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# ELECTRONICS WORLD

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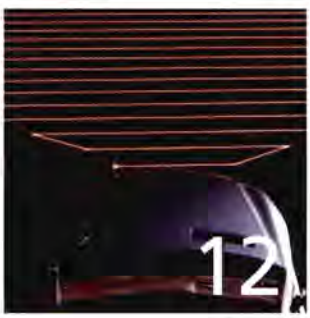
MICROWAVE DICKE RECEIVER

ALSO IN THIS ISSUE: INSIGHT @ CIRCUIT IDEAS @ UKDL


## REGULARS





## FEATURES

ELECTRONICS WORLD

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# WHAT HYPE TO BELIEVE

"Recession, what recession?" asks Malcolm Penn, the head honcho at the market research house Future Horizons based in Kent, the UK. He says there are grumbling financial and housing troubles in the UK and the US, but this is hardly a reflection of what other nations are going through. In 2008 India's GDP is expected to grow 8.4%, Russia's 6.5% and China's 10%. Indeed, in comparison, in the UK and the US GDP will only grow by 2.3% and 1.9% respectively. So for once, the phrase 'global economy' truly merits its title, which is a good thing in itself.

But, as we all know, the global economy does have an impact on the semiconductor industry. The relationship is not as linearly reciprocal as the industry would like to have it, however. For example, there have been instances where world GPD has been on a downward spiral, whilst the semiconductor industry has been enjoying a positive peak or two, and vice versa. Nevertheless, a continuing strong economy is vital to the chip market, and if the economy does take a plunge, eventually and rather quickly, the semiconductor industry will suffer similar effects.

According to Malcolm Penn, there's no way of telling precisely what the economy might do, or indeed how well the semiconductor industry could be doing. He says that nowadays there isn't a single (semiconductor) company that could act as a barometer to what the industry is doing, like, say, Motorola did once upon a time. Penn says that there's no "sanity check" of that kind any more.

His predictions for 2008 are rather optimistic however. The industry is likely to grow by 12% (one of the highest predictions around; the average is around 9%), with capital and semiconductor equipment spending cut back this year, but a well paved way for a good 2009. At present, even though the economy seems to be suffering in some geographical regions (which traditionally we have been relying on to tell the state of the world), for the semiconductor industry this is not seen as a 'recession type' environment but a 'structural type' one, which is deemed good.

So, expectations are that there won't be a global recession, apart from in the UK and the US suffering due to their recent woes. And, if worries of 'global recession' are not to be "whipped up" and out of context due to media-generated hype (which has been known to create self-fulfilling prophecies), if there's a recession, analysts expect it to be a short-lived one, and then - yet again - we will be back on our merry way.

**Svetlana Josifovska**
**Editor**


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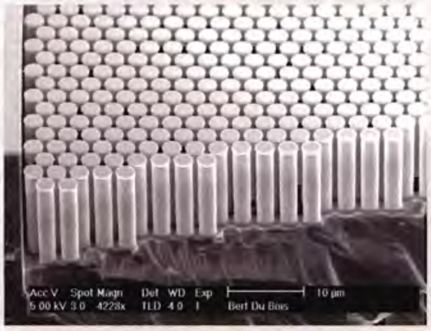
# SUB-MICRON MACHINING FORMS HIGH PERFORMANCE ON-WAFER CHROMATOGRAPH




*Cylindrical pillars in the separation channel, etched with DRIE, using silicon oxide as the hard mask*

*On-wafer liquid-phase chromatograph*

An on-wafer liquid phase chromatograph built by sub-micron machining provides a five to ten-fold increase in the speed of analysis, combined with an improved separation capacity, relative to the current state of the art macroscopic chromatographs. An additional advantage is that the separation obtained is not degraded at increased velocities of sample transport, unlike that with macroscopic chromatographs.

The device can be used to separate and identify molecules, such as proteins in biochemistry.

The chromatograph has 56 separation channels with a length of 40mm, a width of 50-150µm and a depth of 5-18µm. The channels are packed with vertical micro-cylinders or pillars, each 1-5µm thick and separated by gaps of 0.1-1.0µm. All of the pillars in one channel have an identical shape, size and a uniform spacing from the other pillars.

The chromatograph was implemented on a 200mm silicon wafer. A layer of silicon dioxide was first deposited on the wafer, on which the sub-micron structures of the chromatograph were then patterned and etched. Using the silicon dioxide layer as a hard mask, the separation channels and the pillars were etched by Deep Reactive Ion Etching (DRIE). The separation channels were then connected through wider interconnecting supply channels. A 200mm glass wafer was bonded to the silicon wafer, serving as a roof to close off the separation channels. Finally, access holes were etched through the back of the silicon wafer.

The performance of the chromatograph was tested by injecting a fluid with tracer molecules in the chromatograph and then following the velocity and width of the resulting tracer band.

This sub-micro chromatograph validates fluid dynamic computations that predict that injecting molecules though a submicron maze of perfectly ordered structures will considerably increase the separation speed of liquid phase chromatography.

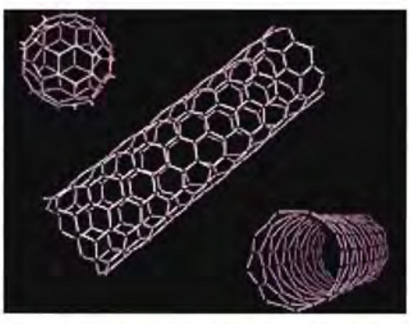
This collaborative work was carried out by the Inter-University Microelectronics Centre, Leuven, Belgium (IMEC) and the Vrije Universiteit Brussel (VUB).

# BLACKER THAN BLACK, CREATED BY US SCIENTISTS

Scientists at a US laboratory have used carbon nanotubes to create the darkest man-made material, which they claim is the closest to the "ideal black material" that absorbs all wavelengths but reflects none.

Researchers at Rensselaer Polytechnic Institute "rolled" the atom-thick nanotube sheets into cylinders.

"The periodic nanotube structures make an ideal candidate for creating superdark materials, because it allows one to tailor light absorption by controlling the dimensions and periodicities of nanotubes in the structure," said Houston-based Dr Pulickel Ajayan, whose team built an array of vertically aligned, low-density carbon nanotubes.



*Carbon nanotubes are capable of being "rolled" into structures*

The discovery is expected to have applications in the fields of electronics and solar energy, such as in creating efficient solar cells and solar panels, but also in areas where light needs to be harvested.

# FULL CELL USES HYDROGEN TO POWER MINIBUS

A prototype minibus developed by a team of researchers at the University of Glamorgan in Wales was the only passenger vehicle larger than an ordinary car to be exhibited at the tenth Grove Fuel Cell Symposium in London. This event is the platform that shows the progress being made in the fuel cell industry in the UK, together with the many advances in the applications of fuel cell technology.

The featured minibus uses hydrogen as its fuel and therefore emits only water vapour into the atmosphere. As such it completely eliminates the non-environmentally-friendly gases produced by fuel combustion in conventional vehicles. If this technology is eventually adopted, it would result in future vehicles being refuelled at hydrogen filling stations.

# ELECTRONIC DEVICES ASSIST PATIENTS WITH PARALYSED LIMBS

New Functional Electrical Stimulation (FES) devices have been developed by Bioness Inc in Santa Clarita, California, and its R&D centre in Israel. The technology can help patients who have suffered neurological damage to regain much of their lost mobility and hence their independence.

In one system, a soft polymer prosthesis can be fitted over the hand and forearm of the patient. Five electrodes embedded in the prosthesis provide a modest electrical stimulating charge that causes the muscles in the hand to perform a desired sequence of movements. This prosthesis is used in conjunction with a control unit little larger than a hand that can be set by a trained patient to exercise the hand or grasp objects. The system is said to not only improve the functional use of the hand, but also to reduce the chance of complications associated with central nervous systems (CNS) problems, including the atrophy of muscles as a result of their disuse, spasticity, painful contraction and oedema.

Another type of FES neuro-prosthesis has been designed to be worn on the lower leg and foot, so that it can deliver electrical impulses to the common peroneal nerve that controls certain foot movements. It can help those with upper motor neuron injuries that can prevent a patient from lifting his foot or his toes when walking. This device has a wireless FES system incorporating a sensor to detect the type of surface on which the patient is walking and make appropriate adjustments for it. It is said to prevent or retard muscle atrophy due to disuse, stimulate muscle re-education, increase blood flow and maintain the range of motion of joints.

*A new Functional Electrical Stimulation (FES) device can help patients who have suffered neurological damage to regain much of their lost mobility*

The RF link provides the clinician with an ability to visually analyse and record the walking of the patient during the initial setup and simultaneously to make adjustments in real time, so as to fine tune the walking. A mean increase in walking speed of 16.2 % and an improved symmetry index of 32.2% is reported.

# ROLLABLE DISPLAYS VOLUME PRODUCTION

Netherlands-based Polymer Vision has developed a rollable display technology that enables mobile devices to incorporate a display larger than the device itself. The company's first commercial product is the Readius e-reader with a 5-inch diagonal screen, produced by its recently acquired manufacturing facility, Polymer Vision (UK) Ltd in Southampton, UK.

Polymer Vision uses organic transistors for an active-matrix TFT to address an E-Ink display system, which can therefore be processed at low temperature. The first batch of the rollable displays produced has delivered functional displays and from last December onwards volumes are being ramped up to meet growing customer demand.

# IN BRIEF

**Researchers at MIT and Texas Instruments (TI) developed a new chip design for portable electronics that can be up to ten times more energy-efficient than present technology. The design could lead to various portable devices lasting far longer when running from a battery.**
**The key to the improvement in energy efficiency was to find ways of making the circuits on the chip work at a voltage level much lower than usual. While most current chips operate at around 1V, the new design works at just 0.3V. In the design there's a built-in DC-to-DC converter, which reduces the voltage to the lower level. This is a lot more efficient than having the converter as a separate component.**

**The European Nanoelectronics Initiative Advisory Council (ENIAC) will have around €3bn at its disposal for nanoelectronics R&D in Europe from 2008 to 2013. One of the key areas of focus identified by ENIAC will be low-cost communication chips. According to ABI Research, ultra-low cost and entry-phones had a market share of roughly 16% in 2007. This share should rise to nearly 28% by 2010.**
**ENIAC believes that the broad experience of European companies and universities from the semiconductor and nanoelectronics sectors can focus successfully on increasing the communicative performance of mobile devices while at the same time lowering the cost considerably.**

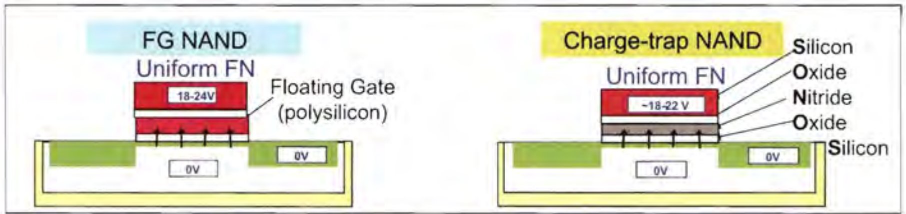
**DiBcom has launched what it claims is the world's first DVB-SH (Digital Video Broadcasting from Satellite to Handhelds) receiver – the DIB29098. It is designed to complement DVB-H in higher frequency bands, such as S-band. It addresses the unique characteristics of the hybrid satellite/terrestrial mobile TV solutions for nationwide coverage on mobile phones, portable and vehicular devices.**
**The DIB29098 is the first component to feature Diversity-2 (support for dual antennas) in one single chip, which dramatically enhances receiver performances either in mobility or indoor coverage.**
**DVB-SH was approved as an open standard by the DVB Forum in February 2007.**

- A report from the National Microelectronics Institute (NMI) states that to be a successful UK semiconductor firm of the future, businesses should partner with others. Instigated by NMI to examine how firms are adapting to the effects of increasing globalisation and supply-chain transformation, the original research has produced a report which proposes and discusses reasons why some firms perform well while others don't, in spite of each having world-class semiconductor technologies. Strategic partnering or alliances became the report's key focus, seen as essential in helping firms improve commercial performance.
'Partnering the Future – Business Innovation in UK Microelectronics' is based on post-graduate research carried out during 2007.

- Some one million tonnes of electrical and electronic equipment are thrown each year in the UK alone, says a report by WE3 Recycled Ltd, a UK based consultancy. Many types of electrical equipment that finish up in landfill contain toxic metals such as cadmium and mercury. The newly amended EC Directive on Waste Electrical and Electronic Equipment (WEEE) came into force on January 1st 2008 and it requires such equipment to be minimised through re-use and recycling wherever possible.
The directive further makes producers responsible for financing the collection, treatment and recovery of waste electrical equipment, and obliges distributors to allow consumers to return their waste equipment free of charge.

- A major new parliamentary inquiry by the Innovation, Universities and Skills Select Committee focusing on the provision of engineering skills in the UK is currently underway.
A recent study by the Association for Consultancy and Engineering (ACE) states that the shortages are already severely affecting UK businesses. ACE's CEO Nelson Ogunshakin said: "Immediate action is needed if we are to solve the engineering skills crisis. Today, there are 20,000 unfilled vacancies in the consultancy and engineering sector alone."
According to ACE, the issues revolve around education and the lack of suitably qualified engineering graduates coming out of universities. The consultancy insists that waiving university fees and helping graduates find jobs easier will solve some of these skills shortages.

