be configured in this way.
GetConfD + CR	The DVRS-8x8 returns the active configuration in the syntax OutInXXXXXXXX+CR, where X is 1-8 for inputs 1 to 8 or D if the corresponding output is disabled.
RYX + CR	Single output switch command. Y is the output concerned and X is any number between 1 and 8 or D for output disabled.
GetConf + CR	Get configuration command (for the AVRS-8x4). The DVRS-8x8 will only return the configuration for the first 2 outputs. This command makes it possible to connect the existing PVRS-1 8x2 keyboard to the digital router and control the first 4 outputs.
GetConfF + CR	Get full configuration command (for the AVRS-8x4). The DVRS-8x8 will only return the configuration for the first 4 outputs.

Commands for the AVRS-8x4 routing system. These are retransmitted by the DVRS-8x8 system. The commands are not modified.

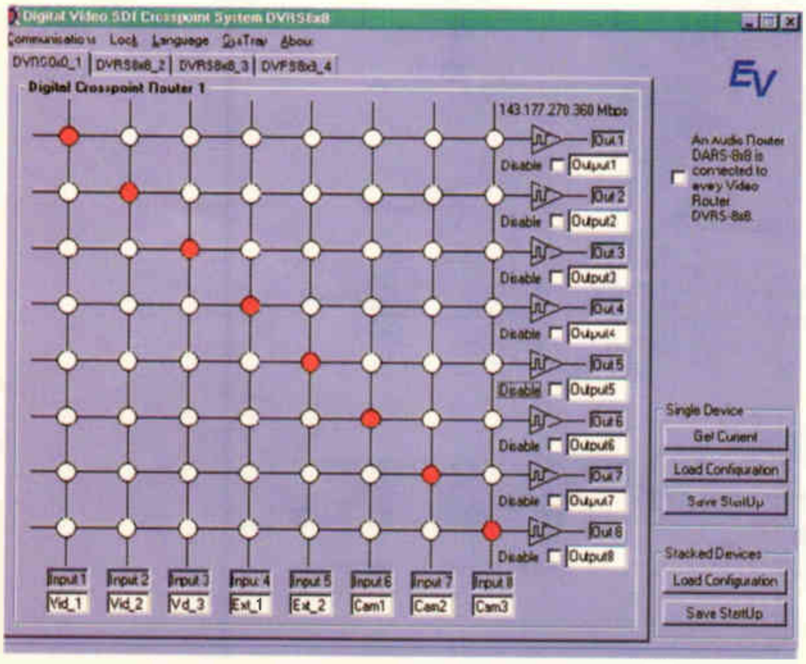
Out1234InXXXX + CR	Configuration command for the AVRS-8x4 system.
SOut1234InXXXX + CR	Save Start-Up configuration command for the AVRS-8x4 system.
DIXXXXDIXXXX... + CR	Configuration command for stacked AVRS-8x4 systems.
OutYInX + CR	Single output configuration for the AVRS-8x4.

about the current row to see if a new key is pressed or whether the same key is pressed twice. If a new key depression is detected, the information stored is changed and a new word is loaded into the LED-registers.

Of course this may look simple as an algorithm, but many software tricks have been implemented, including button debounce.

LEDs associated with the 64 buttons are $D_{3\text{-}66}$ and their associated current limiters are $R_{12\text{-}75}$. I chose red 3mm type

Fig. 6. Software has been developed to allow the router to be controlled via a PC. This is a screen shot from the software showing the status of the matrix.



LEDs because they more easily visible than other colours, and compact.

All information relating to keys pressed – and depressed – is transferred by microcontroller IC_1 in form of a command to the DVRS-8x8 controller. This is carried out via the integrated serial interface within the microcontroller, the level converter IC_2 and the serial port, P1 DB9.

This serial link is carried via a dedicated cable that mates with the DB9 female connector on the back of the router. This cable could also carry the power supply. However, in the interests of keeping the serial connector compatible with standard PC serial connections, the cable is split and a separate power banana jack is used to provide power supply.

In the circuit diagram, the power jack J_1 is symbolic. Power carrying wires of the cable are soldered direct to special pads on the PCB. See below for details.

In the power supply, **Fig. 5**, diode D_1 protects against accidental supply reversal. Capacitors C_1 and C_2 are DC-input smoothing capacitors. Raw power supply coming from the DVRS-8x8 is regulated down to 5V via IC_{12} and associated components $C_{3\text{-}5}$.

Power-on is indicated on the keyboard via the yellow LED D_2. Capacitors $C_{13\text{-}21}$ are power supply decoupling capacitors placed at individual chips.

An interesting feature of the keyboard is that it can also retrieve the start-up configuration loaded into the router when it is powered on. This means that if you change the configuration with a PC and then connect the keypad to the matrix, or you power up the whole system with the keyboard inserted and the start-up configuration is enabled, then the correct LEDs on the PVRS-2 will be lit to represent the actual status.

The firmware of the keyboard is relatively small. It fits into the 2k internal flash of the 89C2051 microcontroller, **List 2**. It can be obtained on request via the editorial offices, as can the PCB, Please email J.lowe@highbury.biz.com for more information.

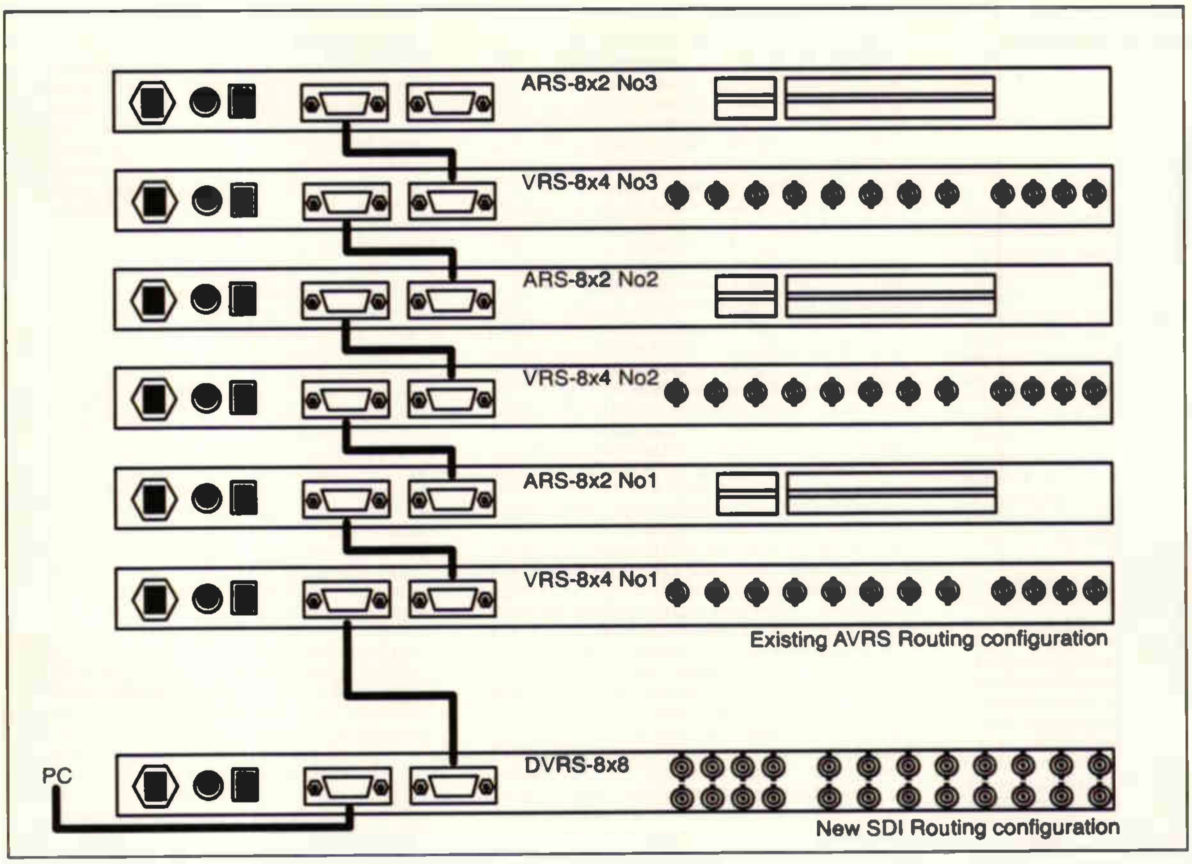


Fig. 7. In studio applications, routers can be stacked in a daisy-chain fashion so that only one command interface is needed.

The graphical user interface, running on PC

The second way of controlling the DVRS-8x8 digital router is to connect it to a PC via the master serial port.

Standard serial cable can be used, as the DB9 connector at the back panel of the system does not carry any power for the keyboard. A screen shot of the 'graphical user interface' program that I developed is shown in **Fig. 6**.

The program is tested and works in Windows 95 or 98. It should run under Windows NT too but I have not tried it.

The program provides all necessary features to control a single DVRS-8x8 device, a DVRS-8x8 device with an optional DARS-8x8 digital audio AES3 router or four independent stacked DVRS-routers. More useful information on digital audio signals in format AES3 can be found in reference 2.

The graphics side of the software represents the routing matrix in an intuitive way, where a valid connection from input to outputs is indicated by a red dot over the relevant crossing. The user can lock the software, to ensure that accidental switching cannot occur. Every input or output can be individually labelled, so the operator does not need to remember destination or source information.

The router's command set

For those of you who will not be using the dedicated keyboard or the GUI program written by me – or if you want to develop your own application/device – **Table 1** shows all of the commands that the DVRS-8x8 system can responds to.

It is a remarkable feature of the digital router that it supports the whole command set for the analogue AVRS-8x4 audio and video router too, described in earlier issues of the magazine[3,4].

Commands for the AVRS-8x4 routing system are retransmitted by the digital router from the master to the slave port immediately after they are received. This means that the user can not only connect many DVRS-8x8 devices in a stack, but also use the new digital equipment without making the old analogue routers obsolete.

This convergence situation is depicted in **Fig. 7**, where the PC is connected to the digital router and the slave communication port of the DVRS-8x8 is connected to the existing analogue routeing system consisting of three video routers VRS-8x4 and 3 audio routers ARS-8x2 connected in stack.

The PC has the GUI programs for both the DVRS-8x8 digital and the AVRS-8x4 analogue systems installed. These programs can be run in parallel with the unused program is minimised or hidden in the task bar so that simultaneous control of both new digital and old analogue routing systems are provided.

In summary

The DVRS-8x8 is a full-featured SDI digital router with many user control options. It is intended for upgrading broadcast and production studios from the analogue solutions to the new digital devices, which all support the uncompressed serial digital video standard.

A useful feature of the device – especially for the intermediate period of the transition from analogue to digital technology – is that the DVRS-8x8 router uses the same control set as existing analogue routing solutions and the same PC user interface. ■

For listings see page 42

Reference

1. Atmel, *8-Bit Microcontroller with 2K Bytes Flash.*, AT89C2051 Data Sheet, www.atmel.com.
2. Watkinson, J., *The Video Engineer's Guide to Digital Audio* – An NVISION Guide. ISBN 0-9640361-3-4.
3. Vladkov, E., *Pro audio-visual router*, Part 1, *Electronics World*, June 2001, pp. 423-431.
4. Vladkov, E., *Pro audio-visual router*, Part 2, *Electronics World*, July 2001, p-p. 538-543.