# EUROPEAN CONSORTIUM WILL DEVELOP 32NM MEMORY DEVICES



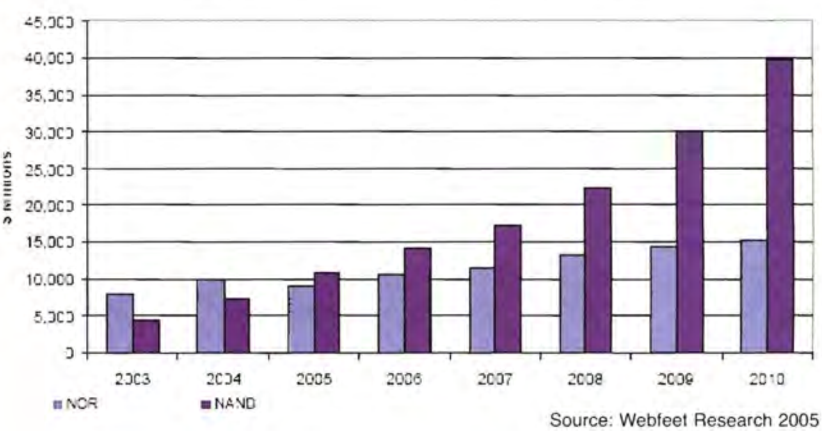

*The basic differences between floating-gate NAND and charge-trap NAND memories*

A three-year, pan-European project called GOSSAMER aims to develop enabling technology for the production of high density memories using 32nm-feature processes and beyond. This project, for which funding has already been approved, will investigate new architectures and materials for gigabyte non-volatile memory devices for mass storage NAND memories.

NAND memories is one of the fastest growing sectors of the semiconductor market, with sales expected to roughly double to some £20bn by 2010, driven by the increasing demands for portable devices that require larger memory capacity.

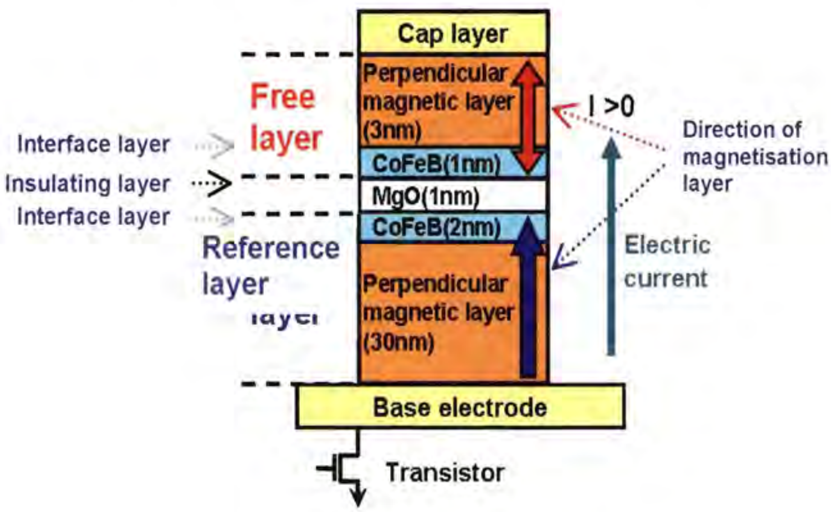
There is considerable doubt about the feasibility of using conventional flash memory technology as dimensions fall to less than 32nm, owing to capacitive coupling between cells, charge storage requirements and the reliability of the dielectrics employed. Strong gate and dielectric material innovations are needed so that charge trapping NAND can be considered as an alternative to floating gate devices with dimensions of less than 40nm. It is hoped to develop a 32nm technology by 2011 with improved isolation between high voltage lines followed by a 22nm technology by 2014.

The GOSSAMER project is being led by the two major European memory manufacturers STMicroelectronics and Qimonda, in collaboration with SME partners, research centres (such as IMEC and the Fraunhofer Institute) and a number of universities. The markets addressed will include cellular phones able to display rapidly moving pictures and solid state drives that are able to replace the conventional magnetic hard drives in portable computers.

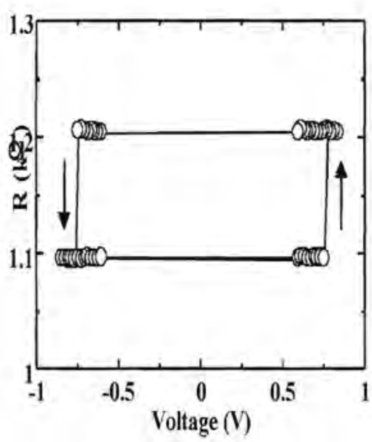



*NAND memories are one of the fastest growing sectors of the market*

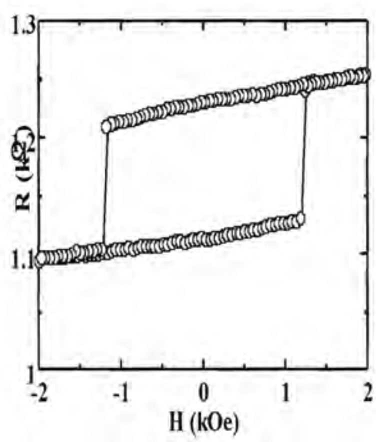
# NEW MRAM DEVICE OPENS THE WAY TO GIGA-BITS CAPACITY




*The MRAM cell structure. A material with perpendicular magnetic anisotropy, which is used for recording media and a type of cobalt-iron, is employed in the magnetic layer, with magnesium oxide in the insulating layer and cobalt-iron-boron in the interface layers*




*Operational results. The resistance-versus-voltage graph shows device resistance characteristics after voltage pulses are applied to perform the write operation. The switching between high and low resistive states is clearly seen at the voltage threshold in both the positive and negative directions*




*The resistance-versus-DC magnetic field graph shows device resistance characteristics when the magnetic field is applied perpendicular to layers. The high and low resistive states are clearly observed, and are produced by the magnetisation direction in the free layer with reference to the reference layer*

Japanese giant Toshiba has successfully fabricated an MRAM memory cell, using a novel perpendicular magnetic anisotropy magnetic-tunnel junction (MTJ), and verified its stable performance.

MRAM is a highly anticipated next-generation non-volatile semiconductor memory device that offers fast random write/access speeds, enhances endurance in operation with very low power consumption. MRAM can theoretically achieve high level integration as the memory cell structure is relatively simple.

In making its MRAM devices, Toshiba applied and proved the spin transfer switching and perpendicular magnetic anisotropy (PMA) technologies in a magnetic tunnel junction, which is a key component in the memory cell.

Spin transfer switching uses the properties of electron spin to invert magnetisation and writes data at very low power levels. It is widely regarded as a major candidate among next-generation principles for new memory devices. PMA aligns magnetisation in the magnetic layer perpendicularly, either upward or downward, rather than horizontally as in in-plane shape anisotropy layers. The technology is being increasingly used to enhance storage capacity in high-density hard disc drives (HDDs) as well as semiconductor memory devices. With PMA data write operation and magnetic switching can be achieved at a low energy level. Toshiba also overcame the hurdle of achieving the required precision in the interface process and significantly cutting write power consumption.

The MTJ is 0.13um in diameter and circular in shape. The magnetisation switching current is 3 x 106A/$cm^2$. The write performance pulse is from 30 through to 100ns.

The work was partly supported by grants from Japan's New Energy and Industrial Technology Development Organization (NEDO).

# AUTOMATIC VEHICLES RALLY TO SAFETY

## SENSORS AND VARIOUS OTHER ELECTRONICS ARE AT THE FOREFRONT OF CREATING NEW, SAFER AUTONOMOUS VEHICLES, SAYS **BRIAN DANCE**

Autonomous vehicles, sometimes known as automatic or robotic vehicles, can operate without any human driver. The speed and direction of movement of such vehicles is controlled by their internal microprocessors, which use complex signals from many types of sensor placed around each vehicle. These sensors can detect any obstruction, such as another vehicle or a pedestrian, and will need to be co-ordinated with traffic signals. If perfectly designed and correctly programmed, such systems may make it possible to prevent collisions of any type, at least in theory.

It will doubtless be a considerable time before such vehicles can be almost guaranteed to offer collision-free travel, but work already being conducted towards autonomous vehicle development is leading to important improvements in the safety of ordinary vehicles with human drivers. For example, improved sensor systems, including those using infra-red or radar to penetrate fog, rain and snow will provide drivers with much better visibility around their vehicles.

Some people believe that it will be possible to construct intelligent autonomous vehicles using systems that are programmed to ensure that accidents become almost impossible. However, one can only wonder if the designers of such vehicles will be able to ensure that they operate safely when the internal microprocessors they contain themselves crash. It has even been suggested that, if such a vehicle that is guaranteed to be safe, should be involved in a collision, then the company that designed the faulty vehicle should be responsible for the resulting damage, so that neither the owner nor his insurance company would pay for any damage. However, there could still be disputes to which vehicle is


*Stanford Racing making a turn at DARPA's Autonomous Vehicles Grand Challenge* responsible for any accident and manufacturers would doubtless build their potential liability into the price of their autonomous vehicles, or they might not be able to remain solvent.

**Sensors and Electronics**

A combination of many sensors will be required to give a 360° view in three dimensions around the vehicle. They will include imaging sensors for visible light, with infra-red and radar to detect all obstructions even in haze, fog, rain, falling snow and hail more effectively and at far greater distances than is possible with the human eye or with any imaging system using visible light.

Light detection and ranging (LIDAR) systems are good candidates for measuring the distance of objects by timing the arrival of reflected pulses. Thus, we may expect to see quite an array of sensors on autonomous vehicles, but eventually they will doubtless be miniaturised in combined units and so appear less prominent. These sensors will generate a vast amount of data that must be rapidly processed by software to be able to replace the ability of a human driver's brain to control the vehicle.

Much, or most, of the innovation in car design is currently determined by new developments in electronic vehicle systems. Over 20% of the cost of a modern vehicle is now due to the electronics it contains and this figure is predicted to double to 40% by the year 2010. Indeed, the automotive sector is currently the most rapidly growing sector of any field of electronics.

The use of autonomous passenger-carrying vehicles is currently limited mainly to links over fixed tracks that prevent collisions. Much more development in sensor applications for vehicles is required before it will be possible to use them autonomously in large numbers on ordinary roads, automatically recognising road signs and traffic lights, and negotiating objects such as roundabouts, apart from automatically parking the vehicles. They will work in collaboration with the Global Positioning System (GPS) or Galileo in the vehicle for navigation.

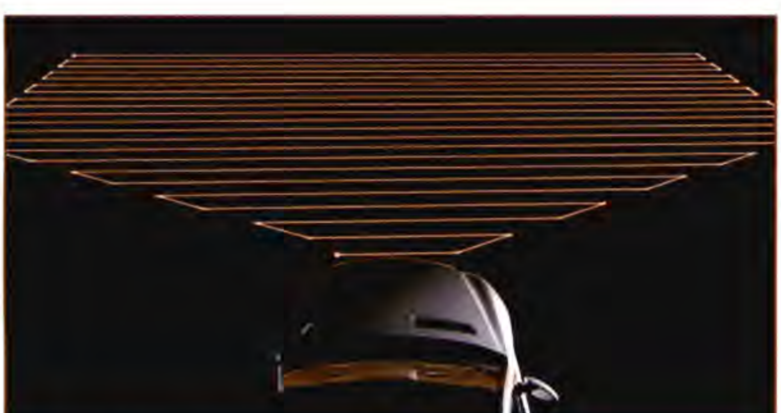
A completely new requirement for autonomous vehicles will be that of easy inter-vehicle communications between moving vehicles, where no telephone numbers or other contact details are known. As microprocessors should be less offensive than human drivers, we can expect that such communications between vehicles will be far more polite than the offensive shouts one sometimes hears from road-rage drivers.

**Safety**

Many past attempts to provide passenger protection, such as airbags, have made little change to the death rate from car collisions, but more emphasis is now being given to sensor techniques for collision avoidance. Radar systems are already used in some production vehicles, but incorporating them into cars in the mid-price range is a challenge, as many owners are more willing to pay for comfort than for safety.

Some 1.7 million people are injured and 40,000 killed on Europe's roads each year. The European Union intends to continue its safety campaign aimed at decreasing road accidents by 50% by 2010. There is an urgent need for the widespread introduction of integrated safety systems that can help reduce the risk of accidents. Long (77GHz) and medium (24GHz) range radar systems can warn of obstacles at distances between 20 and 200 metres in front of a vehicle and should play a critical role in identifying obstacles and cars, even in poor optical visibility. If a collision seems likely, the detectors can pass signals to braking, steering and airbag systems to try to avoid a collision and to put seatbelts and headrests into the best position to minimise injury if a collision occurs.

General Motors (GM) launched a new in-vehicle system to alert drivers to an impending accident. This 'vehicle to vehicle' (V2V) technology uses GPS data to plot the precise location of a car and relays this over a wireless network to other vehicles within its range, triggering a warning if the vehicles get too close. If they are on a collision course, it sounds an alarm to alert the driver. Car communication can take place at distances



*Short range radar observing the area in front of the motorcar.*

*Truck cab instrumented for NIST tests of collision warning systems* up to 250m, including around corners, improving visibility and helping to eliminate 'blind spots'. At present the V2V system can be retrofitted to vehicles for some 175 Euros. Andrew Marshall, Vauxhall GM, said: "We have deliberately based this technology on inexpensive, proven components, giving it the potential to become standard equipment in many vehicles." GM plans to install it in new cars from 2012.

**Radar Sensing**

It is predicted that the use of long-range distance warning systems in cars could increase by over 65% per year up to 2011, when a demand of 3 million per year is forecast. Of these, 2.3 million will be radar sensors, including long range sensors operating at 77GHz and short range at 24GHz. By 2014 it is expected that some 7% of all new cars will incorporate a distance warning system, especially those for use in Europe and Japan.

A highly integrated front-end IC for the 76-77GHz frequency range has been developed by Infineon Technologies to provide long and medium range radar sensing for mid-priced cars by mid-2010. Earlier radar discrete component systems cost over 1,000 Euros and were therefore suitable only for luxury car markets. Designated the RXN7740 and known as RASIC (Radar System IC), the Infineon device includes function blocks for the oscillator, power amplifier and four mixers for multiple antennas. This chip uses a SiGe technology in one of the fastest RF chips yet produced, having a 200GHz transit frequency. This technology enables smaller, more economical radar sensors to be built than those using GaAs components. The Infineon device was developed as part of the German KOKON project, specifically for automotive use. It is claimed that its use will enable the size of radar systems to be reduced to a quarter of that of earlier systems, while the cost of the RF module will be reduced by over 20%.

"Radar technology is the key to building innovative driver assistance systems to help avoid automobile accidents," says Hans Adlkofer, Vice President of Infineon Technologies Sense and Control business unit. "Thanks to this chip, long-range radar could become standard equipment for automobiles in the mid-range automotive segment by mid 2010."

"IN HIGHLY DEVELOPED COUNTRIES, IT IS FORECAST THAT ANY FALL IN GROWTH DUE TO THE MARKET MATURITY IN SOME OF THE MORE TRADITIONAL AUTOMOTIVE SECTORS WILL BE MORE THAN COMPENSATED BY EXTREMELY STRONG DEMANDS FOR MAJOR ADVANCES IN ELECTRONICS SYSTEMS FOR VEHICLE SAFETY, ENTERTAINMENT AND COMMUNICATIONS"

The US National Institute of Standards and Technology (NIST) has developed and tested a laser-based ranging system to assess the performance of automobile collision warning systems. Researchers in industry and at the US Department of Transportation (DOT) will be able to use the NIST technology to accelerate the commercialisation of safety systems that alert drivers to multiple crash hazards.

Sometimes, virtually simultaneous potential crash hazards occur, from both forward and side collisions, as well as from running off the road. The DOT believes such warning systems could significantly reduce both the number and the severity of injuries and save lives. It estimates that the widespread deployment of advanced integrated driver assistance systems may reduce such collisions by 48%.

Crash warning systems generally use radar, so NIST needed an accurate measurement tool based on an entirely different principle. Its independent measurement system (IMS) consists of a camera and microphone in the vehicle cab to detect the driver warning, a suite of calibrated cameras to measure the distance to lane boundaries and laser scanners to measure the distance to obstacles. This system can be mounted on cars and requires no modifications or connections to the warning system being tested. It can measure object distance to within about 80cm from up to 60m away at vehicle speeds of up to 25m/s.

The IMS revealed problems in warning systems for detecting if vehicles were in or out-of-lane on curves and during lane changes. It also measured significant warning delays that resulted in test failures. Problems like this are common in automotive crash warning systems that must operate in real-time, at highway speeds and use multiple low-cost sensors to measure complex 3D scenes.

**DARPA 2007 Challenge**

Autonomous vehicles have enormous potential for military applications and could revolutionise ground warfare, as there they may greatly reduce the loss of human life. In the US National Defense Authorization Act, 2001, the US Congress mandated that the armed forces shall aim to achieve the fielding of unmanned remotely controlled vehicle technology, with 33% of their operational combat vehicles being unmanned by 2015.

To speed the development of autonomous vehicle technology, in November 2007 the U.S. Defense Advanced Research Projects Agency (DARPA) organised an autonomous vehicle Urban Challenge at a former Air Force Base in Victorville, California. This third event followed previous autonomous vehicle competitions. It extended the concept to autonomous vehicles that safely execute missions in a complex urban environment with moving traffic. It is a R&D program conducted in a competitive format to address the most challenging aspects of

*Test-bed vehicle with dual-head laser range scanner*

autonomous vehicle design, with prizes of up to $2m. The maximum speed was 30 miles per hour. However, capabilities such as the recognition of external traffic signals, the recognition of pedestrians and pedestrian avoidance were outside the scope of the program, which did not include travel in difficult off-road terrain.

The vehicles competing in the Urban Challenge were required to think like human drivers. They continually had to make split-second decisions so as to avoid other moving vehicles, some of which were robotic vehicles without drivers. They were required to operate safely on the course. The urban setting of this challenge added considerably to the complexity of the challenge faced by the vehicles. Indeed, it replicated some of the environment conditions where many of today's military missions are conducted. It was essential that the software used could make 'intelligent' decisions in real time and adapt those decisions to the movements of other vehicles.

The finalists had to go around a 60-mile urban course. Initially there were 35 teams, but only 11 of these reached the finals instead of an expected number of about 20 teams. A DARPA director said that some vehicles were found not to be safe enough to be on a road, while some of the others crashed in qualifying events. This tends to confirm that a great deal of future research is required before autonomous vehicles can be allowed to use ordinary roads. He said the qualifying event tested the capability of the vehicles to merge into traffic, navigate four-way intersections, respond to blocked roads, pass on-coming cars in narrow roads and keep up with traffic on two and four-lane roads. The only major difference between the qualifier events and the final event was that other robotic vehicles formed part of the traffic in the final event.

This Urban Challenge was won, together with the $2m dollar prize, by 'Boss' a vehicle developed by the Tartan Racing organisation of the Carnegie Mellon University at the George Air Force Base in California, where the US forces carry out training operations for urban use. The competing vehicles had to operate entirely autonomously, whilst navigating the 60-mile course in less than six hours. They were tested on their ability perform manoeuvres and to obey the Californian traffic regulations. ■

## IMEC Sensing

Maarten Willems, Emerging Business Strategy Director at IMEC, presented a paper entitled'*Towards Autonomous Driving*' at the Annual Research Review Meeting (ARRM) at IMEC (Inter-University Microelectronics Centre, Leuven, Belgium) in October 2007. He said world demand for automotive electronics for Original Equipment Manufacture (OEM) use is forecast to rise at a rate of 7.5% per year, reaching a total of about $153bn in 2011. This demand will rise much more rapidly than production of the light vehicles themselves, as the use of electronics in all vehicles is growing at increasing rates. In highly developed countries, it is forecast that any fall in growth due to the market maturity in some of the more traditional automotive sectors will be more than compensated by extremely strong demands for major advances in electronics systems for vehicle safety, entertainment and communications.

Automotive electronics fields in which IMEC is working on related development work include device packaging and reliability, 3D packaging for some devices, radar technology, wireless technology and wireless sensor networks. For example, in the field of 3D ranging cameras, automated systems are required to achieve low cost and information-rich vision systems. For this purpose CMOS imaging devices are the optimum choice, as they can be manufactured using standard silicon chip processing lines at relatively low cost. Charge-coupled imaging devices are generally more expensive, as their production requires dedicated fabrication lines.

IMEC is also working on 3D packaging that can provide high-resolution video images beyond the current state of the art of some 120 x 160 pixels. IMEC has very extensive experience in CMOS detector design, readout electronics, 3D packaging technologies and testing for characterisation and optimisation. Hence, it is in a good position to make important contributions to the design of future autonomous vehicle electronics.

Experimental autonomous vehicles for mixing with other road traffic are unlikely to become generally available for at least 20 years. However, work towards the development of such vehicles is resulting in the availability of features to improve the safety of human driven vehicles. Indeed, the current aim is more towards driver assistance techniques than towards autonomous vehicles, including the provision of better all-round visibility and avoidance of blind areas currently experienced by lorry drivers.

The US Department of Defense is interested in autonomous vehicles for bomb disposal, but a person using images from the vehicle sensors could remotely control them.

*Gary Nevison is chairman of the AFDEC RoHS team, and Customer Support Manager, Legislation and Environmental Affairs at Premier Farnell. As such he is our industry expert who will try and answer any questions that you might have relating to the issues of RoHS, WEEE and REACH. Your questions will be published together with Gary's answers in the following issues of Electronics World.*

# IMPACT ON DESIGN – THE WEEE DIRECTIVE / RECYCLING

The EU WEEE (Waste Electrical & Electronic Equipment) Directive requires ten categories of electrical and electronic equipment to be collected, treated, recycled and disposed of when they reach end-of-life. The directive sets targets for the percentages of materials that must be recovered and includes a list of parts that have to be removed and then recycled separately. Crucially, the directive also includes a requirement that manufacturers design equipment so that it can be easily recycled, although this has not yet been translated into national legislation in any EU State.

Recycling is a cost that can be significant and is paid for by the producer (usually the manufacturer or importer). In effect it is a sales cost, as it must be financed when the product is sold. The cost of recycling can be influenced by the design of the equipment, although whether the manufacturer can realise these benefits depends on whether they collect and recycle their own equipment at end of life (in which case they can) or if it is collected and recycled by compliance schemes that gather a wide range of products from many producers and where the benefits are more limited.

The main cost of recycling is usually the labour which is required for dismantling equipment into separate the parts listed in Annex II of the directive. These parts include batteries, LCDs, printed circuit boards and plastics containing brominated flame retardants.

It is worth bearing in mind that in most types of products, it is essential that plastics can be separated and re-used to meet the EU recycling targets. For example, on average, IT equipment contains 65% plastic and the recycling target for the product category is 65%.

The dismantling time for products can vary enormously depending on whether or not they have been designed for easy recycling from the outset. The overall cost of recycling will depend on many factors including dismantling time and, therefore, it is key that designer engineers consider what happens to their products at end-of-life.

For example:

- Design components/assemblies that can be easily dismantled into their equipment (PCBs, enclosures, etc) and those that can be recycled separately and economically.
- The removal of screws is time consuming, whereas plastic clips can be undone more quickly, therefore, it makes sense to use as few screws as possible.
- Marking larger plastic parts with the type of plastic (and flame retardant) aids recycling. Single types have a value and can be sold whereas unidentified mixtures have very little value.
- Avoid metal inserts in plastic mouldings; these reduce the value of the plastic to zero.
- Avoid labels that are incompatible with recycling.
- Consider metal housings, these are easier to recycle and the recycled metal has value, but avoid combining metals as much as is feasible. Steel, copper and aluminium have most value when free from each other.
- Batteries: attach with clips, do not solder them onto PCBs.
- Heat welding is preferable to adhesives. Recycled plastic scrap of one plastic type has the highest value.

Weight is also an issue as WEEE has to be transported. Even if compliance is achieved through a compliance scheme, savings can be made by reducing the weight of equipment. Most schemes charge their members based on weight sold.

### The US

In North America, there is currently no national collection programme for used electronic equipment. However, numerous states, counties and local governments have implemented requirements for the management of electronic waste. Several trade organisations are calling for a harmonised approach. The US Environmental Protection Agency is encouraging manufacturers to address the challenge by taking environmental considerations into account at the earliest stages of product design.

When purchasing new electronic equipment, buyers are asked to look for "green" products that:

- Are made with fewer toxic constituents
- Use recycled content
- Are energy-efficient
- Are designed for easy upgrading or disassembly
- Use fewer screws and more snap-fit parts
- Utilise minimal packaging
- Have been recognised by independent certification groups as environmentally preferable.

Some manufacturers are replacing difficult to recycle plastics at the design stage with, where available, lighter and more durable metals that be recycled easily.

### Does the Consumer Really Care?

To give an indication, 96% of Canadians said they preferred to buy products that can be recycled efficiently at the end of their performance life, and 88% would be prepared to spend more on environmentally-friendly options.

To achieve this, improvements in the recycling process must start early in the design phase. ■

*Please email your questions to:*
***svetlana.josifovska@stjohnpatrick.com***
*marking them as RoHS or WEEE.*

# POWER FOR YOUR MODULE: PRIMARY CELLS

by Myk Dormer

High-spec personal consumer electronics - MP3 players, cellular phones, portable computers etc - are now usually powered by rechargeable batteries, with lithium ion and lithium polymer predominating over the older nickel hydride and nickel cadmium chemistries.

Simple consumer products (torches, cameras, remote controls) on the other hand are frequently still powered by primary cells, mostly alkaline or non-rechargeable lithium, with a few niche applications using silver oxide.

"REALISTICALLY, YOU'LL ALWAYS BE IN A COMPROMISE BETWEEN THESE TWO EXTREMES. BUT IF IT WAS EASY, YOU WOULDN'T BE AN ENGINEER, WOULD YOU? "

The reasons for this difference are key to understanding the correct choice of power source for your low power radio project, and it's generally simpler than you'd think.

Duty cycle and self-discharge rate are the most important issues to consider: if a unit draws significant power for hours at a time (a portable computer, a music player), it is turned on for most of the day (cellular phone) or draws very high currents periodically (power tools), then rechargeable batteries are far superior in terms of economy and, often, in power density too.

But if a device is turned off for most of its life (a torch is usually used for tens of minutes at a time, a remote control or a camera for seconds), or if a long lifetime at very low (microamp) currents is desirable (alarms, clocks), then primary cells are the correct choice. They are cheaper to install initially and their low self-discharge rates allow the engineer to design for service life between battery changes measured in years.

Many ISM band applications require this sort of profile. Environmental sensors, security transmitters and data logging devices frequently need month or year-long battery life, at very low duty cycles, often less than a transmission per minute.