Listing 1. Object code for the DVRS-8x8's microcontroller.

```
:030000000200807B
:0800030032323232323232323265
:08000B0032323232323232325D
:0800130032323232323232323255
:08001B0032323232323232324D
:080023001201F03232323232D8
:1000800075A800D2B5D2B4C2B3C296C297C2B2C2EA
:10009000D1E587C2E7F587758DFD758BFD758921E3
:1000A000D28E759850D2ACD2AFE4C0E07980E4C370
:1000B00012082240F9B45A06D0E02401C0E0799039
:1000C000E4C312082240F9B45A06D0E02402C0E08A
:1000D00079A0E4C312082240F9B45A06D0E02404FF
:1000E000C0E0D0E0B40003020111B40702800302B3
:1000F00001BA1208FF78307900E4C312082240F9EF
:10010000F60809B40DF312027880FE80FC80FA80B4
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:10012000F4097A441209F0E4C3D2D11207E340F48F
:1001300097A441209F0E4C3D2D11207E340F4096A
:100140007A441209F0E4C3D2D11207E340F4097AE9
:10015000441209F0E4C3D2D11207E340F4097A440F
:100160001209F0E4C3D2D11207E340F4097A441231
:1001700009F0E4C3D2D11207E340F4097A4412092A
:10018000F0E4C3D2D11207E340F4097A441209F033
:10019000E4C3D2D11207E340F4097A531209F0E420
:1001A000C3D2D11207E340F4097A0D1209F0E4C377
:1001B000D2D11207E340F41208C879807A5A1209A2
:1001C000F0E4C3D2D11207E340F479907A5A1209CD
:1001D000F0E4C3D2D11207E340F479A07A5A1209AD
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:1002F00051C2AC9009FE1209DDC2997970879930 1C
:1003000099FDC299900A051209DDC2997971879900
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:1004400073F775F03412061308E67974F775F03512
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:100A1000496E804F757434496E804F7574496E808D
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:100A30006768742043203230303020456D696C2067
:070A4000566C61646B6F76D8
:00000001FF
```