Handheld control devices ("keyfobs" and their larger, industrial, cousins) frequently are operated on a daily (or even less frequently) basis, while fire alarms, personal distress alarms and other safety devices might be activated fully only once in their service life. This article concerns itself with the primary batteries used for these low average power drain applications.

**- Alkaline.**

By this we refer to the generic class of 'one and a half volt' common usage primary cells. Historically, these are 'Leclanche' or 'zinc-carbon' cells, although modern construction and chemistry has resulted in far higher performance units.

Commonly available in a small range of single cell sizes (AAA, AA, C and D) and a few higher voltage multiple cell designs (the small 9V PP3 is the most common survivor of what was once a far larger range of types, and small, very low capacity 6V and 12V tubular batteries are seen in older remote control designs), the alkaline cell is inexpensive and capable of producing large pulses of current. Holders, boxes and clips for these common forms are available in a bewildering variety.

Shortcomings of this cell type include a relatively short shelf life (2-3 years), capacity degradation at low temperatures and at high current, unimpressive energy density and a non-constant terminal voltage; an alkaline cell delivers over 1.5V when new, but falls to 0.9V at the end of its life.

Although cheap, the cheapest examples ought to be avoided, as performance can be uncertain and leakage of corrosive electrolyte materials far more likely. Most of the higher end manufacturer's products are interchangeable and have similar cell capacities, despite deliberately vague advertising claims by competing makers.

**- Lithium.**

There are two basic families of lithium primary cells: low discharge current lithium manganese dioxide or lithium polycarbon monoflouride, intended primarily for memory backup supplies, and the more useful, higher discharge current, lithium thionyl chloride parts.

In addition to the standard alkaline sizes, lithium cells are made in 1/2 and 2/3AA, and the larger diameter 2/3A sizes. In addition to plain 'holder' type cells, versions are available with PCB mounting tags and with axial wires. AAA lithium cells are not made, but there is a wide range of smaller 'button' cells, with the larger examples (often used in led torches) having useful capacities, and some 'camera' battery forms which do not have alkaline equivalents.

Characteristics of the lithium cells are: very long shelf-life (10 years or more, with correspondingly low self-discharge rates of less than 1% per year), high terminal voltage (3.5-3.7V, reasonably constant throughout the battery life) and very wide operating temperature range (to at least -30 degrees, with many types going to below -55).

Their shortcomings are: high cost (a good alkaline AA cell costs 40-60p, a lithium thionyl AA will be over £4), and strictly limited maximum current. Considerable care must be taken when selecting a lithium battery, as maximum discharge currents vary from maker to maker; typical maximum current for an AA cell is 55-100mA, but some are as low as 20mA.

Lithium batteries also suffer from a perceived chemical hazard, although modern examples are not prone to exploding under overload, as some earlier types were.

A recently introduced variant on the basic chemistry delivers much higher maximum current, of over 5A for an AA type, at 4.1 volts. These parts are very expensive.

**- Other.**

While the two preceding categories cover the majority of primary cell applications, there are a few others:

- Lithium iron disulphide. This is a battery with the characteristics of a high current lithium thionyl cell, but a terminal voltage of 1.5V. These are sold as deliberate 'upgrades' for more demanding alkaline cell applications, but are considerably more costly. They are only seen in AA and, occasionally, PP3 sizes.

- Silver oxide. Usually limited by the price of silver to button cell sizes (watch, or hearing aid batteries), the basic chemistry has a terminal voltage of 1.55V and a flat voltage/discharge curve. Peak current is better than that of similar sized lithium, but energy density is somewhat lower. Self discharge is negligible and shelf life is long. Avoid confusion with alkaline cells sold in the same sizes; for example, an SR44 is a silver oxide part, but the identical looking LR44 is a simple alkaline.

- Zinc/air. Optimum for constant moderate current drain applications, these cells are rarely seen outside of hearing aid applications. They require oxygen from the air, and once the 'seal' is removed their self discharge is very high (unsealed shelf life is in months).

- Mercuric oxide. No longer used, owing to the toxicity of the mercury, these cells were functionally equivalent to modern silver oxide cells but had a very constant 1.35V terminal voltage.

So, which battery should be used? As usual, there is no absolute rule. If cost is the overwhelming consideration, use alkaline and work around its limitations. If maximum performance or a specific operating spec (lifetime, operating environment, and minimum size) is required, then use lithium (or occasionally silver oxide) and accept the bigger price tag.

Realistically, you'll always be in a compromise between these two extremes. But if it was easy, you wouldn't be an engineer, would you?

*Myk Dormer is Senior RF Design Engineer at Radiometrix Ltd*
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# NETWORK OPTIMISATION: THE IMPORTANCE OF LOOKING WITHIN

**ANDREA CASINI,** VICE PRESIDENT, EUROPE, MIDDLE EAST, NORTH AFRICA SALES AND MARKETING AT ANDREW CORPORATION, EXPLAINS HOW ONGOING OPTIMISATION IS THE ONLY WAY OF SUCCESSFULLY PROVIDING A MOBILE NETWORK THAT COPES WITH THE DEMAND OF ITS USERS BUT ALSO KEEPS COSTS DOWN

Mobile pone operators are now faced with the pressure of providing high levels of service, while reducing spend on network infrastructure. Mobile penetration has reached saturation point in the developed world and average revenues per user (ARPUs) are expected to increase slightly at best. Customer retention and satisfaction are imperative to survival.

Meanwhile, subscription growth is set to tail off during 2007. It's safe to say that double-digit revenue growth in Western Europe is a thing of the past. Operators must focus on trimming costs in order to stabilise their bottom lines, looking at any and all ways to reduce both operational expenditure (OpEx) and capital expenditure (CapEx).

The plateau in subscription numbers is compounded with connection troubles. Operators are constantly looking at ways to extend mobile coverage networks, but now face the inevitable problem of capacity limitations. Given the ease of switching service providers in the current climate, the frustration caused by calls that are dropped or can't be made, even when handsets show full coverage, can mean the loss of customers. In particular, with a lack of new customers signing up, this scenario can be critical for operators.

Next Generation Network (NGN) technology is also forcing service providers to adopt new business models around IP convergence and third generation services. By supporting NGN services, operators can maximise return on investment (ROI) within the network and leverage it for competitive advantage. Nevertheless, they need to better manage increasingly complex networks to respond more effectively to customer demands, while at the same time become more streamlined with regard to their capital investment.

With this in mind, it is important to understand the need to continually optimise existing mobile networks. Currently, many operators follow the standard path and address capacity problems by installing additional basestations at huge expense both in terms of outgoings, man hours and high OpEx. This can actually compound the problem because 3G is notoriously sensitive to interference and too many basestations too close together can disrupt and weaken the very signal they were supposed to strengthen.

Deploying the appropriate network optimisation software at a fraction of the cost of a new basestation site can help mobile operators avoid the issues of network overload and dropped calls. The software, which includes performance management, traffic management and capacity support, allows network planners to fine-tune capacity by a click of a mouse and understand underlying network infrastructure. It also plays a critical role in asset management by monitoring individual resources and the levels they are working at. Service providers can run real-time scenarios to explore the most efficient and cost effective option to enhance coverage and capacity, as well as monitor core network in real-time to optimise delivery of service. Benchmarking tools are increasingly being used to review and enhance subscriber experience, by allowing specific network

**The frustration caused by calls that are dropped or can't be made, even when handsets show full coverage, can mean the loss of customers**

problems to be fixed and providing records of competitive advantage over similar wireless services.

Using analysis software, operators can easily see when lower-cost alternatives such as Multi-Carrier Power Amplifier (MCPA) systems can be implemented, instead of introducing new cells or repeaters. MCPAs provide a flexible answer to several common cellular-network problems whilst enabling greater coverage to be achieved from a single cell-site or allowing the cell-site to become a distributed system. One of the major benefits of MCPA deployment is that it often results in CaoEx and OpEx savings at the cell site, the current Holy Grail for mobile operators.

There will be times when a new basestation is necessary to fill a hole in coverage. Even then, optimisation software can fulfil an important role by deferring the investment while temporarily fixing the coverage problem. This allows operators to hold off until subscriber rates, and therefore income, reach the level that makes investment in new infrastructure essential as well as financially viable. In such scenarios, optimisation not only keeps outlay manageable, but also keeps it in tune with revenue growth.

Optimisation isn't without its own challenges, from a legislative aspect as well as the obvious technical ones. Different laws in different countries mean operators often need a variety of permissions for new sites, with many countries, such as Italy and Poland, having very specific rules when it comes to new antenna placements. However, these inconveniences are often negligible in the face of the many benefits that optimisation brings.

To survive in the current competitive and developed marketplace, new technologies will need to exploit existing infrastructure and co-exist with current technologies if they are to prosper. Operators also need to make the most of what they have already put in place to remain competitive. By optimising networks to ensure maximum capacity, they can reduce churn and increase market share, whilst saving on unnecessary infrastructure expenditure and providing a good investment for the future. ■


JEFF DUMAS, BOB LANOUE, BISHARA TAHHAN FROM PICOR CORPORATION HERE PRESENT ACTIVE FILTERING TECHNOLOGIES INCREASINGLY DEPLOYED TO TACKLE EMI REGULATORY LIMITS

# IMPROVED EMC/EMI PERFORMANCE USING ACTIVE ANALOGUE POWER FILTERS

As the demand for power continues to rise at the system, subsystem and board level, increased capabilities are sought for power density, efficiency and reduction in volume of the power distribution portion of the system. Providing these increased capabilities, however, also increases the challenge of addressing EMI requirements.


Passive differential and common-mode filters are commonly used between the bus source and loads to bring regulated systems below the mandated limits (such as for CISPR 22 Class B) that may be placed on the total noise the system can conduct back to the input source. It is well documented that the conducted noise sources of differential and common mode are generally caused by the power conversion portion of the system. Typically system designers attempt to locate passive filters at a cost-effective common point, providing bulk filtering to all the conversion inputs or placed on boards as needed to bring the total system into compliance.

With many of today's systems focusing on interoperability of hardware, the burden of meeting the EMI requirements is moving more towards the sub-system and board level designers. For example, in the AdvancedTCA PICMG 3.0 specification, the power architecture conversion and EMI filtering is specified on a per board basis.

In an application already focused on power density, the additional "distributed filtering" may be space prohibitive. The best solution in this case may be an Active power filter. Active filtering for conducted noise as an alternative to passive solutions can provide higher power density and more noise attenuation for input current filtering, to meet EMI regulatory limits. Active filtering can also minimise the output voltage ripple and noise of the converters for improved EMC. The following are some design considerations and examples of 'active' filter implementations.

### Input Active EMI Filtering

The traditional technique to reduce common mode noise is to use a common mode transformer, or choke, to create a high impedance path back through the power lines to the source and by connecting "Y" capacitors to the common path, typically earth ground. The earth ground to the system chassis or cabinet in most cases is required for safety reasons to minimise electrical shock hazards.

The "Y" capacitors provide a low impedance return path back to the common mode noise source, usually the converter, while the choke blocks the AC noise path to the power source. The "Y" capacitor values are limited in size and type by the maximum AC current they allow into the earth return at the line frequency and they cannot fail with DC leakage impedance.

For the common mode filter to have effective attenuation in the switching range of the converter the burden is pushed onto the inductance of the choke. Historically, the inductance was large enough that the leakage component could be used to provide significant differential filtering in combination with the input capacitance at the load side of the common mode filter.

In the active solution (**Figure 1**), a common mode transformer is still used to sense the common mode current and provide the input signal in the common mode current-filter circuit. The value of inductance is orders of magnitude lower so the leakage inductance is too small to help reduce differential noise. In this case the transformer has three coupled windings, two primary windings that have the same number of turns and connected in series between the power source and the power converter. The third winding has a higher number of turns than the primary windings and senses the difference in current between the two primary windings. This difference is equivalent to the common mode noise current.

The third winding common mode signal current is converted into voltage that is fed into a high-speed amplifier with high output current capability (20mA), which is used to offset the common mode noise. The output of the amplifier is coupled through a Y-cap to the filter common node that is connected to the shield point or the base plate, if available, of the power converter.

The amplifier modulates the voltage across the capacitor to produce an offset current equal to the magnitude of the common mode current and opposite in phase present at the source. Another capacitor equal to or larger than the Y-cap is added between the shield and BUS- pins to complete the AC current circulation in the circuit.

Using a transformer with very low primary inductance, less than 1µH, and the proper number of turns in the sense winding has achieved an attenuation of 50dB at 150kHz. The inductance between the source and the power converter is kept very low and mitigates normal concerns regarding inductance in the neutral path.

The attenuation curves for a typical input active EMI filter described herein are shown in **Figure 2**. **Figure 3** shows the spectral performance of a power converter with and without an active filter. Without a filter, the conducted EMI exceeds the Class B limits, and with an active filter the noise is attenuated significantly below the Class B limits.

### Active Filtering for Output Ripple Attenuation

It is a common practice to use a passive LC filter on the output of a converter to reduce the differential ripple amplitude in applications requiring a low noise source. In order to achieve at least 40dB of attenuation, the resonant frequency of the LC pair must be more than an order of magnitude below the fundamental switching frequency of the converter. Fast transient load changes will result in a damped ringing voltage response at the LC resonance, with a Q-dependent amplitude and settling time of the filter.

Attenuation with improved transient response (**Figure 5**) can be achieved by replacing the inductor with a power FET and high-speed control device to modulate the FET resistance in a linear fashion. This approach requires setting a DC bias or headroom voltage of the filter that is modulated via the FET resistance. **Figure 4** shows the basic circuit used to replace the inductor component of the filter with associated boosting and compensation circuits.

The headroom voltage can be set with a simple divider to a range that is greater than the maximum expected peak ripple, plus some additional voltage for input voltage drops due to the transient load response of the converter output. The requirement is to avoid the $R_{dson}$ slope region of the FET where the loop will not correct for input variation and the output will just follow the negative transitions of the input ripple.

A typical range of 300-400mV is sufficient consuming around 10% efficiency in a 3.3V application. Using

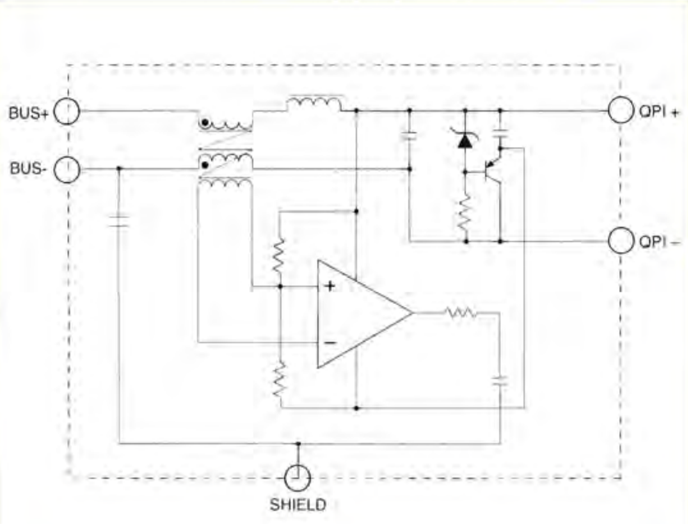


*Figure 1: Typical input active EMI filter (QPI series from Picor)*

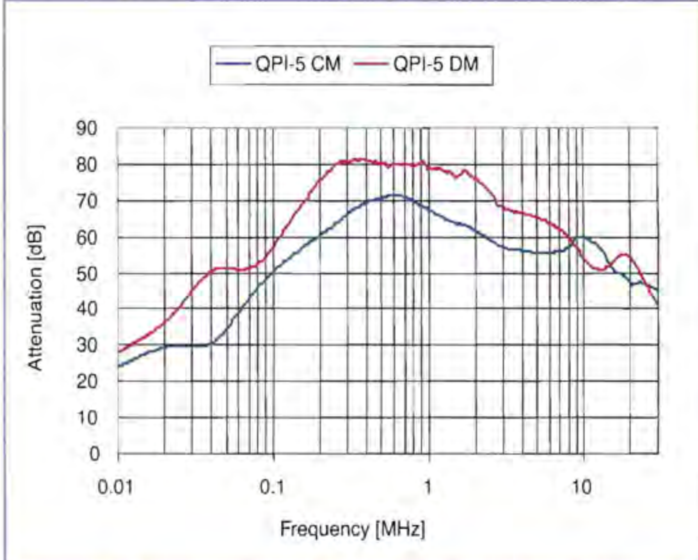


*Figure 2: Attenuation curves for common and differential mode performance for the active solutions*

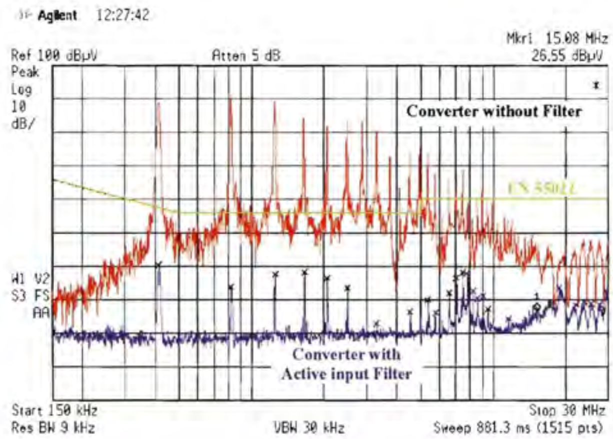


***Figure 3**: Spectral results before and after insertion of the active solution*

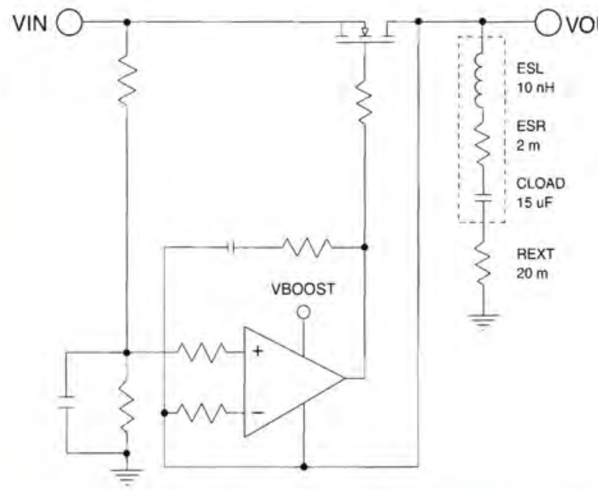


***Figure 4**: Typical active output filter (QPO series from Picor)*

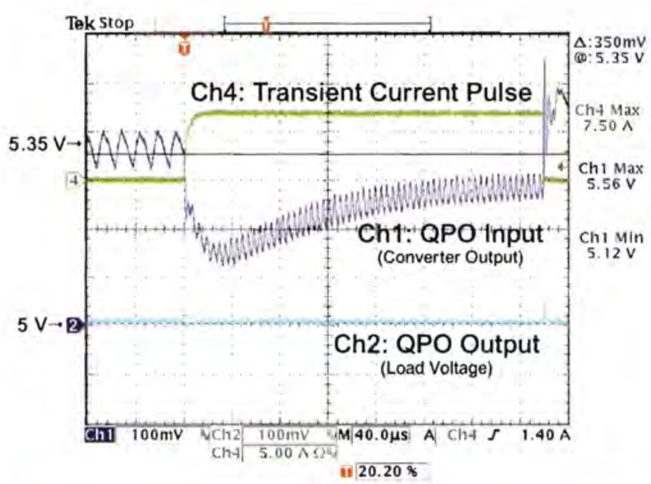


***Figure 5**: QPO series active filter performance under transient load condition*


***Figure 6**: Picor 25mm x 25mm active filters achieve up to 14A for input filtering and up to 20A for output filtering*

commonly available wide bandwidth op-amps (200-300MHz) in combination with small outline, low $R_{dson}$ surface mount exposed pad FETs form an effective, fast, high current and low output impedance unity gain buffer. With proper thermal management and very little PCB area a 10-amp filter can easily be achieved using the latest logic level threshold, low input capacitance FETs.

Scaling up to 40A with four FETs driven from one controller is a feasible configuration for higher current applications. This active filter is biased from the converter output so a biasing source above the filter input voltage must be created for the controller as shown in Figure 4. This can be accomplished using a capacitive charge pump or inductive boost to provide sufficient gate drive above the filter output voltage when using NFETs.

This bias source can be referenced to the input of the filter and the control circuits to the output so low voltage controllers can be used over a very wide DC input range. Any noise the bias generation may create is presented to the input of the filter and will be attenuated at the output.

Compensating the op-amp loop with a pole-zero network can provide a closed loop bandwidth in excess of 1MHz with 45° of phase margin and transient response times or around 1us for the filter.

A broad portfolio of input and output active filters is available from Picor, a subsidiary of Vicor Corporation. There is a selection of high density (1sq inch), low profile (0.2") solutions, as shown in **Figure 6**, that offer superior attenuation performance with very high efficiency.

The input active filters, QPI series, are available for 24V and 48V systems addressing currents up to 14A. A sub-set of the QPI series also integrates a hot-swap function for added system design simplicity. The output active filters, QPO series, are available for 0.3 to 5.5 volt and 3.0 to 30 volt rails at up to 20 amps. ■

IN THIS ARTICLE **ROBERT V. WHITE** AND **ANDREAS STIEDL** FROM EMERSON NETWORK POWER REVIEW TWO MAIN WAYS OF PROVIDING THE REQUISITE DC POWER FROM THREE-PHASE AC POWER SOURCES

# CONFIGURING SYSTEMS FOR OPERATION FROM THREE-PHASE AC POWER

High power computing and networking systems are not new. What is new is that more and more of these systems are requiring more power than can be easily provided by a single-phase ac power feed.

This article reviews the two main ways of providing the requisite dc power from three-phase ac power sources. The first uses true three-phase ac-input power supplies, while the second, more common method, uses three single-phase ac-input power supplies with paralleled dc outputs and with their inputs wired to present a balanced load to the three-phase ac power source. This method allows the use of low cost single-phase ac input power supplies, but demands that a choice be made between simple hardware with complex installation, or more complex hardware with simple installation.

### THREE-PHASE CONFIGURATIONS

There are many different configurations of three-phase ac power sources around the world. The two main configurations – the delta connection and the wye, or star, connection – are illustrated in **Figures 1** and **2**.

Delta configurations generally do not have a neutral connection and the protective earth is separate from the phase leads. There are a number of variations, including phases that are centre-tapped to form a neutral line, and open delta configurations where only two of the three phases are powered.

Wye configurations typically include a neutral line (N) connected to the common point (3 phase plus neutral for a total of four wires). In addition, the common point of the three phases is connected to protective earth (PE) ground to form a five-wire connection (3 phases, N, and PE) as shown in Figure 2.

As well as the numerous phase configuration variations, there is a wide variation in available mains voltages. **Table 1** shows the most common configurations of three-phase ac power that are of interest to OEM manufacturers serving the global market.

### TRUE THREE-PHASE POWER SUPPLIES

The simplest means of configuring a system to operate from three-phase ac power is to use a power supply with a true three-phase input. In this case, we are talking about power supplies with active power factor correction of the input currents and not a simple six pulse rectifier input. **Figure 3** shows a conceptual diagram of the type of three-phase input ac-dc power supply typically used in computing, networking and telecommunications applications.

One key advantage to this approach is that the input power connections are straightforward – Phase A connects to one input terminal, Phase B to another and Phase C to the third. Other advantages include the fact that the input currents are always well balanced across the three phases and it is easy to do configure systems for operation from redundant ac power feeds, as well as for N+N redundancy.

In spite of these advantages, true three-phase input power supplies are not very common, primarily due to their high cost and complexity. One source of complexity is the control scheme needed to control the six switches to ensure that sinusoidal input currents are maintained on all three phases. For single-phase input ac-dc power supplies there are many simple and low-cost control ICs, some with a price as low as $0.15 in high volumes. These devices are easy to use and do not require

| Configuration | Voltage (Vac rms) Phase-Neutral | Voltage (Vac rms) Phase-Phase | Region Typically Used |
|---|---|---|---|
| Wye (3P + N + PE) | 230 | 400 | Europe |
| Wye (3P + N + PE) | 120 | 208 | North America |
| Delta | N/A | 208, 230 | North America |
| Open Delta[1] | 100-105 | 200-205 | Japan |
| Wye (3P + N + PE) | 230-250 | 400-440 | Australia |

[1] One phase with grounded centre-tap to make the neutral

***Table 1:*** *Typical three-phase ac power configurations*

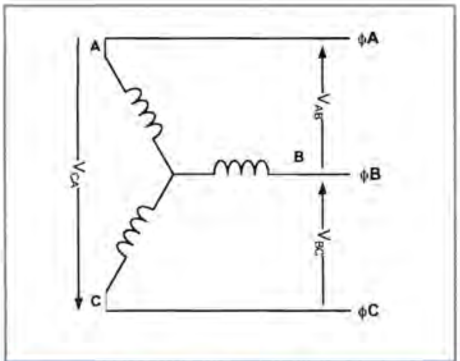


*Figure 1: Three-phase delta connection without neutral wire and separate protective earth connection*

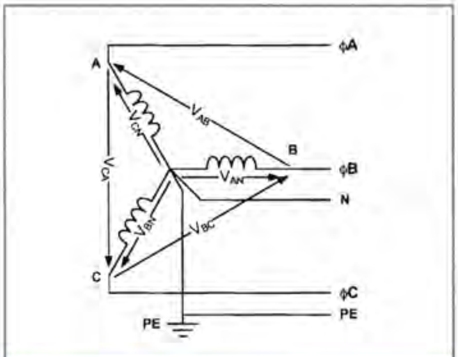


*Figure 2: Three-phase wye connection with neutral and protective earth wires*

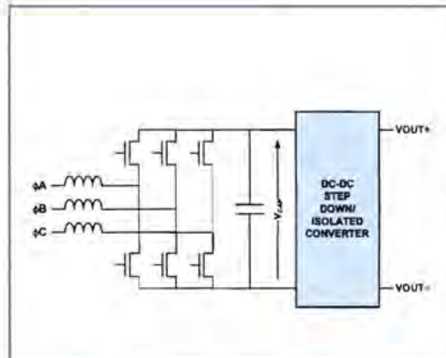


*Figure 3: Conceptual diagram of a three-phase input ac-dc power supply*

advanced control or programming knowledge to use them effectively.

Unfortunately, no such ICs exist today for three-phase input power supplies. Most controllers for three-phase input power supplies are DSP-based solutions that cost at least $2.00.

Another consideration is component cost. Looking at Figure 3, we see that $V_{CAP}$, the voltage at the output of the power factor correction stage, is sqrt (2) x $V_{phase-to-phase}$. For operation from the120/208Vac wye configuration that is common in North America, this is not a problem, because $V_{CAP}$ would only need to be a little more than 300Vdc. However, for operation from the 230/400Vac that is common in much of the rest of the world, $V_{CAP}$ must be 600Vdc or more for proper operation of the power factor correction.