Listing 2. Object code for the PVRS-2 keyboard microcontroller.

```
:1000000002002B1202ED3200000000 1202EE32005C
:10001000000000001202F1320000000 01202F2320071
:100020000000001202F332000000 0075A800C2D1E7
:10003000758A00758C4CC28DD2A9120321D2B2757B
:1000400090FF1204B51204B51204B51204B51204DF
:10005000B51204B51204B51204B51204B51204B5F4
:10006000C2AC9004F81204011204B59004EE12041C
:1000700001D2AFD2ACD28C30D1FDC28CC2A9C2ACFD
:10008000C2AFC2B3C2B4C2B5D2B7797087901203FF
:10009000DB0987901203DB0987901203DB09879045
:1000A0001203DB0987901203DB0987901203DB0937
:1000B00087901203DB098790C2B77590FF30B2FDBD
:1000C0001203DB7590FFE590B4FF06796077FF803F
:1000D000301203B8B4FF028028797087F0B5F013AE
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:1000F00022800E7960B7FF097970F77960F71204F2
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Function generator based on current conveyors

Muhammad Abuelma'atti *et al describe a novel function generator based on current conveyors. Using current conveyors means that the circuit is fast relative to equivalents based on conventional op-amps, and it has a low component count. As a bonus, amplitude and frequency are controlled by simply altering resistance.**

A new function generator using positive-type second-generation current-conveyor, or CCII+, is presented here. This generator can simultaneously produce sinusoidal, square and triangular wave outputs at low impedance.

The circuit enjoys independent resistance control of its frequency and amplitude of oscillation. Experimental results are included.

Background

Function generators having a variety of waveforms, for example sinusoidal, square and triangular, are widely used for testing and characterising electronic devices, circuits and systems. Traditionally, these function generators are designed using operational-amplifier based circuits.

However, function generators based on operational amplifiers are limited to low-to-medium frequency applications. This is attributed to the inherent limitations of the operational amplifiers, such as slew-rate and finite gain bandwidth product.

Without active or passive compensations, the finite gain bandwidth product of operational amplifiers, will limit the accuracy and reduce the operating frequency range.

Unlike operational amplifiers, current conveyors do not have their bandwidth restricted by feedback.

Second-generation current conveyors can, therefore, provide wider bandwidths and better accuracy when compared with operational amplifiers.

Various CCII-based analogue signal-processing circuits, such as sinusoidal oscillators, filters and amplifiers, have been reported in the literature. However, little attention has been paid to the realisation of CCII-based function generators with sinusoidal, square and triangular output voltages.

In this article, a CCII-based function generator is presented. The proposed circuit uses four positive second-generation current-conveyors, three capacitors, two of them grounded, and ten resistors, six of them grounded.

Oscillation frequency can be adjusted by controlling a resistor without disturbing the frequency of oscillation, and the amplitude of oscillation can be adjusted by controlling a different resistor without disturbing the frequency of oscillation. Thus, the proposed function generator enjoys independent frequency and amplitude control.

Proposed circuit

The proposed CCII+ based function generator is shown in **Fig. 1**. Conveyor IC_1 and its associated components form

*Muhammad Taher Abuelma'atti, Riyadh Al-Dakhil and Nezar Al-Said, King Fahd University of Petroleum and Minerals, Dhahran, Saudi Arabia.

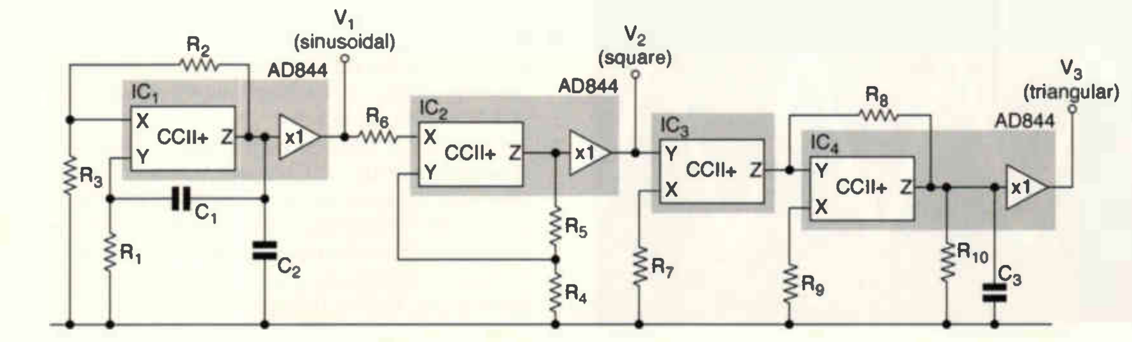

Fig. 1. Being based on current conveyors, this function generator operates at higher frequencies than its conventional op-amp counterparts.

the sine wave oscillator[1]. Next is IC_2, which is configured as a schmitt trigger to convert the sinewave to a square wave[2]. Finally, $IC_{3,4}$ form an integrator to change the square wave into a triangular one[3].

Assuming an ideal CCII+ with $v_x=v_y$, $i_y=0$ and $i_z=i_x$ the frequency of oscillation and the condition of oscillation of the sinusoidal oscillator built around IC_1 can be expressed[1] as:

$$\omega_0^2 = \frac{2}{R_1 R_2 C_1 C_2} \quad (1)$$

and,

$$C_1 R_1 = (C_1 + C_2) R_3 \quad (2)$$

From these equations, it is easy to see that the frequency of oscillation can be adjusted by controlling the resistance R_2 without disturbing the condition of oscillation. It is also clear that the condition of oscillation can be adjusted by controlling the resistance R_3 without disturbing the frequency of oscillation. Thus, the sinusoidal oscillator built around IC_1 enjoys independent frequency and amplitude control.

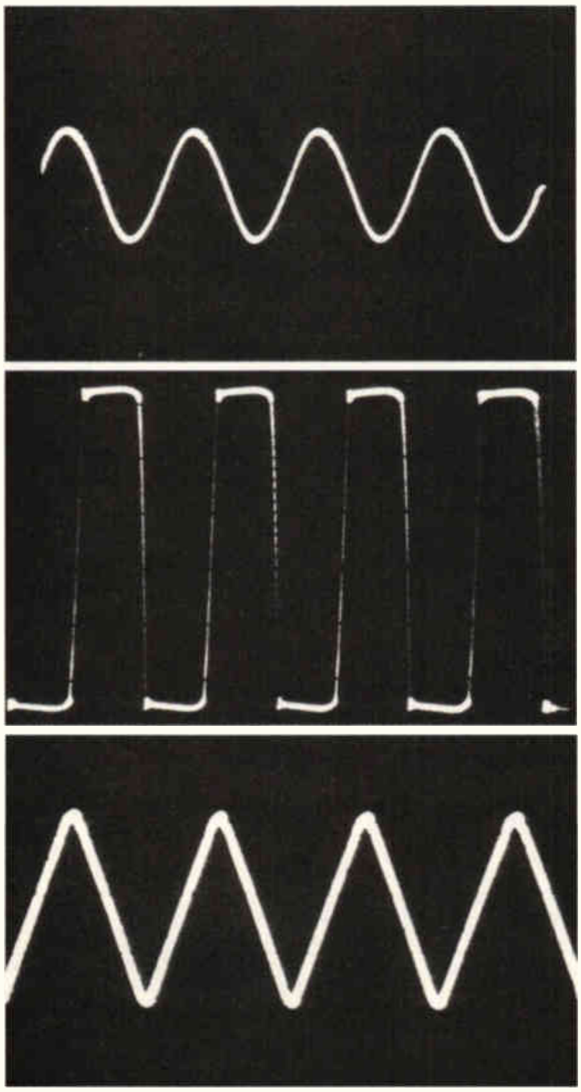

Fig. 2. Outputs at V_1, V_2 and V_3 respectively from the circuit of Fig. 1 with components as listed in the main body text. Operating frequency is 200kHz.

Conveyor IC_2, with its associated components, behaves as a Schmitt trigger with threshold voltages[2] given by:

$$V_{TH} = \frac{R_4 - R_6}{R_4 + R_5} V_{satH} \quad (3)$$

and,

$$V_{TL} = \frac{R_4 - R_6}{R_4 + R_5} V_{satL} \quad (4)$$

where V_{satL} and V_{satH} are two stable states determined by the power supply voltages of the IC_2. Thus, the output of the circuit built around IC_2 will be a square wave.

The transfer function of the integrator, $IC_{3,4}$, is given by:

$$\frac{V_3}{V_2} = \frac{R + R_8}{sCRR_7} \quad (5)$$

where $R=R_9=R_{10}$. Thus, the output of the circuit built around $IC_{3,4}$ will be a triangular wave.

Experimental results

The proposed circuit has been experimentally tested using the AD844 commercial current-feedback amplifier. This integrated circuit comprises a CCII+ and a unity-gain voltage follower.

The CCII+ behaves as an ideal current-conveyor over a wide frequency range. Results obtained at 200kHz with:

$C_1=C_2=1nF$
$C_3=100nF$
$R_1=2k\Omega$
$R_2=63k\Omega$
$R_3=1k\Omega$
$R_4=51\Omega$
$R_5=900k\Omega$
$R_6=510\Omega$
$R_7=5.1k\Omega$
$R_8=R=1k\Omega$

and a DC supply voltage of $\pm 15V$ are shown in **Fig. 2**.

The results reported here were obtained using a breadboard implementation. Obviously, an integrated circuit implementation avoids stray capacitances and would result in even higher operating frequencies. ■

References

1 M.T. Abuelma'atti and N.A. Humood, 'Current-conveyor sine-wave oscillator', *Electronics and Wireless World*, Vol. 94, #1625, 1988, pp. 282-284.
2 G. Di Cataldo, G. Palumbo and S. Pennisi, 'A Schmitt trigger by means of a CCII+', *International Journal of Circuit Theory and Applications*, Vol. 23, 1995, pp. 161-165.
3 S.A. Liu and Y.-S. Hwang, 'Dual-input differentiators and integrators with tunable time constants using current conveyors', *IEEE Transactions on Instrumentation and Measurement*, Vol. 43, 1994, pp. 650-654.

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Please allow up to 28 days for delivery

Specifications

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

Switch position 2

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

Switch position 'Ref'

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

Capacitor Sounds II

Standalone distortion meter

Cyril Bateman continues to describe his improved real-time hardware distortion measuring system

All measurements to date for this series were made using the test equipment, comprising my real time second and third harmonic analyser as described in the July issue, together with my 1ppm low distortion 1kHz generator, buffer amplifier and notch filter preamplifier[1] interconnected but otherwise laying 'loose' on the workbench[2]. While this arrangement worked exceptionally well, with so many separate exposed modules interconnected by easily broken coaxial cables, it was not particularly convenient to move and store away.

I have since assembled this complete system into a relatively small, 250 × 180 × 100mm, low cost commercial case, type LC960 purchased from DIL/C-I Electronics[3], producing a self contained free-standing distortion analyser which can be used testing both amplifiers or capacitors.

As a bonus this arrangement also outputs the notch filter reduced fundamental together with pre-amplified 'harmonic' signals for use with a soundcard and FFT software exactly as in my first *Capacitor Sounds* series[1]. Equally these harmonic signals can be used with my Hewlett Packard 331A distortion meter or my Pico ADC100 16 bit A-D converter improving their distortion measurement capability by 40dB, allowing them to measure distortions 100 times smaller than their unaided minimum. **Fig. 1**

Fig. 1. The Real Time hardware system as described in the July issue, fitted into the low cost LC960 250 x 180 x 100mm case, is shown measuring a 1μF 50v X7R ceramic capacitor at 0.5V using my reference Hewlett Packard test jig. The LED's respond quickly, revealing how this capacitor's distortion changes with time and bias voltage.

Modifications to Modules

To facilitate testing amplifiers, the DC buffer PCB required a minor alteration to isolate the 1μF capacitor C91 from the five 2.2μF capacitors C92-96. As they were designed to measure capacitor distortions, these capacitors were all connected by printed board tracks close to the terminal strip test jig. The five 2.2μF capacitors C92-96 provide DC blocking for the test current which is now taken directly to the 'I-out' or far right front panel and test jig BNC connectors. The 1μF capacitor C91 acts to DC block but couple the test signal back into the notch filter for measurement. This capacitor is now taken directly to the 'V-in' or second from right BNC test connector.

The BNC outer braids are only used to screen the test signals so the remaining two BNC connector inners provide the earth returns for the measured voltage and test current respectively. These four BNC connectors are arranged at 22mm centres to allow use either with standard Hewlett Packard (Agilent) LCR meter test jigs, my new low cost 'terminal strip' test jig or four discrete BNC test leads. **Fig. 2**

To fit into this case the notch filter module had to be mounted vertically. As originally assembled, the two

PTFE insulated terminals on its bottom case side would now foul the case floor and so must be removed. Originally these were used as an optional direct input to the notch filter and also to input the generator signal into the output buffer amplifier. Both were removed and the buffer's input cable was re-routed to now pass through a hole at the end of the screening case, adjacent to U45.

To fit conveniently into a front panel the display LEDs were reassembled 'end on' to their PCB using revised display printed boards. Both LED trees were arranged side by side as two parallel columns some 15mm apart with the forty 3mm LEDs now mounted at 4.1275mm (0.1625") centres, so as to fit vertically into this 100mm tall front panel.

Resulting from these changes we now have a more convenient way to measure both amplifiers or capacitors using a permanent set-up which is easily re-configured externally, simply by choice of the external test jigging used or four separate test cables. We have gained both flexibility and convenience and improved the noise floor, without degrading measuring accuracy. **Fig. 3**

While not part of my original intention, I now see this arrangement of case mounted modules, would also benefit those readers who have built only the original generator, notch filter and DC bias printed boards and have no wish to build the Real Time add-ons.

Simply omit the Real Time hardware printed board complete with its LED displays and front panel level switch. The two panel meters could then be arranged to continuously display both the DC bias voltage and the AC test voltage being used.

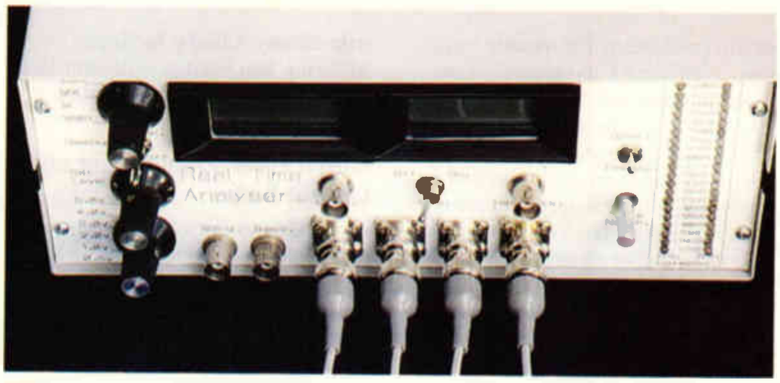

Fig. 2. The four BNC connectors mounted at 22mm centres, provide true four terminal measurements, isolating the test current from the voltage being measured. Enable a quick change from measuring capacitors to amplifier circuits simply by change of test jig, with no change of any internal circuitry.

Fig.3. Testing the 1μF 250v B32653 capacitor which featured in my last article, mounted in my easily fabricated, low cost, four terminal 'replica' capacitor test jig made from a 100mm length of 15mm Aluminium angle, four panel mounting BNC connectors at 22mm centres and a terminal test strip.

Appearance

While the basic metal working needed is quite straightforward using only hand tools, the most difficult aspect of any self assembled test equipment is producing a suitably legended front panel. Over the years I have tried many methods, with some success. In past years few viable options existed, one could use 'Letraset' or similar transfers, cut a silk screen stencil or make an engraving onto the black/white two colour Traffolite or similar plastic laminate.

The best method I've found, which was used for the front panel label of my Tanδ meter, was the excellent but relatively expensive 'Quick Mark' peel apart photosensitive label system from Mega Electronics[4]. This could be used to provide both positive and negative images from a positive master. Even the 0.5pt lines in my logo were clearly legible when using a photoplotted-master.

Mega now offer a lower cost, directly laser printable, A4 sized self adhesive label system called 'Quick-Laser', which can be easily overlaminated for extra protection. Quick Laser is a plastic film available in silver, yellow, blue, green or the white which I used for this assembly. **Fig. 4**

DC bias PCB

Having cut and drilled the case front panel, the first assembly stage is to modify this PCB. Remove the source impedance resistors R91-94 and R97-99, replacing R94 only with a link wire. Remove the charge discharge toggle switch and relocate onto the front panel, then cut through and remove the three PCB tracks which connected C91 to the five 2.2μF capacitors C92-96 also the charge/discharge resistor R95. Insert an insulated wire link from the now free end of R95 to re-connect to all five 2.2μF capacitors C92-96.

To assist in earthing the coax cable from the I-out front panel BNC and also the I-low return current wire, I added an extra Vero pin to earth, fitted close to the bias output terminal connector strip where shown on the figure. **Fig. 5.**

Low Distortion Oscillator Module

To facilitate periodic re-calibration of this oscillator, without removing from the case, I drilled three 6mm holes which are aligned over the three multi-turn pre-set resistors. To prevent stray cut wire ends falling inside this case during construction, these holes were covered by three removable blue sticky labels, as seen in the photo. Because this assembly sits over one case side flange, also the Real Time range switch spindle extension, a piece of scrap copper laminate was affixed, copper side down, underneath this module using four 2mm screws and spacers at the mounting pads provided on the PCB.

In addition to protecting the printed tracks from damage, this earthed copper laminate provides additional screening, further reducing generator noise and distortion. You should also refit three longer power supply leadwires and re-connect the coax cable between this module output and the notch filter input, before finally mounting the module into the case.

I used PTFE insulated coaxial cable simply because while it is harder to strip cleanly, I find it facilitates soldering into position without risk of damage to the inner core insulation.

Notch Filter/Preamplifier and Output Buffer

As for the oscillator module, the track side of this module also was screened and protected using scrap copper laminate affixed using four 2mm screws. Note the top most screw adjacent to the panel meter clashes, so should be left out.

Two PTFE lead through terminals on the case wall opposite to the range switch, conflict with the LC960 case bottom when this module is mounted vertically as shown, so must first be removed. Remove also the short coaxial cable which connects between the test jig terminal strip and notch filter preamplifier input and the coax cable which originally connected between the oscillator output and the output buffer amplifier input.

Fit one end only of each of three new coax cables, to the buffer 50Ω output tag, the notch filter

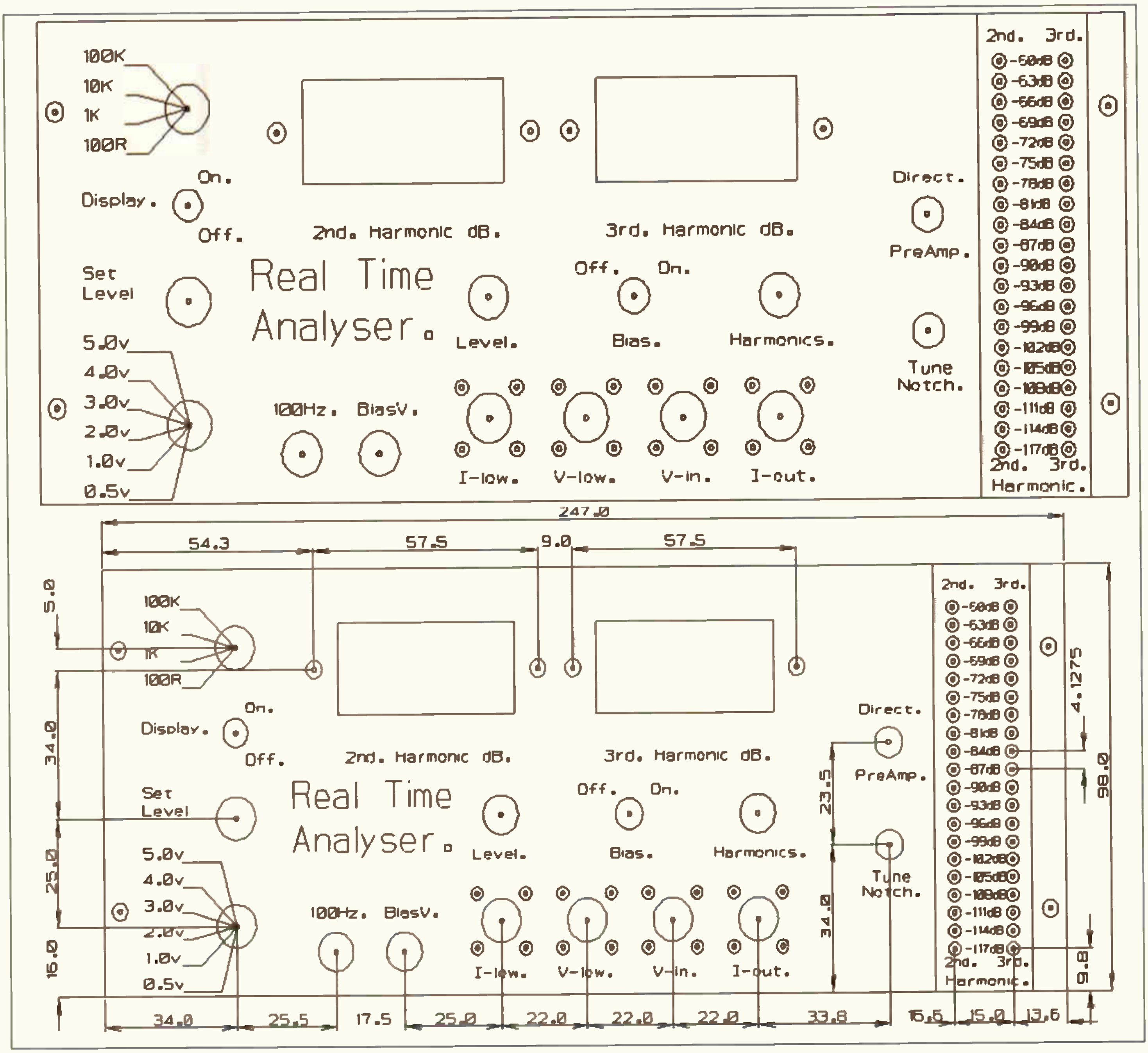

Fig.4. True scale front panel layout as used for my prototype assembly. This drawing is available on my CD ROM as true size PDF file which can be directly printed, also as a fully dimensioned drawing.

preamplifier input tag and the buffer amplifier input tag through the hole in the case end adjacent to U45. The free end of the notch filter input coax will be connected to the DC bias buffer PCB output terminal strip and the buffer amplifier input coax re-connected to the oscillator output terminal.

The free end of the 50Ω output tag cable will later connect to the wire link replacing R94 on the DC bias PCB, via the new front panel mounted source impedance selector switch.

Three more coax cables also power leads will be connected to this module but are best fitted later, after it has been finally mounted into position inside the case.

Trial and initial assembly

Temporarily fix all switches, BNC connectors, panel meters in place on the un-legended front panel and assemble to the case. The PM128 panel meter bezel adjoining ends may need reducing by some 0.5mm to fit into this panel layout. Check to make certain all remaining front panel modules fit correctly then dismantle and fix and trim the front panel label in position. Refit all front panel switches and BNC connectors, but do not refit the panel into the case or install the modules.

Fit and solder all required coax and wire leads to the front panel hardware also the two panel meter displays, but leave the new source impedance selector switch to later. Fit in place the DC bias PCB and connect to the front panel wiring as needed, then refit the front panel to the case.

Install the generator module and notch filter/preamp modules and connect up the free end of the notch filter input coax to the DC bias buffer PCB output terminal strip, to the left side terminal strip as seen in **Fig. 6**.

Source impedance switch

For this I used a three pole four way switch with two poles connected in parallel and used for the 1kHz source resistors which were mounted directly onto the switch tags. The remaining pole was used for the 100Hz source resistors. Both 100Hz from the front panel and 1kHZ from the buffer amplifier 50Ω output coax tag go direct to their relevant resistor chains, so as to supply both frequencies at the required source impedance, direct onto the wire link which replaces R94 on the DC bias PCB.

Final Wiring

Connect the two short coax lengths from the front panel 'Level' and 'Harmonics' BNC connectors to the meter and harmonics out PTFE terminals on the notch filter/preamp assembly and connect the power supply cables to the PCB tags.

Assuming the Real Time display modules are not being used, all wiring is now complete and the assembly can be tested.

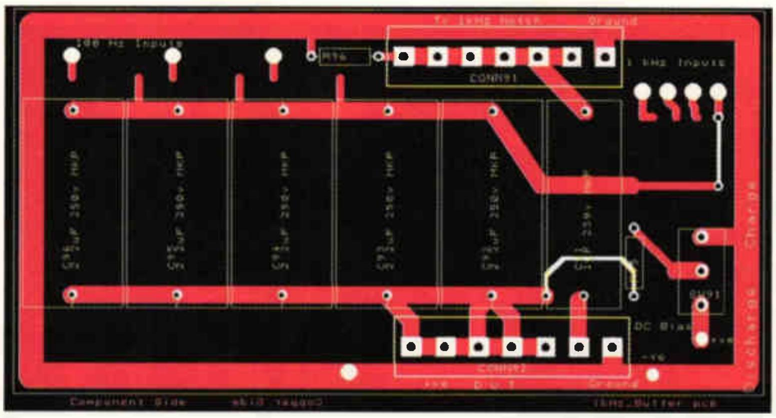

Fig.5. Screen shot showing how I modified my original DC bias printed board for use in this cased assembly. By simply cutting three tracks and adding a short link wire, I isolated C91 from the five 2.2μF C92-96 capacitors to provide full four terminal capability to the test jig, allowing capacitor or amplifier distortion measurement

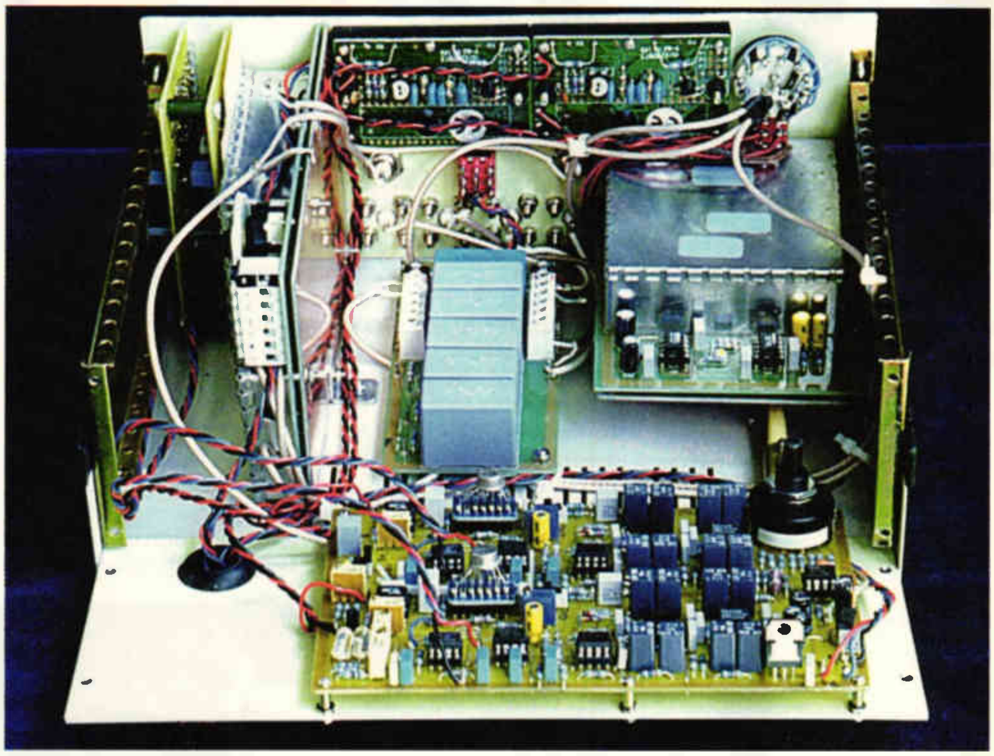

Fig. 6. Rear view with the back panel laid flat shows the various coaxial cable connecting between the modules and front panel, in my assembly. The right hand top switch, with three coax cables is the new combined 100Hz and 1kHz source impedance selector, with the 100Hz source impedance arranged ten times larger than for 1kHz, matching the capacitors impedance at these frequencies.

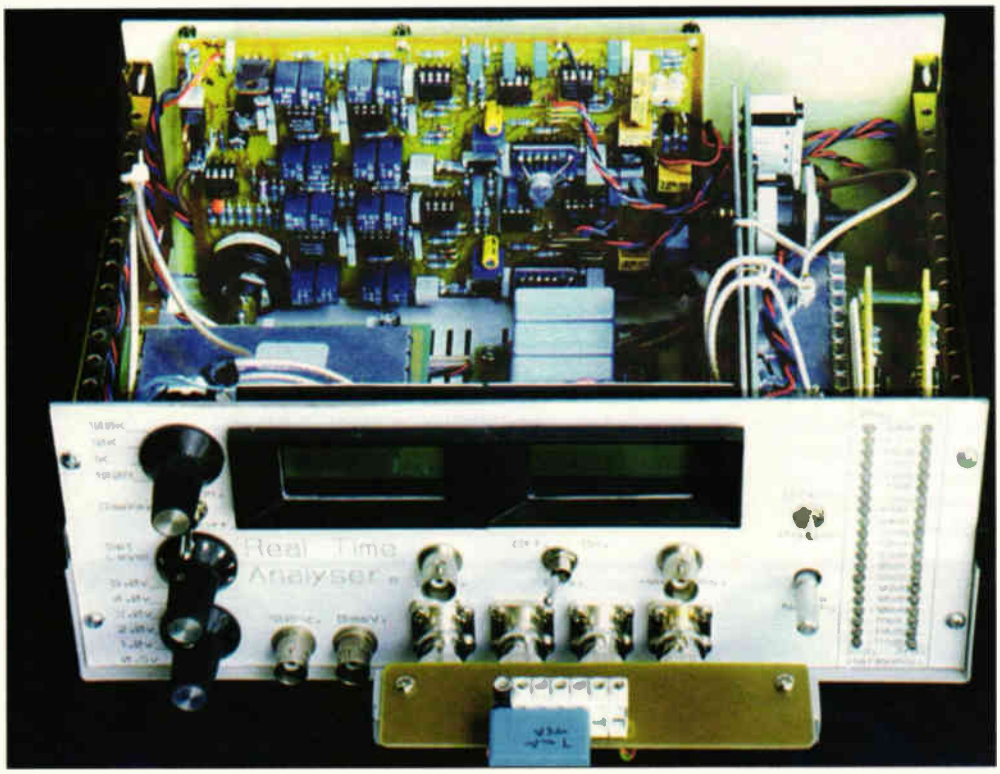

Fig. 7. The same assembly now viewed from the front shows the Real Time printed board mounted on the case back panel. This view also shows the added insulation inserted between the LED display board and the notch filter/preamp case lid.

Real Time Modules

Drill and fix the main PCB to the case back panel such that the input end of this PCB is fixed some 20mm from the left side of the case back, using seven 2mm screws and spacers fastened through the mounting pads on the PCB. Screw the two LED display boards together using 13mm plastic spacers and insert the LEDs into the front panel drillings. It is essential the track side of the display board nearest the notch filter/preamp module is insulated. For this I used a piece of 1mm thick 'plasticard' from a model shop, but any similar thickness and insulator type will suffice, see **Fig. 6.**

Connect a coax cable between this PCB input terminals and the notch filter/preamp 'harmonics' PTFE output terminal. This is the coax cable seen far left in figure 6. For convenience I powered the panel meters using PP3 batteries, simply tucked away under the generator module and retained using 'sticky fixer' pads.

Connect the LED display PCBs to the 15 volt out terminals, the OutA, OutB 2kHz and 3kHz Vero pins as appropriate. Connect both panel meter inputs to the Out2nd, Out3rd dB Vero pins with both negative inputs connected to the 6V reference output and attach power supply leads. **Fig. 7.**

This completes the assembly which can now be tested. Using a 3 volt test level and measuring either a good 511Ω metal film resistor or a good 1μF metallised Polypropylene capacitor, both panel meter displays should read better than -120dB and all display LEDs should be off. **Fig. 3**

Test Jigs

Throughout my *Capacitor Sounds* series I have repeatedly stressed the need to use good test jigs. I fortunately have several of the excellent four terminal Hewlett Packard LCR meter test jigs, having standardised on these for all my tests and measurements, whenever practical, many years ago.

However while these jigs are properly designed and of excellent quality they are expensive, so I don't expect many readers will be similarly equipped. I have designed a low cost alternative jig assembly which can be seen in use in figures 3 and 7 testing the excellent 1μF 250V B32653 metallised Polypropylene capacitor which featured in my last article.

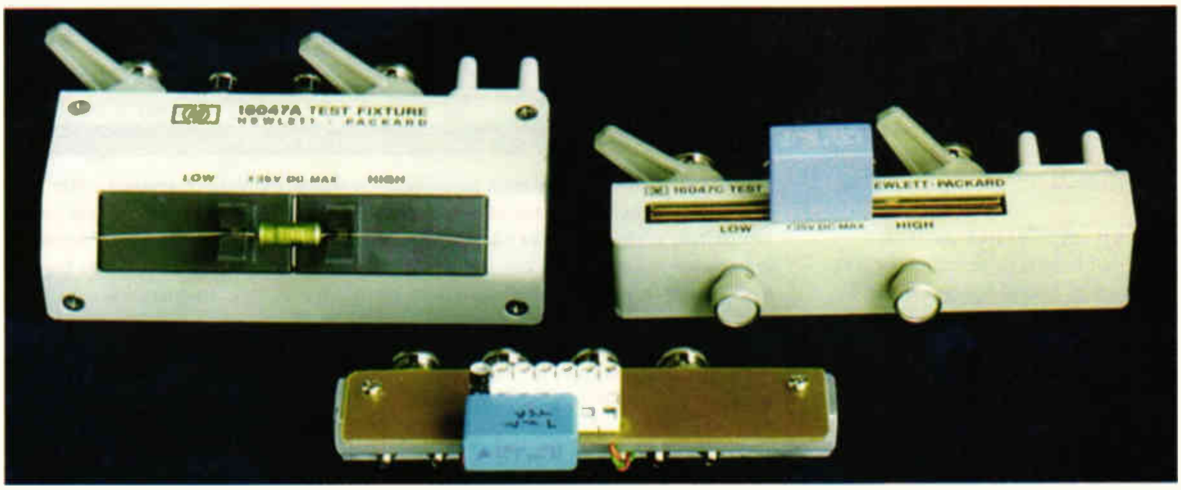

Fig. 8. The jigs used for capacitor measurements. The HP16047A jig left, has plug in exchangeable adapters for axial and radial leaded components. The HP16047C jig right, my reference standard, has gold plated contacts which clamp onto component leads. My low cost alternative with a B32653 capacitor, is shown for comparison.

This jig was assembled using a 100mm length of 15mm Aluminium angle, four panel mounting BNC connectors, Farnell part 3650534, mounted at 22mm centres to match my front panel and another terminal block as used for my DC bias buffer. **Fig. 8.**