This is a problem because the capacitors, MOSFETs and other components rated for operation above 600V are not commonly used in the industry and, therefore, incur a cost penalty. This cost penalty is compounded by the fact that high power equipment needing three-phase input is often produced in relatively low volumes – from a few hundred to a few thousand systems per year.

Another disadvantage is the loss of output power capability when power from a single input phase is lost. In this case, the power supply is effectively operating from a single phase. The output power that can be delivered to the load is reduced to one third the normal value. This is true of any arrangement of power supplies that operate with a delta input. These disadvantages – mainly the extra complexity and higher cost – have led system OEMs to generally adopt another approach to power systems from three-phase ac power.

With the need for higher power supplies increasing, ways to use a true three-phase input power supply without requiring higher voltage rated components are being investigated.

There is little or nothing that can be done about the need for higher voltage components in the ac-dc conversion stage. The output voltage needs to be greater than the peak of the input voltage for the power factor correction stage to work properly. However, two circuit techniques are used to design the dc-dc conversion stage so that higher voltage components are not needed. Both of these techniques make use of capacitive voltage dividers to reduce the 600-800Vdc output of the ac-dc stage.

The first technique involves the use of multilevel converters; for computing and telecommunications applications, these generally use clamped diode and flying capacitor topologies. These can work well and use 400-500V rated semiconductor devices and capacitors. The disadvantage is that there are more semiconductors with a more complex control. Of particular concern is the need to avoid imbalance in the capacitor voltages due to component variation or changes in the converter loading.

The other technique is to use two power supplies with their inputs connected in series and their outputs connected in parallel, as shown in **Figure 4**. Again, there is the challenge of preventing imbalance in the capacitor voltages due to component variations, such as those that cause one of the dc-dc converters to operate at a higher duty cycle and higher average input current than the other. This problem is manageable, but it does require some care with the overall control of the two converters. Also, the total parts count of the two converters will be higher than that of a single converter of the same total output power capability. The smaller, lower voltage and lower current components of the two dc-dc converters make up much of the cost difference.

It will be interesting to see, in the years ahead, how far these techniques can go to make true three-phase input ac-dc power supplies economical, robust and easy to design.

## USING THREE SINGLE-PHASE POWER SUPPLIES

The most common approach to powering systems from three-phase ac power is to use three single-phase ac input power supplies. Each supply operates with its ac input connected from phase to neutral or from phase to phase. The dc outputs of all three power supplies are connected in parallel (**Figures 5** and **6**). These power supplies are typically designed for a worldwide ac input voltage range of 100-240Vac nominal (85-264Vac full design range).

This approach offers a number of significant advantages: each of the power supplies uses a well known technology and is a low cost, low complexity product; and the input current among the three phases can be well balanced (±5-10%) under normal operation.

One key disadvantage is that in N+M redundant applications, each increase in M requires three more power supplies. To implement 1+1 redundancy and maintain input current balance requires adding three power supplies for a total of six power supplies. However, the lower cost and complexity of the single-phase ac input power supplies has more than offset this disadvantage to date.

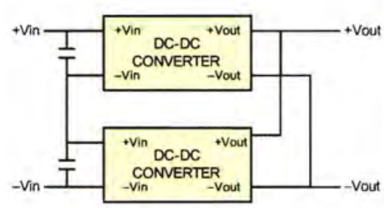


***Figure 4:*** *Series input, parallel output technique for reducing converter input voltage*

### Option 1: Complex System Manufacture, Easy Install

Looking at Figures 5 and 6 we can see another disadvantage to using three single-phase ac-dc power supplies. The input wiring schemes are very different for wye and delta sources. It is not possible to have a single wiring scheme for both. For systems wired at the factory and shipped as 'plug and go', this means that the type of ac power at the end user's site must be known and the system configured for that power.

The first problem with this is that the ac power configuration at the installation site may not be known, and even if it is, the supplier must be able to provide many different configurations of the same system, varying only in their ac input configuration. This means that for every system configuration the supplier intends to provide (variations such as number of processors, memory capacity, disc drives, I/O type and capacity), there must be at least two times (and probably more like three or four times) as many variations in order to account for the ac power configuration. This places a huge design and manufacturing burden on the supplier and means that customers must ensure that they order the correct configuration.

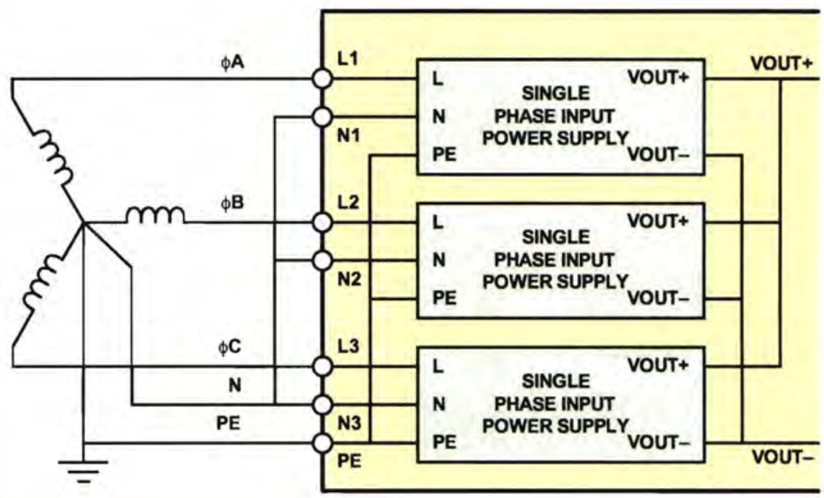


***Figure 5:*** *Connecting three single-phase input ac-dc power supplies for operation from three-phase wye ac power*

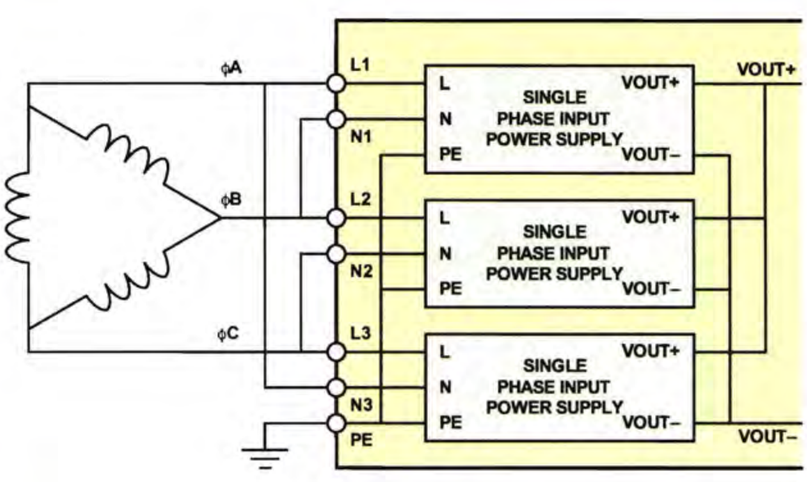


***Figure 6:*** *Connecting three single-phase input ac-dc power supplies for operation from three-phase delta ac power*

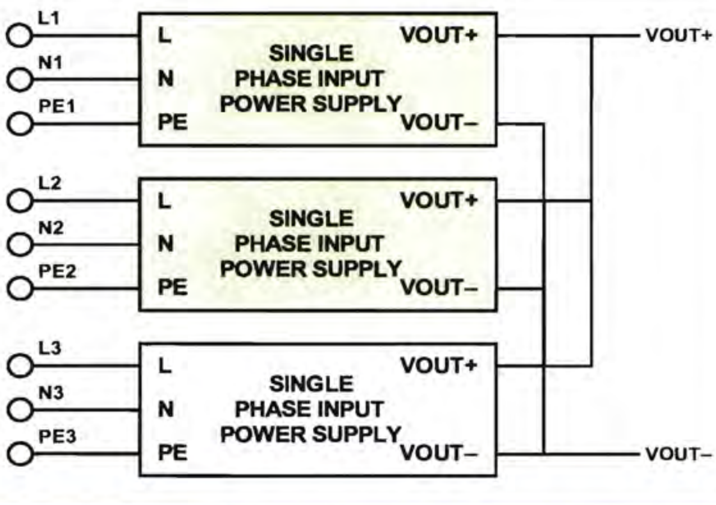


*Figure 7: Three single-phase ac-dc power supplies with undedicated input connections*

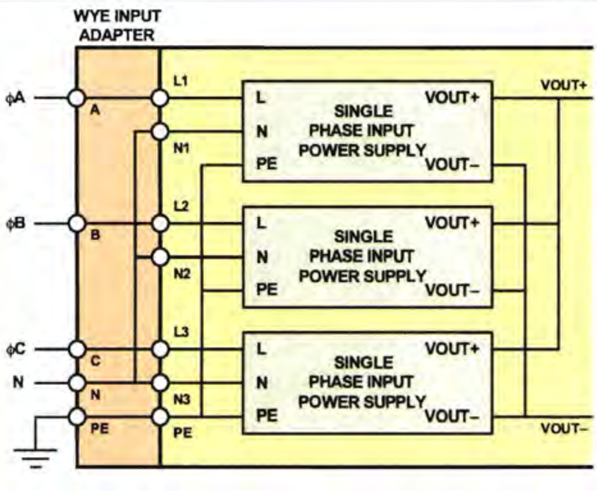


*Figure 8: Using an ac adapter assembly to configure three single-phase power supplies for operation from three-phase wye ac power*

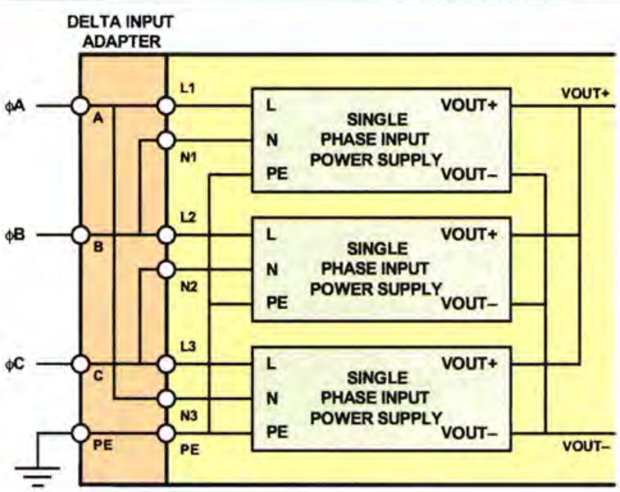


*Figure 9: Using an ac adapter assembly to configure three power supplies for operation from three-phase delta ac power*

## Option 2: Simple System Hardware, Complex Installation

It is possible to ship a system with the inputs to the three power supplies completely undedicated (**Figure 7**). Once the system is delivered to the installation site, the input power leads can be connected as needed for the local power configuration.

One advantage to this configuration is that single-phase (two- and three-wire configurations) can also be easily accommodated. This makes it possible to manufacture only one version of the ac power configuration for use anywhere in the world. From the design, manufacturing and logistics point of view, this represents huge savings. However, these savings are offset by the need to have a skilled electrician make the connections from the site ac power to the system.

## Option 3: Simple Installation, Complex System Hardware

While a system that can be configured at the installation site for any ac power configuration, single or three-phase, is very attractive to some OEMs, others have concerns. For example, suppose the installer mistakenly wires these power supplies from line-to-line in Europe. The 400Vac input in this case would probably destroy the power supplies, as they would only be rated for 264Vac maximum continuous input voltage. Damage can be prevented with input overvoltage detection and protection circuits, but this adds cost and complexity.

The solution is use ac input adapter assemblies. This requires that the customer order the correct input assembly for their type of three-phase ac power (wye or delta, and of course single-phase variations) but once the proper choice is made, installation is simple. The adapter assemblies contain the necessary wiring to connect the input power terminals to the three (or 3N) power supplies in the proper fashion. **Figures 8** and **9** show how these ac input power assemblies are internally wired.

In principle, this is no different to the factory-wired situation with which we started. In many cases, only three input assemblies are needed (three-phase wye, three-phase delta and single-phase). System OEMs often find this a much more manageable situation, both for manufacturing and logistics complexity, than manually pre-wiring each rack or cabinet. Each of the various ways that a system can be powered from three-phase ac power has its advantages and disadvantages, in both technical and business issues. No universal recommendation of one method as being best for all applications can be made. Each system OEM will have to decide for themselves which approach is best for their customers. ■

# THE DRIVE TO DC/DC CONVERTER INTEGRATION

**JOHN QUINLAN,** ENGINEERING MANAGER AT THE UR GROUP ANALYSES THE CHALLENGES OF POWER SUPPLY DESIGN PRESENTED TO TODAY'S DESIGN AND DEVELOPMENT ENGINEERS

Designers of today's electronic products find themselves on a seemingly endless drive to integrate more functions into a smaller space. Coupled with consumers' desires for longer battery life and environmental concerns over energy usage, these requirements are exacting.

These pressures put power supply designs under close scrutiny. The power supply, and in particular the DC/DC converter, is not only the key to the efficient delivery of power to increasingly complex circuits. It is also a major subsystem that itself requires considerable PCB area and space. Design improvements here can, therefore, make a significant contribution to end users' overall perception of a product.

## Major Trends

For some time now, the trend has been away from traditional linear converters and toward switch-mode power supplies (SMPSs) that provide higher efficiency (and hence reduce heat generation and simplify cooling requirements) and tight regulation. There have, however, been a number of penalties for designers who choose the switch-mode route: in particular, designs tend to be more complex and require more and larger external components than linear regulators.