The terminal block was mounted on a scrap piece of laminate and its active or white terminals simply isolated by hand carving. The black common (low) terminal was connected to both the current and voltage 'low' BNC connectors using a short length of twisted pair wires, with the wires placed one on each side of the terminal pin solder.

In similar fashion the white (high) test terminal pins were connected to the 'high' BNC connectors with the voltage wire to the test terminal adjacent to the common terminal, the current wire going to the opposite end terminal pin. In this fashion full four terminal connections were maintained right up to these capacitor test jig terminals.

Performance

Using a 3V test level and with the original module calibration unchanged, my 1μF 250v foil and Polypropylene FKP reference capacitor now reads better than –130dB both for 2nd and 3rd harmonics, a clear indication that the improved screening with the modules assembled inside the case has lowered noise levels and reduced extraneous noise pickup. Altogether a significant improvement on an already excellent measuring system.

In my next article I explore using this equipment to measure distortions in amplifier circuits. ■

References

1. Capacitor Sounds, C. Bateman, Electronics World, July, September, October 02.
2. Capacitor Sounds II, C. Bateman, Electronics World, July 2003.
3. DIL/C-I Electronics, Holland. email to dil@euronet.nl
4. Mega Electronics Ltd. http://www.megauk.com

Technical support

Full details of this new hardware test method and my original *Capacitor Sounds* series 1ppm low distortion oscillator, buffer amplifier, notch filter/preamplifier and DC bias assemblies, together with parts lists, assembly manuals and full size printed circuit board drawings, all as .PDF files arranged for easy viewing on screen or hardcopy, are provided in my new *Capacitor Sounds* CD.

This CD ROM includes updated and much expanded re-writes with very many more figures, of my recent series of six *Capacitor Sounds* articles, supported now by some ninety capacitor distortion measurement plots. Also on the CD are PDF re-writes of my earlier 'Understand Capacitors' series together with articles how to diagnose failed capacitors while still mounted on printed circuit boards and essential low cost capacitor measurement methods, more than twenty popular articles.

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C.Bateman.
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Answers to Test Yourself from page 35

$$E = n \times \frac{d\phi}{dt}$$

This is Faraday's law of induction. For a coil of n turns, the EMF generated is equal to the rate of change of the flux, ϕ, multiplied by the number of turns. The law can also be stated as the rate of change of flux linkages, but this form is more understandable for stationary devices such as transformers.

$$E = L \times \frac{di}{dt}$$

This is a key equation for an inductor, stating that the EMF across an inductor is equal to the rate of change of current through it, multiplied by its inductance. The equation can be re-arranged to work out the rate of change of current from an applied EMF. This is essential for an understanding of switched mode power supplies.

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

This is the current in a capacitor caused by a changing potential difference across its terminals. This was explained in the text.

$$r = \frac{dV}{di}$$

The small signal resistance of a component is the slope of its voltage/current curve. It is the small signal form of Ohm's law.

Answers to Final Test

A sinusoidal voltage is mathematically represented by the equation, $V=V_{MAX}\times\sin(w\times t)$. Now ω is the *angular frequency* in radians/second. It has to be in radians/second to make the calculus work correctly. The slew rate is the derivative of the voltage with respect to time.

$$\frac{dV}{dt} = \omega \times V_{MAX} \times \cos(\omega \times t)$$

The maximum value of a cosine function is one, so:

$$\left.\frac{dV}{dt}\right|_{MAX} = \omega \times V_{MAX}$$

Remember that ω=2πf and that the peak value of a sinusoid is √2 times the RMS value.

$$\left.\frac{dV}{dt}\right|_{MAX} = 2\pi \times 10^6 \times \sqrt{2} \times 3 = 26.66\text{V / ms}$$

2) $i = C \times \frac{dV}{dt} = 0.1 \times 10^{-6} \times \frac{100}{1.5 \times 10^{-6}} = 6.667\text{A}$

25kHz is a period of 40μs. The waveform is therefore at 10V for 10ms and 1V for 30μs.

$$V_{RMS}^2 = \frac{1}{40}\left[\int_0^{10} 10^2 \times dt + \int_{10}^{40} 1^2 \times dt\right]$$

$$\therefore V_{RMS}^2 = \frac{1}{40}\left([100 \times t]_0^{10} + [1 \times t]_{10}^{40}\right)$$

$$\therefore V_{RMS}^2 = \frac{1}{40}(1000 + 30) = 25.75$$

$$\therefore V_{RMS} = 5.074\text{V}$$

As a quick check, we ensure that the RMS value is smaller than the maximum voltage (10V) and larger than the minimum voltage (1V).

4) If you answered with just a number then you failed. If you were unsure, but thought it seemed wrong then you failed; you need a *much* better understanding of the basics than that. The answer I am looking for is that the *question* is faulty. The mean power in the resistor is of course 25.75Ω. The peak power is 100W. The crest factor is 1.97. The question asks for a stupid quantity, which, if calculated, would give a meaningless result. If anyone asks you for "RMS power" you have to interpret the request as being for mean power *and then point out the error.*

LETTERS
to the editor

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

Ellis replies

With reference to Kevin Aylward's letter (*EW*, June 2003) regarding my article on audio amplifier compensation, some points need answering.

Miller compensation is mathematically robust. Many circuits which were published, particularly in the 1970's and 1980's, used it without regard to the consequences on the slew induced distortion on the input stage. Perhaps we can credit Otala[1] at least for drawing our attention to this, even though his recommendations for a wide open loop bandwidth and limited feedback have largely faded from popular use.

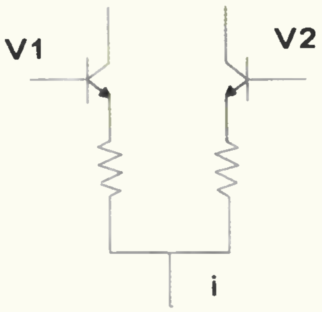


Fig. 1. Typical input stage.

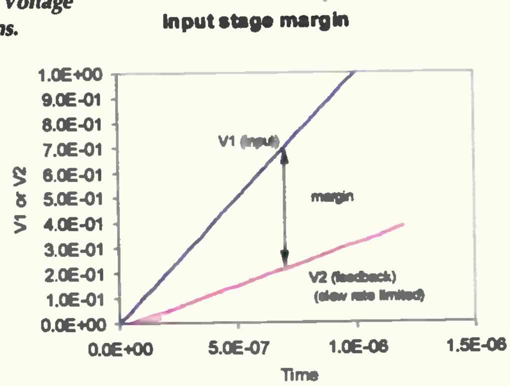


Fig. 2. Voltage margins.

Overloading of the input stage is a possibility in Miller-compensated amplifiers if the differential voltage margin is insufficient. **Fig. 1.** shows a typical amplifier input stage. V1 is the input, V2 the feedback point, and i the tail current. If we apply an input signal of the form V1 =kt, then it can be shown, subject to two provisos, that

$$V2 \approx \frac{gm.k.t^2}{2.C.G}$$

where C is the Miller capacitance, G the amplifier gain (from the feedback ratio), and gm the input stage transconductance. The provisos are (1) that the input stage does not become current limited and (2) that the feedback signal is still suppressed relative to the input. **Fig. 2.** shows a graph where the input stage has become current limited: the initial square law response becomes linear.

The differential voltage margin between V1 and V2 is also the minimum requirement for the input stage to remain linear. The definition of linear depends on tolerable distortion, but a minimum is where neither transistor becomes cut off. Two possible solutions are to use large enough values of emitter degeneration resistor so that the maximum input voltage excursion can be tolerated without cutting off a transistor or to increase the input stage tail current with smaller resistors to achieve the same voltage margin, as I said in the article. Mr Aylward does not say whether he considered either of these solutions as a resolution to the overload problem.

A better question may have been to ask whether extreme input conditions are possible. For most audio source material and media, it may be unlikely - Baxandall said as much, a long time ago, but it is worth revisiting in respect of new media such as CDs and DVDs. However, the worst-case situation is still in all probability with 'live' material and in my view 'the best' amplifier should have full input overload capability without becoming current limited. It is not always within the designer's control how amplifiers might be used. For example, it would be possible for a digital signal to switch from all zeros to all ones and create a fast transient, subject to any other amplifiers and filters before the power amplifier. Also, for high-end applications, it is possible that sampling rates will increase from the standard 44kHz - so conservative, pedantic design may be more future-proof.

I am not familiar with the particular 1980's amplifier Mr Aylward referred to, and therefore cannot comment on that particular model. However, in general terms, it is possible to obtain lower THD and higher slew rates when the input stage gain and tail current are increased. This would encourage the use of small or no degeneration resistors, but would reduce overload margins. As well as quoting THD and slew rate, the input stage overload behaviour needs to be specified. Some designers circumvented the problem using a low-pass input stage filter, which at least one *Electronics World* reader has objected to.

Mr Aylward says that it was difficult to determine the real loop gains and phase margins of the design. Actually, this was precisely why I included the open loop gain curve, but I expected that interested readers would set up their own simulation and check the PLIL technique before using it rather than comparing graphs point by point. Nevertheless, having got

Table 1: Miller and PLIL distortion. Components above 3rd harmonic were either below noise or above audio band.

Frequency	Output voltage	Config	Distortion characteristics	
			2nd	3rd
	V RMS		µV RMS	µV RMS
1kHz	1	Miller	33	40
		PLIL	40	40
	10	Miller	421	300
		PLIL	483	475
10kHz	1	Miller	156	51
		PLIL	267	121
	10	Miller	2600	361
		PLIL	2630	600

the simulated data files it was very easy for me to perform the subtraction, giving the Nyquist plot shown in Fig. 3. This is the polar form comparing return difference with phase angle. The trace does not include the origin. I regret not including this graph in the article, as it confirms that the PLIL approach is stable.

Regarding the performance of a PLIL amplifier, I compared the distortion between a Miller compensated amplifier and a PLIL configuration. The results are shown in table 1. The Miller configuration used emitter degeneration resistors of 330 ohms, a tail current of 6mA, giving a good overload margin, and a 47pF Miller capacitor. The PLIL configuration used 100Ω degeneration resistors, 4.7kΩ base resistors, a 1nF - 100Ω series network between the two input bases and a 100pF phase lead capacitor.

The PLIL amplifier has similar distortion level to, or within a factor of 2 of, the Miller figures. Both sets of results are quite respectable, being in the hundredths of percent level or less. These results are only offered as a quick comparison, since some conditions, such as power transistor temperature, was not controlled between tests. Both sets of data also include any distortion my oscillator is generating, hence are maximums.

The PLIL distortion figures could also have been predicted from the simulated open loop characteristics I presented. In that graph, the PLIL open loop gain was a fraction below that of the Miller circuit.