However, there is a beguiling solution to the need to reduce SMPS footprint. Running at higher frequencies allows the use of much smaller external components. For instance, in a typical application stepping down a lithium ion battery voltage of 3.6V to 1.8V, with a 500mA drive current and 25% ripple, a 1MHz switching circuit would require an external inductor with a value of around 10μH. But choosing a figure of 5MHz reduces the required value to around 1μH; a much more practical figure in a very small footprint with low profile. Higher frequencies also allow the use of smaller output capacitors, with consequent further savings in cost and board space.

This move towards higher switching frequencies, however, itself poses challenges for the designer. High frequency content from these fast switchers leads power engineers into the realm of RF and requires careful attention to the small signal properties of the converter components and the parasitic elements of the PCB.

## Basic Mode of Operation

To understand these effects, it is first worth reviewing the basic mode of operation of such a power supply. A step-down SMPS functions by "chopping up" a DC input with power MOSFET switches and filtering the resultant pulse-train to produce a lower-level, steady output. A feedback loop controls the on and off times of the MOSFETs, ensuring that the right amount power is passed from output to input to satisfy the instantaneous loading conditions.

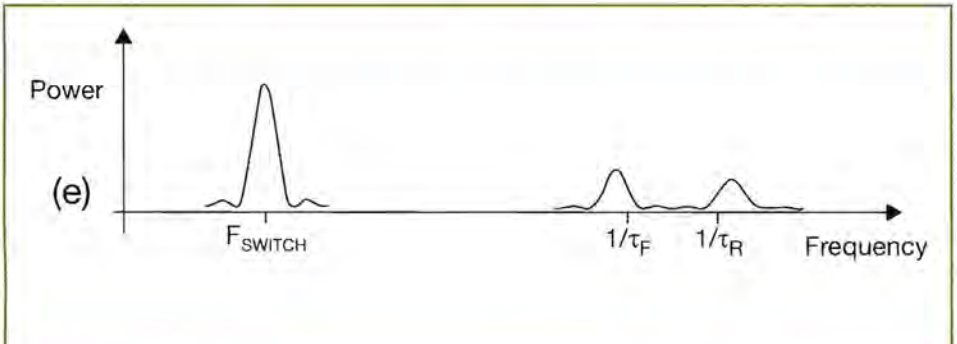


***Figure 1:*** *Switching waveform and associated frequency spectrum.*

Although faster switching produces higher efficiency and enables the use of smaller external capacitors and inductors, practical frequencies have to date been restricted by two factors: limitations in semiconductor technology; and the propensity of such circuits to produce noise.

Switching losses in semiconductor devices increase linearly with frequency. Each time the circuit switches, the input and output capacitances of the power MOSFETs are charged and discharged. The effect is quantified by a parameter known as the "figure of merit" (FOM), which is a constant for any semiconductor process technology and is calculated by taking the product of the gate charge and the MOSFET drain-to-source "on" resistance or $R_{DS(ON)}$.

The FOM embodies the concept that, while decreasing $R_{DS(ON)}$ cuts conduction losses, the result is proportionally increased switching loss. Engineers at Enpirion, part of the Power Semiconductor Research Team at Bell Labs, devised a semiconductor process that can tolerate high voltages, while delivering low FOM, which is one of the key breakthroughs achieved. While typical FOMs for power semiconductors range from 80 to 400mΩ∗nC, Enpirion's LDMSO process attains a figure below 10mΩ∗nC. Since the gate capacitance is reduced by as much as a

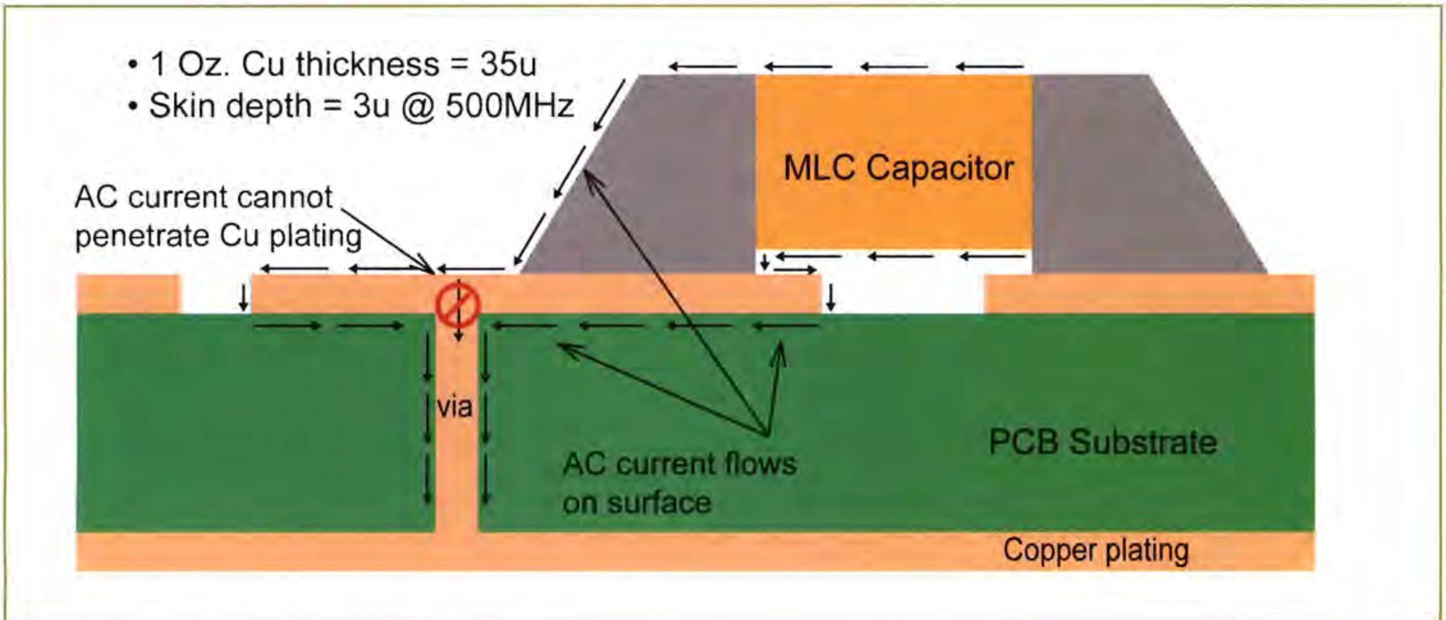


***Figure 2:*** *Skin effect and AC current flow on a PCB.*

factor of ten, the device can be operated at ten times the speed for the same efficiency, and inductor values can be decreased accordingly.

**Solving Circuit Challenges**

Solving the semiconductor design problem, however, does not necessarily solve the circuit design and noise challenges. The large, megahertz-range current pulses passing through the switches can make their way by conduction to other parts of the circuit. These same pulses may also propagate by radiation, risking system instability. Equally problematic can be the inevitable output ripple current, the magnitude of which is dependent upon the quality of the output filter.

It might at first sight seem that dealing with switching noise at frequencies of a few megahertz would be a relatively simple problem. However, the task is more complex than it appears. The frequencies involved can in fact be much higher than the fundamental switching frequency; at such speeds the behaviour of the circuit is dependent upon detailed device parameters that may escape the characterisation efforts even of the suppliers of the constituent parts of the assembly.

The first point to understand is that the switching waveform within a converter is not an ideal square wave. The fast yet finite rise and fall times of the waveform contribute significant transient energy at frequencies which may be up to a hundred times that of the fundamental. For example, the Enpirion EN5335QI 3A-integrated inductor DC/DC converter operates at a nominal 5MHz (that is a 200ns switching period) but has a rise time of 2ns and a fall time of approximately 3ns. Although these fast speeds contribute to high efficiency, they also correspond to frequency contributions at 500MHz and 330MHz respectively. In terms of power spectral density, the familiar sin(x)/x envelope of the square wave is extended with additional contributions well above the fundamental (**Figure 1**).

These transients can cause components to behave in unexpected ways. The most common source of problems is the external inductor. At high frequencies, it is necessary to take account of the small but not negligible inter-winding capacitance presented by the component. Effectively the device will act as a parallel LC combination with a resonant frequency dependent upon the precise values of inductance and capacitance. Below this frequency the component behaves as one would expect from an inductor, with increasing loss as frequency increases. But above this frequency, which can occur at a few hundred megahertz for a high-value device, capacitive effects begin to dominate, and high-frequency noise can pass straight through.

The reverse effect is exhibited by the output capacitors, with one important difference; the behaviour of most common capacitors is better characterised and in most cases standardised. For instance, the dielectric material properties, voltage tolerances and physical dimensions of an MLC capacitor are standardised: a 1206-size 10µF X5R MLCC will therefore have an ESL (equivalent series inductance) of approximately 1-2nH, irrespective of manufacturer; 0805-size device of the same value will have an ESL of around 0.5nH. ESR will tend to increase with decreasing case size, while ESL will tend to decrease with increasing case size.

Finally in terms of components, the behaviour of the MOSFET must be understood. It, too, exhibits an equivalent output capacitance. In addition, its body diode becomes important if the DC bias of the junction turns the diode on and offers an alternative conduction path.

**Understanding the Parasitics**

It is worth pointing out that many of these "stray" or parasitic phenomena are temperature dependent. This is particularly true of the inductor, in which DC (resistive) and AC loss are most affected. Saturation flux density may also change, depending on the core material used. Even the engineer who is aware of these possibilities may not be able to design for them: thermal characterisations are often difficult to obtain from inductor vendors; and even when they are available, it may in any case be impossible to predict or control the thermal environment in which the final assembly will be deployed.

The devices that make up the converter are most commonly interconnected via a PCB, which can also contribute to the design difficulties. For example, a copper PCB trace 0.035mm thick, 10mm in length and 1mm wide presents a parasitic inductance of around 7nH, a significant number when dealing with 300MHz to 500MHz transients. Vias also have a smaller, but quantifiable inductance.

Even more complex is the "skin effect", which causes high-frequency currents to be carried in the surface of conducting features, rather than within the bulk material. At 500MHz, the skin depth of copper interconnect is just 3µm, implying that current may "choose" a significantly longer conduction path than the designer might expect (**Figure 2**).

The combination of all of these effects produces a complex picture indeed (**Figure 3**). If the high-frequency content of the output signal is above the output inductor's self-resonant frequency, noise will freely pass through it. The input and output filter capacitors will typically have a resonance of between 1MHz and 10MHz and so, from a high frequency perspective, will be dominated by the inductive properties of the capacitor itself and of the trace, pad and via inductances associated with the PCB.

The picture starts to look even more challenging when one considers the magnitude and nature of the pulsed currents in the input current loop, contrasted with the aim of providing smooth DC from the output. The engineer seeking to prevent transients from making it past the output filter section must look well above the 20MHz typical bandwidth quoted by DC/DC converter manufacturers. If spikes are observed, it may be necessary to choose an output filter capacitor with a lower ESL. If necessary, another lower value ceramic capacitor can be placed in parallel with the bulk output filter capacitor.

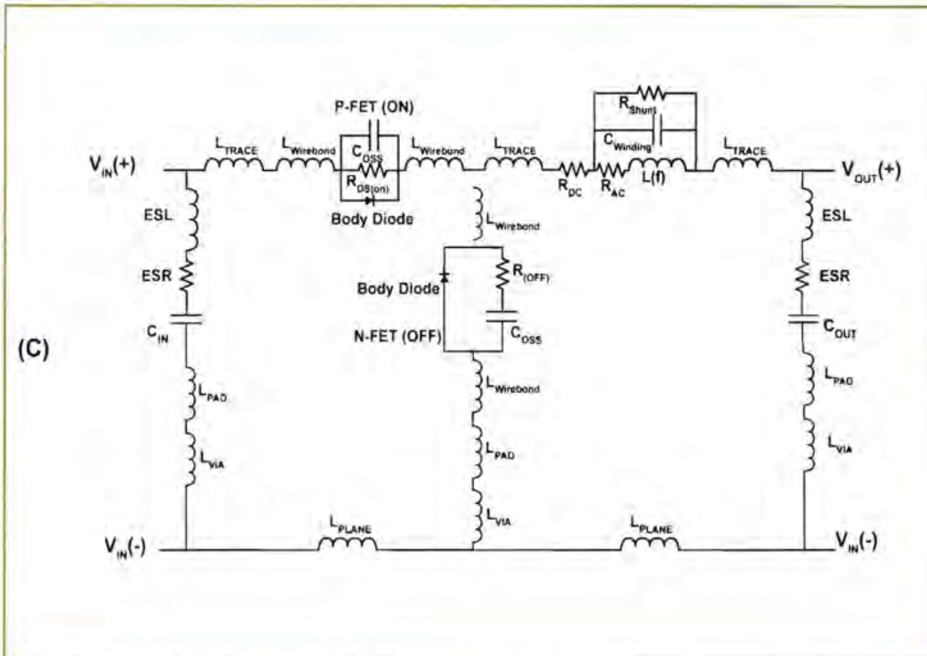


*Figure 3: Block diagram showing the complete high frequency model including the PCB effects.*

The input and output current loops are the primary source of radiated noise in the converter design – they effectively act as loop antennas. To minimise the problem, the physical size of the loops must be reduced. The input filter capacitor must be as close to the DC/DC converter package as possible.