The question I posed in the article was whether the PLIL approach was an alternative to the Miller capacitor. The data I presented was objective and pointed out the disadvantages as well as the advantages, which does not warrant the label contradictory In conclusion, the PLIL seems to be a possibility which gives competitive performance to the Miller method and an alternative means to preventing input stage overload. To continue to be objective, it can be seen from the results given that it is possible to obtain a good performance from a Miller design which has a good input overload margin, so I am not sure why this has not become standard practice. If it were, then perhaps I would agree with Mr Aylward that the Miller issues are resolved.

John Ellis
Tavistock
Devon
UK

Reference

1. Otala, W "Transient Intermodulation Distortion in Audio Power Amplifiers", IEEE T-AU18, Sept. 1970

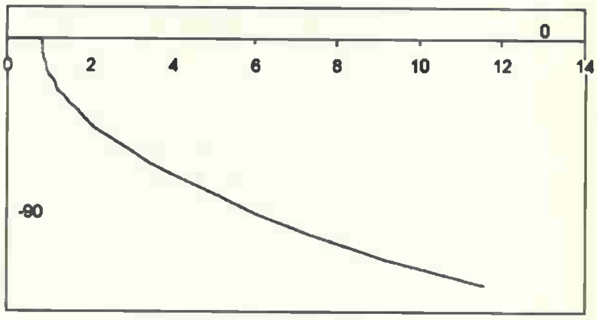


Fig. 3.

In praise of John Ellis

Once again I see a 'letter' relating to a published article that moans deconstructively about a personal presentation, without actually adding to anyone's understanding. I don't know either of these gentlemen, but in *EW* June 03, Kevin Aylward has taken words out of their original context and not even acknowledged that the original author had a name.

John Ellis, B.Sc, Ph.D, in his 'Audio power amplifier frequency compensation' article, clearly stated measurements relating to the differential input base potential in an amplifier being increased from 2mV to 25mV due solely to a VAS collector connected Miller capacitor. (This was not voltage at the Miller capacitor itself!) The greater the input stage voltage differential that is caused by Miller capacitor current, then the greater will be the distortion introduced by the base-emitter characteristics of that first stage. Also, due to the current flowing through the Miller capacitor increasing with frequency and amplitude, the input stage errors also increase with frequency and amplitude, whilst that same dominant pole capacitor simultaneously reduces nfb loop

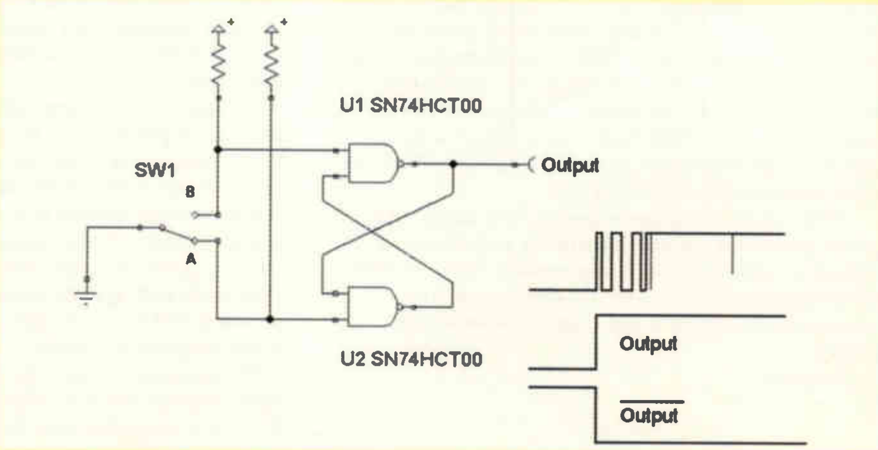
Modern Impedance measurement and de-bounce

In response to the letter from Mr. AJ Munday in *EW* April 2003, the FFT approach replaces the phase sensitive detector and associated reference stepped sine wave and phase shifting logic. This functionality is needed to extract the in-phase and quadrature components of the both the unknown voltage (represented in my article as Eu) and the voltage signal from the current measuring guard circuit represented as Es. The stimulus, or test frequency must not only be the same frequency for Eu and Es, but also remain constant throughout the whole measurement sequence. Normally Eu and Es will be of different amplitude and phase but the same frequency, hence the need for two measurements whether carried out using the PSD or FFT approach. The advantage of the FFT approach apart from higher noise rejection, was the potential to measure simultaneously the fundamental and also harmonic impedance's. One possible use for this could be production testing of TV line output transformers which I understand are tuned to the third harmonic of the TV line frequency in order to distort the scan current into the required S-shaped response to achieve linearity at the CRT face.

Also in the same issue Mr Yong's de-bounce ideas appear to 'go around the houses'. His idea is more complex and less efficient than the simple two-gate latch approach used throughout electronics. This circuit does not rely on RC delays and gives a clean edge coincident with the first edge of the switch 'rattle' and is also independent of the length of the mechanical burst.

See the following circuit and waveforms. The latch is initially set at power up by the original switch position. On a key press the latch changes state as soon as the switch contact momentarily opens at A. By the time the switch pole is contacting at B, the latch has already set and locks out any further mechanical bounce. Simple and efficient. Although keys can be de-bounced simply, in software using a loop with a delay, this circuit is still used to avoid tying up processor time, particularly for simple non-multitasking microprocessor systems.

Alan Bate MIEE
Bradford
West Yorkshire
UK



error correction capabilities at the higher frequencies.

As for 'technicalities', I cannot see anything wrong with the published open and closed loop simulations, so maybe Mr Aylward would care to state exactly what he thinks is unclear. At the same time could he please explain how he knows a Miller capacitor to be essential for stabilising an audio amplifier. Does he not see the photographed differential input stage spikes of fig.10a, which show exactly how the considerable delaying effect of a VAS collector connected capacitor causes the nfb loop to induce input stage non-linearity, before that VAS stage can itself complete nfb loop induced correction? And of course increasing the amount of nfb cannot reduce the effect of the Miller capacitor upon the input stage either, for the extra closed loop gain degeneration will merely lead to an increase in the amplitude of the error spikes. The PLIL distortion figures quoted are negligible compared to such spiky errors; errors that would not have been measurable on a THD distortion test set!!!!!

Far too many 'writers' have read 'text book' explanations as to how a dominant pole capacitor can control an amplifier, and then they have assumed that a Miller capacitor can do the same job in audio circuitry without investigating. The Miller capacitor so commonly fitted is then connected to the non-linearly acting output stage bases and resistors, not to an output node, which means that the capacitor waveform is no longer in phase with the input, and due to output device delays that vary with load, not in phase with the nfb loop output node either. The capacitor slows the amplifier down, and complex small signal stage errors increase when dynamic loudspeakers further load the output stage. Yes the amplifier is stable, but its high amplitude transparency is impaired, and no amount of nfb can improve it. It would be interesting to know if the 100V/µS amplifier mentioned by Mr. Aylward used a sole Miller capacitor C.dom, or a more complex stabilizing network.

Congratulations Mr. Ellis. You have imaged error effects that some writers fail to consider when studying audio power amplifier design. You have also discussed an alternative method for assuring amplifier stability. Maybe those who have yet to understand the significance of this topic should be less quick with their criticisms, and others their grumbles about the audio content of the magazine, which is always novel.

Graham Maynard
Newtownabbey
Northern Ireland
UK

Robots

I would just like to say that the May 2002 article "Quickie - the inside story" put a few credits into my subscription renewal pot. Good article but I did feel some sympathy for the less technically enlightened entries to the Techno Games. However, now the facts are published the field is levelled for all to follow, provided the school science budget co-ordinators are sympathetic to the cause.

My interest in this article was also partly due to the work I did on matching a cycle dynamo to the lights and a NICAD charging circuit using switching technology. The results of this were published in the Dec 1994 *EW+WW* Circuit Ideas, however the descriptive text translation was not entirely accurate, the circuit works at all normal cycling speeds not from walking speed to 15Mph as published! It is also worth pointing out that an electronics publication that has now disappeared from the shelves rejected the dynamo article with a single slip of paper "Does not work" This despite me providing a working prototype and documentary evidence that it did work. Thank you to your predecessors for publishing this.

Returning to school science lessons, I was dismayed to read this week that some schools are having to eliminate parts of the practical experiment side of the curriculum, this being due to class discipline having deteriorated to a point where it is impractical and dangerous to allow students to participate.

Pete Fry
Southampton
UK

Student knowledge and EMC

Recent editorial and letter comments about the lack of fundamental knowledge or mental calculations exhibited by some young graduates is not new. It existed more than 30 years ago when I was responsible for managing and recruiting engineers for our 25 strong field sales force.

To ascertain the ability of new recruits to think while standing, I found a simple circuit problem most revealing. It can easily be solved mentally in a couple of minutes, without benefit of calculators, simulators etc, however a pencil and paper does help. The question is this 'If all resistors shown have a value of 1 Ohm, what is the resistance between the two marked points ?' (See fig 1).

I claim no originality for this exercise, I first saw it I think in 'Smitty's Workshop' in Television or Electronics magazines sometime in the mid sixties.

I've also a few comments regarding EMC. Having been deeply involved with EMC filters ever since the first crewed Apollo flights, I read the various comments which resulted from the Catt article, with more than a passing interest. Obviously design stage attention to EMC problems must vary according to the cost and physical size of the equipment concerned.

When physical size and weight are far more important than cost, often one is left with no alternative other than to 'design in' EMC suppression as a 'bolt

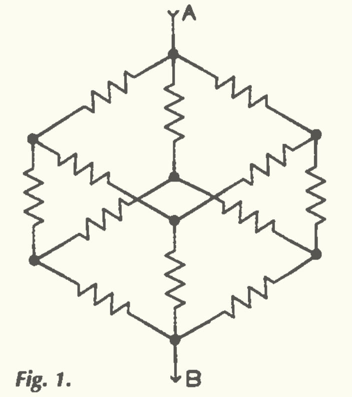


Fig. 1.

on afterthought', depending on the results of EMC tests. For example, domestic washing machines for the past 30 years have always included custom designed EMC filter solutions, introduced at a very early part of the design phase.

In contrast I still have vivid recollections of problems surrounding a military helicopter 28 volt DC de-icing motor. In tracking down that problem I destroyed the inputs of two quite expensive storage scopes before finding a 600 volt spike which occurred quite at random. Needless to say space and weight were crucial, cost of minor interest.

It is possible much of the myth surrounding EMC filters results from misunderstanding how a filter works. A 50dB attenuator for example, is simple to understand, in effect just a simple resistive network which dissipates energy as heat. An EMC filter in contrast, while it may still produce 50dB attenuation, dissipates almost no energy. It cannot because it contains no resistive element other than the tiny loss components of its capacitors and inductors. A filter attenuates simply because it reflects back to the noise source energy which does not pass through the filter.

This is fundamental to the working of all conventional EMC filters, yet on almost every occasion in past years during discussion with design engineers, this reflection was to them a new topic. This reflected energy can result in aggravating the very problem one is seeking to solve. Interested readers may wish to look up an old article, 'Understanding EMI filters' EW May 1996, which explained these points in more detail.

Cyril Bateman
Acle
Norfolk
UK

Dinosaurs

Ivor Catt's article "Dinosaur Computers" in the June issue of *EW* raises the question of multiple processor systems, and the failure by companies to exploit this technology. I recall that in the 1980's, Inmos marketed a system known as a

Transputer, which, if memory serves, was a parallel processing system. As far as I am aware, it has disappeared without trace, (along with Inmos?).

As far as his complaints against management generally, with their desire to keep power in their own reins and to withhold it from the technocracy, there is, no doubt truth in this, but I think it fair to say that this is a fault of human nature in general rather than one of management in particular. It is also true to say that whilst some engineers are happy to make the transition to management, many (including me and, I suspect, Mr. Catt), prefer to remain on the technical side of the fence, because by temperament and training, we are happier dealing with a world bounded by formulae, numbers and established principles, rather than the untidy one of company politics, changing situations, and fickle people. It is therefore perhaps not surprising that engineering is poorly represented at board level and that the type of people who prefer this activity are those perhaps from more of an arts or humanities background rather than a science or engineering one. I am not defending the situation, merely offering a possible explanation for it; like Mr. Catt, I find it deplorable that a company which was originally established to pursue an aspect of technology should subsequently run away from it, (often handsomely rewarding the defecting directors for their failure).

Changing subject, it is obvious from the letters in *EW* that many of the readers (and contributors) are, like me, in mid-life, having cut our teeth on electronics in the 1960's and 70's. In those days electronics hardware was much more accessible in the sense that it could be opened up, understood, modified and generally experimented with in a way that is impossible now. What is a young person who opens up a DVD player, computer or mobile phone supposed to make of, or do with, a multi-layer P.C.B. filled with surface mounted components? Where does he start? Perhaps our generation will be the last in which for so many of us, a boyhood hobby has turned into a fulfilling career. The new generation of electronics designers will be, perhaps, professional in the sense that their electronics education is wholly college or university acquired and their electronics endeavors are purely a 9 to 5 activity. Progress?

The recent series of articles on capacitors by Cyril Bateman, and LCR measurement by Alan Bate were excellent and just the sort of thing I want to read. I would also like to be able to learn in general terms about subjects such as, digital broadcasting, Bluetooth, DVD recording etc. if there are any potential contributors out there.

Finally, there is no excuse for some of the rather sloppy English which has appeared in *EW* recently; for instance, Ivor Catt's article was subtitled 'Personnel view', which should surely have read 'Personal view'.

R. Harris.
Brislington,
Bristol
UK

Thankyou for your suggestions. Quite how we got 'Personnel' and 'Personal' mixed up is beyond me – however I must admit to being too reliant on Bill Gates' excellent spell checker in Word – which can lull one into a false sense of security. – Ed.

Class AB, VAS & C Dom

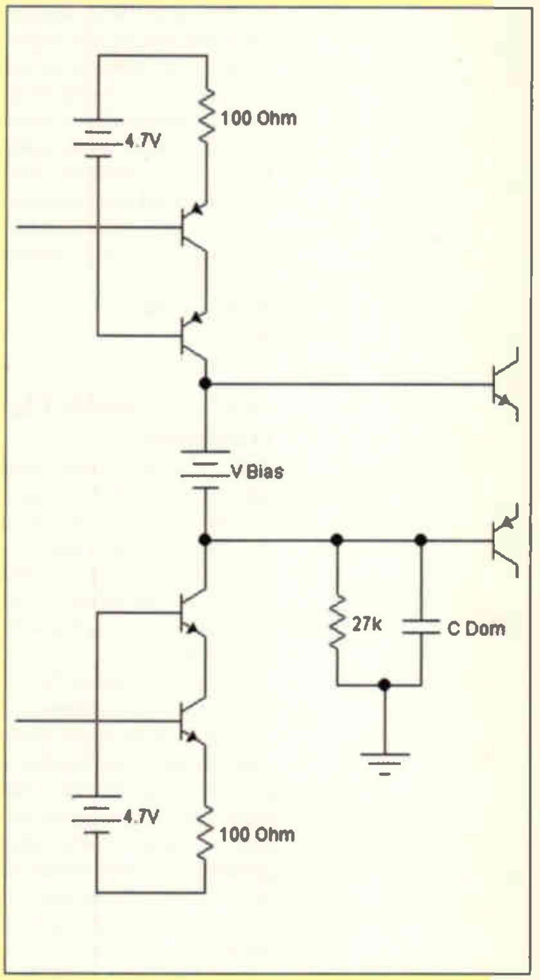
Class AB has had a bad press over the past few years, partly because of 'Gm Doubling'. Put simply, Gm Doubling has the effect of halving the open loop output impedance of the amplifier whilst both output devices are on during the 'A' phase at crossover. In closed loop, this means that at the output of the Voltage Amplifier Stage (VAS) the voltage gain and therefore the rate of change is modified by, for example 3% with emitter resistors of 0.25Ω and a load of 4Ω. The Quad 404 'Current Dumping Amplifier' on the other hand, modifies this rate by many fold! and that sounded O.K. didn't it?

I personally have never liked the 'sound' of a grounded common emitter VAS, preferring instead a much more linear amplifier consisting of a symmetrical cascode stage with a relatively large emitter resistor (100Ω) and C Dom connected from the collectors to ground, NOT in the 'Miller' configuration to the bases (see Fig. 1).

Perhaps using a non-linear VAS to compensate for non-linearity in the output stage, leads to unnecessary Intermodulation Distortion? I know that this configuration is more complex, however when good transistors like the FMMT493/593 only cost about 10p, I think it is well worth it given the smoother and more 'open' sound of amplifiers using this configuration.

My point: I have successfully designed and built several 'pot-less' class AB amplifiers in recent years, and realized that the home designer can build very good amps without the need for very expensive distortion analysis equipment for setting the pot required in class B amps. Class AB also has the advantage that it is less temperature sensitive than it's class B counterparts, especially during thermal transients caused by peak current demands.

J. R. Charlesworth
Wombleton York UK



Kernels

I have read Ivor Catt's fascinating and vicious article about his work over the last 3 decades to break from the 'von Neuman Bottleneck'. In the past, DDP arrays have been tried but SDP systems are the 'tried n' true' way, especially after the PC revolution of the 1980's (blast them decadent 80's). One of the problems is coordinating the efforts of all those parallel processors on to single task. Organizing the actions of a single CPU is far simpler than tasking many. A 'kernel' used to be defined as the minimal utilities of a microprocessor based computer (cpu, ram, op-rom, dma, pic).

Chad Castagana
Woodland Hills
California
USA

Praise indeed

I have been following the debate in your letters pages regarding the content of *Electronics World* for some time, and I find myself in broad agreement with many readers who lamented the past lack of informative and interesting articles published. I find myself in good company with the majority of people who decided to stick with *EW* and wait for the old *Wireless World* (though I understand that it is no longer permissible to call it that). I am sure that those of us who have carried on with our subscriptions agree that your publication is improving monthly. Congratulations.

I am personally most pleased at the return of the redoubtable Ivor Catt, whose recent piece on EMC was a godsend. Those who criticise him for his lack of presentational skills and diplomacy are missing the point entirely. Have they actually read anything on Associative Memory, the Catt Spiral, or Kernel Machine? This innovative and creative engineer should be awarded a regular column, and given free rein to air his refreshing views about whatever subject he chooses.

Keith W. Saxon,
St. Helens,
Merseyside.

EMC - A Fatally Flawed Discipline.

Numerous letters commenting on my article in March 2003 *EW* have been published, and I have written lengthy replies which can be found at www.ivorcatt.com/31.htm. However, shortage of space in *Electronics World* causes me to write the following shorter reply for publication.

In May 2003, Graham Elvis argues that EMC regulations are primarily to drive out competition from outside Europe. This is similar to my feeling that they serve primarily to suppress small company competition. He also points out that the EMC community is indifferent to a major source of interference which occurs only occasionally; harmless enough in the days of analogue systems but disastrous for today's digital systems.

In the same issue of *EW*, "Name and address supplied" puts his finger on further key issues. "For each type of product there is a committee of the great and the good from government departments, interested companies and 'EMC Magicians'". Only big "interested companies" could afford the time, and would not object to a bureaucratic way to drive out their small competitors, in Europe and abroad. Like Elvis, this writer regards EMC regulations as part of a dirty trade war by Brussels.

I would like to give examples from the past. In 1962, Ferranti's Head of the Drawing Office, who had never done any logic design and never would, was the man adjudged important enough to go on the committee which would devise the British Standard for logic diagrams. He was so important that he did not consult any of us, who were busy actually doing logic design and drawing logic diagrams. The result was a ridiculous British Standard which meant that all our logic diagrams had to be redrawn three times larger, so increasing his empire of draughtsmen. This ridiculous British Standard for logic diagrams soon disappeared without trace. There are limits to British patriotism.

One of the minor issues at the core of the matter was whether a logic diagram should emphasise the circuit or the logic. De Morgan's Theorem tells us that the same circuit can do an AND function or an OR function. The problem is, should the logic diagram tell us how the logic designer viewed the role of the particular circuit? The British Standard got it wrong, while US MIL STD got it right by siding with the logic designer. Regardless of any other committees, US MIL STD 806B became the de facto world standard, including Britain.

In June, Ian Darney also criticised the EMC community. However, he was mistaken when he proceeded to criticise me. I did exactly what he said I should have done at West Herts College. I designed a revolutionary mains filter, which got over the problem that conventional mains filters generate too much earth leakage. The revolutionary circuit was drawn in my March article.

Eima Burdd, yet another joke name like the many that buried me in Wireless World in the 1980s, wrote an incredibly long riposte to my article, giving me the Bird, ending by writing that ".... Mr. Catt is miauwing up the wrong branch", in case we would not otherwise grasp the joke, which I did not at first. More of the animal names used in *Wireless World* can be found at www.ivorcatt.com/31.htm

Michael O'Beirne began by saying he was not a professional engineer, but then proceeded to write at length! David Bridgen, commenting on my torpedo-proof line printer, remembered a bomb blast-proof unit which plugged into a man-pack. John Blythe spoke up for GEC, ".... a fairly stable, profitable company for many years ....", and called Mr. Catt incoherent.

In sharp contrast, in July, Roger Wilkins wrote; "[Catt] still retains his deep technical understanding ....", and Ian Johnson wrote "I like [Catt's] .... in depth knowledge and his ability to shrug his shoulders when confronted by the lesser brains of people who should know better. I read the article on EMC and agreed with every word, having also worked for the great GEC empire ...." So was pro-GEC Blythe (*EW* May) ever employed by GEC?

Finally, Leslie Green wrote a lengthy letter, in which he writes; "Good EMC textbooks always give guidance on .... correct design procedures to minimise both emission and immunity problems." As the author of *EW* articles, Green has stature. (He also figures on my new website.) Please would he give the titles of "Good EMC textbooks", and we can go from there?

In August, Michael Turner wrote on ".... Catt's wearisome and paranoid rant ....". He seems to think that, when I criticise today's EMC standards, it follows that I am opposed to having any standards. I suppose that if I criticised an accident black spot, it would follow that I thought we would be better off with no roads at all. Kenneth Gundry went deeper. He says that academics, not practising engineers, devised them. His has the interesting idea that susceptibility to interference should not be in Standards, but should be left to the market. I think I agree. He also says that I am wrong in that EMC regulation now involves entering inside the unit involved. I would repeat his final remark; ".... The EMC standards are seriously flawed, but [they have] imposed a needed discipline on designers ...."

Chris Griffiths says the expensive standards have driven new products out of the market. Michael Edinger write that Catt ".... Sums up what many engineers feel about the EMC legislation and practice. ...."

What is appalling it that, after all this copy, my last paragraph in March has been comprehensively ignored; "I need assistance to winkle out the technocrats responsible for the present standards, to require them to defend the test standards, and to be accountable for them....."

The reason for my involvement in the matter today is that these committees have the temerity to make it a criminal offence if we ignore their standards. The failure of our industry to organise the setting of standards competently means they have to be ignored and some of us have to be jailed, unless I gain enough support from you to identify and go after those who try to defend the EMC standards. "Name and address supplied" writes; ".... The prosecution only has to prove that the law has been broken ....". However, there are

Help Wanted

■ Complete set of boards, components and article reprints for the *WW* 1965 'High Quality Audio Amp' by J. Dinsdale. The copies also include all follow-up letters and modifications. These were discovered in a loft during a house clearance by a contributor. Cost will be about £15 to cover p&p. If interested please contact the editor, by mail or email, details on page 3.

■ Does anybody have a schematic for a Grundig TK 120? If so, please contact C. Holwill, 275 Laburnum Grove, North End, Portsmouth, Hants, UK.

■ A deceased reader has left a large quantity of *WW* and *Practical Wireless* magazines dating back to 1962. There are also a small quantity of *Radio Constructor*, *BRTR Service Engineer* and the *RSGB Bulletin*. If interested please contact the editor, by mail or email, details on page 3.

■ Does anybody have remember some years ago, a couple of articles in *EW/WW* magazine that dealt with electronic warfare during WWII? In subsequent issues each part of the sequel focused on another point, e.g. 'radar and countermeasures', 'enigma and breaking its code', and so forth. In my opinion, all the articles had been taken from a single book, but I cannot remember its title; can anyone help me? Wolf-Dietrich Molzow, c/o Fraunhofer-Institut für Nachrichtentechnik, Heinrich-Hertz-Institut, Einsteinufer 37, 10587 Berlin. Fon: +493031002678, Fax +493031002602.

many ways to wipe out the power of a law based on fantasy and ignorance, if I get your support.

Do all of the readership of *EW* think I can do that on my own? Sorry, I won't. I need the weight of aggrieved companies and other institutions behind me before I would be willing to take up the cudgels. If you want to see what Catt achieves on his own against decadent institutions, do a Google search for "Pepper FRS". On his own, "A cat may look at a king," but if he is alone, the Queen will merely say; "Off with his head!" Nobody fears a disembodied cat. If our profession does not care enough, this problem will continue, and even worsen. What a pity the IEE is inert.

Ivor Catt
St. Albans
Hertfordshire
UK

More demise

Ray Lee BSc. Wrote to you about the demise of the electronics press. I have noted this same falling away of once famous titles, the main problem has been the ease with which people can now purchase well made items at low cost. With more and more components becoming hard to track down or just completely obsolete. Even obtaining parts to repair manufactured equipment is now a major problem. Projects that once were easily put together now have to be looked at very carefully before any ordering takes place. Even if all can be found at a suitable cost, there is the matter of what to put it all in?

Often this is where it all falls apart because the case can cost several times the total of the other components. Then there are the switches, knobs, sockets, etc. to be thought about. How many people have the machinery to produce metal enclosures? Then if all this is possible is the finished item going to prove useful? After all you only need so many amplifiers, power supplies and digital add-ons.

A good publication should be a forum where like-minded people can exchange ideas and, learn from each others experience. The well-presented article helps those who need some inspiration to achieve their ambition to complete a project. *Electronics World* has always been a publication for professionals and those studying electronics. I used to think it above my status, with many articles too complex for my experience at that time.

I feel sorry for you having to cater for a very diverse readership. We must frustrate you with our comments. I used to mainly read *ETI Electronics Today International* and other hobby publications now gone. Too many magazines were trying to compete for a rather small readership. Many shops and mail order companies have gone, also much government surplus had since been used up. Fewer manufacturers exist to supply surplus, to companies like Greenweld and Mainline surplus to name but two.

Fewer people advertise in the few publications now available. Maplin are the main supplier to the hobbyist to purchase from, the only thing is that they to continue to cut the variety of components available. Manufacturers trim back on their output as no one wants to keep stocks of any but the most commonly used lines. If you're not a manufacturer, ordering by the several thousand, it is impossible to purchase special parts at a reasonable cost if at all.More surface mounted components are used that do not lend themselves to home use. Even ten years ago it was plain to see the writing was on the wall for all to read. Too much reliance on all things digital, computer, and PIC, has made many decide to give up on electronics. People need to keep spending more to do less. This is because many digital projects are very task specific, with a lot of software problems attached. The future is uncertain as to where amateur electronics will be in the next few years.

I hope *EW* will keep going despite a diminishing readership.

Ian Johnson.
Kidderminster
Worcestershire
UK

We'll keep trying as long as you guys keep reading. – Ed.

Enticing

Ray Lee asks "whether an electronics magazine such as *EW* can find enough to sustain it" to which many subscribers might answer "no!" for reasons that he and others have outlined. Nigel mentioned circulation, upon which advertising revenue is very much dependent, and vice versa!

The May issue of *EW* offers a CD (Pandora's Drums) for £12, which may be popular, but many journals and tabloids have these on the front covers, free of charge! My wife's built up quite a collection already including two by Andrea Bocelli, at £4 a time including an all-colour 100 page magazine (Classic FM). If some publisher offers Bob Dylan or Kate Bush CDs, well, I'm sorry but I've just gotta have 'em, even if they're on a computer journal. Gardening magazines have seeds and bulbs on the cover at a price less than they would cost if purchased separately. So popular are the flowers that one cereal producer has increased its range of freebies to include a choice of herbs along with the usual Goeditia, Nigella, and Eschscholzia californica. Can you imagine future issues of *EW* with seeds on the cover? No, of course not! Manuals, chips and various electronic items including CDs have been tried, with what success, I'm not sure. Solar panels, AAA rechargeables or wheels for *Robot Wars* might be popular with school kids, although they're heavily overloaded with course work which leaves little time for the outside activities like we had back in the 50s converting war surplus equipment to amateur bands. *EW* readers may have some better ideas for attracting young blood, but for the moment, music CDs seem to be the best bet!

Tony Callegari BSc.
G3OMD
Much Hadham
Hertfordshire
UK

Readers will be interested to know that we are working on 'freebies' for EW and past results have been encouraging. As to how to attract the younger reader – we are devising a new reader survey – that will also target some non-reader groups to get their feedback. I will bear Kate Bush in mind when thinking of material for our next cover CD. But given your call sign – would not 'Orchestral Manoeuvres in the Dark' be more appropriate? – Ed.

Big Reductions

With reference to the letter from A G Callegari the editorial comment after this letter that use of word processing and email helps to avoid transcription errors may be true - but this poor chap's obviously only allowed to use crayon.

What is this incoherent nonsense doing in the pages of a respectable journal? The third paragraph (beginning "It's interesting to note...") in particular reads as if he had forgotten to take his medication that day. Please reserve your valuable space for rational contributors.

(I could do without Ivor Catt as well... His diatribes are vaguely amusing, but convey far more information about his personal grudges than anything in the way of useful or reliable facts. I agree entirely with Orde Solomons: the "Catt Anomaly" is an artefact of Catt's own psychology and failure of understanding, and has no objective existence.)

Pigeon

Hot valves

Further to the interesting article on German Warfare receivers in *EW* August, I was reminded of the remarkable valves of the Third Reich by Ostar Ganz which had 230V heaters. I experienced no trouble with heater/cathode leakage, unlike some later CRTs. The insulation withstood the 326V peak potential difference without complaint. They used a 7-pin holder, C07, with an earthed plate between heater, cathode and other elecrtrode pins to avoid hum pick-up. With no mains transformer, the result was a very light and simple AC/DC chassis.

Graham Cox
Bexhill-on-sea
East Sussex
UK

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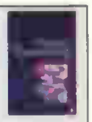

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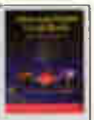

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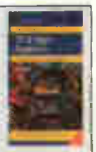

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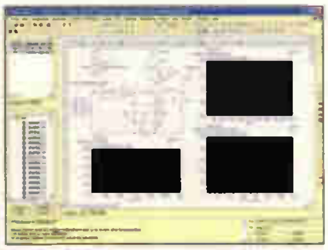

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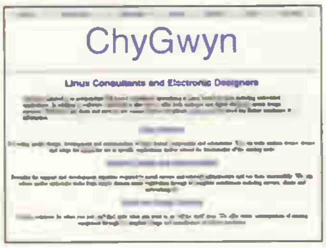

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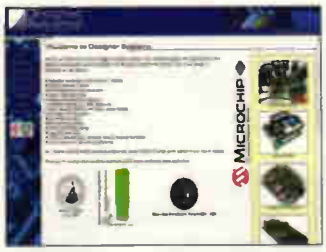

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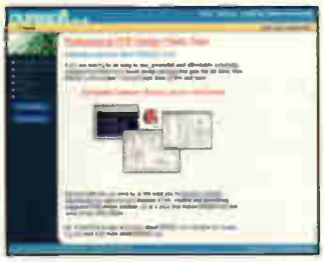

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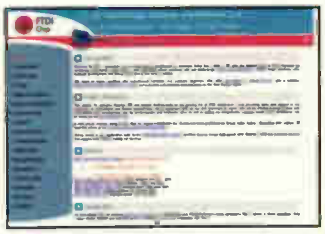

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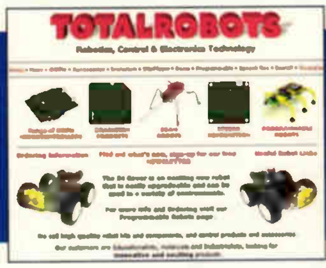

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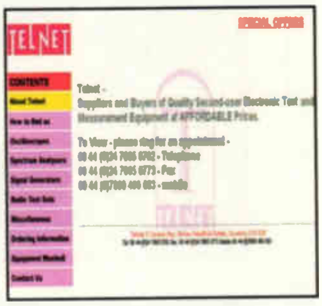

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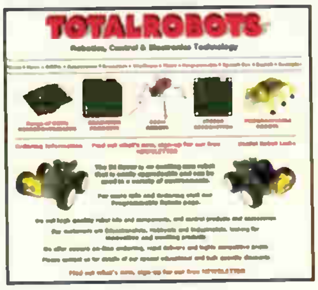

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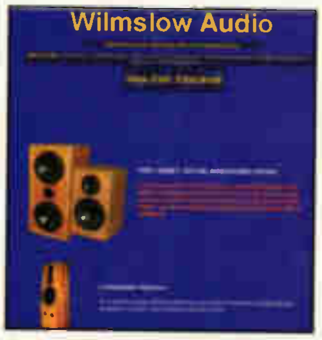

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