### Successful Designs

At the output, placing the magnetic components is the most important element in a successful design, for both conducted and radiated noise. The designer must ensure a low impedance path between the switch and the inductor to reduce the voltages generated by the large pulsed currents flowing between the two. This path includes the switch's wire bond and package lead, a solder joint, a board trace and a further solder joint and component lead at the inductor end.

A DC/DC converter with an integrated inductor can both reduce the loop length and provide improved isolation between input and output. A device such as Enpirion's EN5322QI integrates all converter functionality, including MOSFETs, control and compensation and the required inductor, in a tiny 6mm x 4mm x 1.1mm QFN package.

Integration of the inductor also removes the burden of characterisation and associated variability from the designer and places this on the power semiconductor vendor. With the inductor housed within the semiconductor package, thermal dependency is also reduced and overall system footprint is cut.

Moreover, once the semiconductor design is completed, the converter can be tested as a whole unit, ensuring that the design and manufacture of the device have produced the expected results. As a result, high levels of integration can make DC/DC converter design considerably easier and perhaps even banish the high-frequency demons that are beginning to plague power designers.

This illustrates the level of support a company like UR Group can provide to designers working in a number of industries, from broadcast, medical and industrial to automation and test and instrumentation, as well as military and avionics. Today's drive to integrate a host of functions into a smaller space may seem endless, however few designers would dispute the benefits of teaming-up with a partner who has design-in expertise and a wide portfolio of products. ■

# CHARGING AND DISCHARGING METHODS TO EXTEND LI-ION BATTERY LIFE

**FRAN HOFFART** FROM LINEAR TECHNOLOGY IN THIS ARTICLE DISCUSSES PRESENT METHODS FOR CHARGING AND DISCHARGING LI-ION BATTERIES TO CONSIDERABLY INCREASE BATTERY LIFE

Much emphasis has been put on increasing Lithium Ion battery capacity to provide the longest product run time in the smallest physical size. But there are instances where a longer battery life, an increased number of charge cycles or a safer battery is more important than battery capacity. This article will present methods relating to charging and discharging Li-Ion batteries that can considerably increase battery life.

Rechargeable Lithium-Ion, including Lithium-Ion polymer batteries can be found in practically every high-performance portable product and the reason for this is well justified. Compared to other rechargeable batteries, Lithium Ion batteries have a higher energy density, higher cell voltage, low self-discharge, very good cycle life, are environmentally friendly and are simple to charge and maintain. Also, because of their relatively high voltage (2.9V to 4.2V) many portable products can operate from a single cell, thereby simplifying an overall product design.

### Lithium Ion Battery Basics

Before covering the battery charger's role in extending battery life, a quick review of the Lithium Ion battery is necessary. Lithium is one of the lightest metals, one of the most reactive and has the highest electrochemical potential, making it the ideal material for a battery. A Li-Ion battery contains no Lithium in a metallic state, but instead uses Lithium Ions that shuttle back and forth between the cathode and anode of the battery during charge and discharge.

Although there are many different types of Li-Ion batteries, the most popular chemistries presently in production can be narrowed down to three, all relating to the cathode materials used in the battery. The Lithium Cobalt chemistry has become more popular in laptops, cameras and cell phones mainly because of its greater charge capacity. Other chemistries are used based on the need for high discharge currents, improved safety, or where cost is the driving factor. Also, new hybrid Li-Ion batteries are in development, based on a combination of cathode materials incorporating the best features of each chemistry.

Unlike some other battery chemistries, Li-Ion battery technology is not yet mature. Research is ongoing with new types of batteries that have even higher capacities, longer life and improved performance than present day batteries. **Figure 1** highlights some important characteristics of each battery type.

### Lithium Ion Polymer Batteries

A Lithium Ion Polymer battery is charged, discharged and has characteristics similar to a standard Li-Ion battery. The main difference between the two is that a solid ion conductive polymer replaces the liquid electrolyte used in a standard Li-Ion battery, although most polymer batteries also contain an electrolyte paste to lower the internal cell resistance.

Eliminating the liquid electrolyte allows the polymer battery to be housed in a foil

| Cathode Materials | Advantages | Disadvantages |
|---|---|---|
| Lithium Cobalt Oxide (most common) | • High capacity | • Lower charge and discharge rates<br>• Higher cost |
| Lithium Manganese Oxide | • Lower ESR<br>• Higher charge and discharge rates<br>• Higher temperature operation<br>• Inherently safer | • Lower capacity<br>• lower cycle Life<br>• Shorter lifetime |
| Lithium Phosphate (newest, A123 & Saphion) | • Very low ESR<br>• Very high charge and discharge rates<br>• High temperature operation<br>• Inherently safer | • Lower Discharge voltage<br>• Lower float voltage<br>• Lower capacity |

***Figure 1:*** *Most common Lithium Ion batteries*

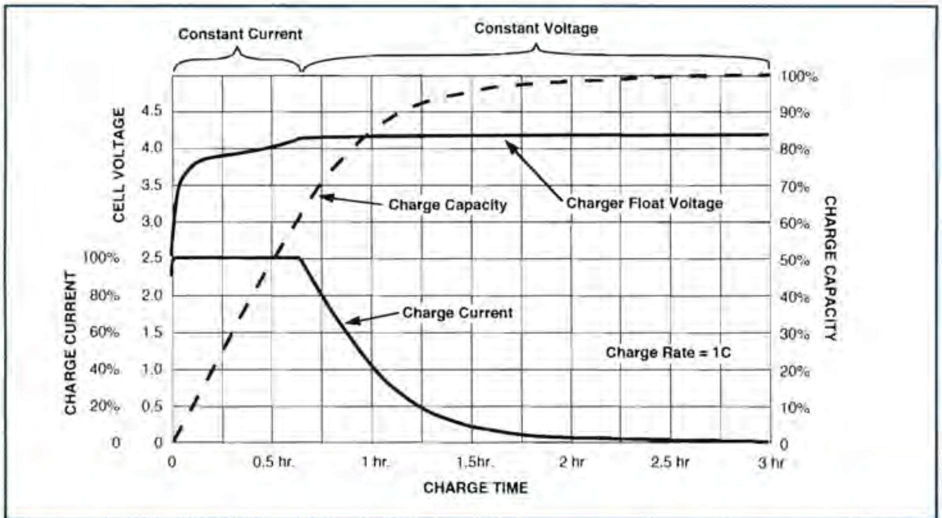


***Figure 2:*** *Typical charge profile showing battery current, voltage and capacity*

pouch rather than the heavy metal case required for standard Li-Ion batteries. Li-Ion polymer batteries are gaining popularity based on their cost-effectiveness to produce and their flexibility for fabricating in many different shapes, including very thin.

**Battery Lifetime**

All rechargeable batteries wear out and Li-Ion cells are no exception. Battery manufacturers usually consider end-of-life for a battery to be when the battery capacity drops to 80% of the rated capacity. However, batteries can still deliver usable power below 80% charge capacity, even though run time is shortened.

The number of charge/discharge cycles is commonly used when referring to battery life, but cycle life and battery life (or service life) can be different lengths of time. Charging and discharging will eventually reduce the battery's active material and cause other chemistry changes, resulting in increased internal resistance and permanent capacity loss. But permanent capacity loss also occurs even when the battery is not in use. Permanent capacity loss is greatest at elevated temperatures with the battery voltage maintained at 4.2V (fully charged).

For maximum storage life, batteries should be stored with a 40% charge (3.6V) at 40°F (refrigerator). Perhaps one of the worst locations for a Li-Ion battery is in a laptop computer when used daily on a desktop with the charger connected. Laptops typically run warm or even hot, raising the battery temperature, and the charger is maintaining the battery near 100% charge. Both of these conditions shorten battery life, which could be as short as six months to a year.

If possible, remove the battery and use the AC adapter for powering the laptop when the computer is used on a desktop. A properly cared for laptop battery can have a service life of 2-4 years, or more.

**Lithium Ion Battery Capacity Loss**

There are two types of battery capacity losses, recoverable loss and permanent loss. After a full charge, a Li-Ion battery will typically lose about 5% capacity in the first 24 hours, then approximately 3% per month because of self-discharge and an additional 3% per month if the battery pack has pack protection circuitry. These self-discharge losses occur when the battery remains around 20°C, but will increase considerably with higher temperature and also as the battery ages. This capacity loss can be recovered by recharging the battery.

Permanent capacity loss, as the name implies, refers to permanent loss that is not recoverable by charging. This loss is linked to battery life because when the permanent capacity loss drops to approximately 80%, the battery is considered at the end of its life. Permanent capacity loss is mainly due to the number of full charge/discharge cycles, the battery voltage and battery temperature. The more time the battery remains at 4.2V or 100% charge level (or 3.6V for Li-Ion Phosphate), the faster the capacity loss occurs. This is true whether the battery is being charged or just in a fully charged condition with the voltage near 4.2V. Always maintaining a Li-Ion battery in a fully charged condition will shorten its lifetime. The chemical changes that shorten the battery lifetime begin when it is manufactured, and these changes are accelerated by high float voltage and high temperature. Permanent capacity loss is unavoidable, but it can be held to a minimum by observing good battery practices when charging, discharging or simply storing the battery.

Using partial discharge cycles can greatly increase cycle life and charging to less than 100% capacity can increase battery life even further.

**Determining Cycle Life or Service Life**

There isn't any one factor that increases or decreases battery life, but it often is a combination of several.

For increased cycle life:

(1) Use partial discharge cycles. Using only 20% or 30% of the battery capacity before recharging will extend cycle life considerably. As a general rule, 5 to 10 shallow discharge cycles are equal to one full discharge cycle. Although partial discharge cycles can number in the thousands, keeping the battery in a fully charged state also shortens battery life. Full discharge cycles (down to 2.5V or 3V, depending on chemistry) should be avoided, if possible.

(2) Avoid charging to 100% capacity. Selecting a lower float voltage can do this. Reducing the float voltage will increase cycle life and service life at the expense of reduced battery capacity. A 100mV to 300mV drop in float voltage can increase cycle life from 2 to 5X or more. Li-Ion Cobalt chemistries are more sensitive to a higher float voltage than other chemistries. Li-Ion Phosphate cells typically have a lower float voltage than the more common Li-Ion batteries.

(3) Select the correct charge termination method. Selecting a charger that uses minimum charge current termination (C/10 or C/x) can also extend battery life by not charging to 100% capacity. For example, ending a charge cycle when the current drops to C/5 is similar to reducing the float voltage to 4.1V. In both instances, the battery is only charged to approximately 85% of capacity, which is

an important factor in battery life.

(4) Limit Battery temperature. Limiting battery temperature extremes extends battery life, especially prohibiting charging below 0°C. Charging below 0°C promotes metal plating at the battery anode which can develop into an internal short, producing heat and make the battery unstable and unsafe. Many battery chargers have provisions for measuring battery temperature to assure charging does not occur at temperature extremes.

(5) Avoid high charge and discharge currents, as they reduce cycle life. Some chemistries are more suited for higher currents such as Li-Ion manganese and Li-Ion Phosphate. High currents place excessive stress on the battery.

(6) Avoid very deep discharges below 2V or 2.5V, as this will quickly permanently damage a Li-Ion battery. Internal metal plating can occur causing a short circuit, making the battery unusable and unsafe. Most Li-Ion batteries have electronic circuitry within the battery pack that open the battery connection if the battery voltage is less than 2.5V, exceeds 4.3V, or if the battery current exceeds a predefined threshold level when charging or discharging.

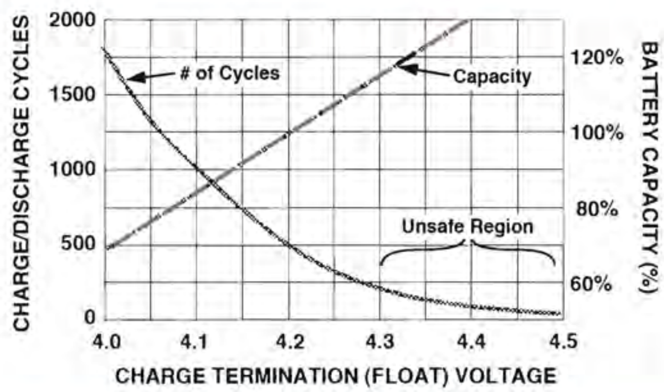


***Figure 3:*** *Charger float voltage vs battery capacity and cycle life*

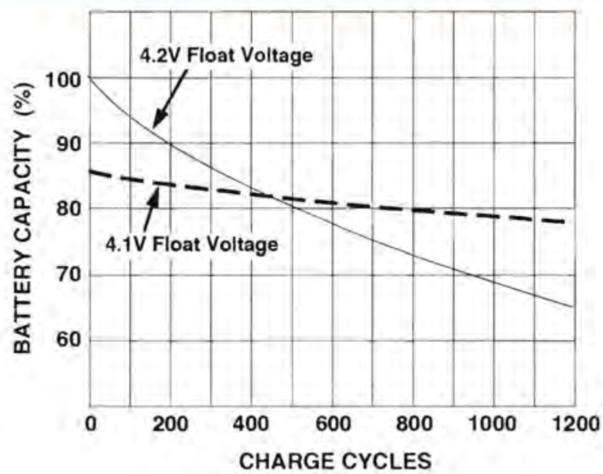


***Figure 4:*** *Cycle life and capacity vs 4.1V and 4.2V float voltages*

### Li-Ion Charging Methods

The recommended way to charge a Li-Ion battery is to provide a ±1% voltage-limited constant current to the battery until it becomes fully charged and then stop. Methods used to determine when the battery is fully charged include timing the total charge time, monitoring the charge current, or a combination of the two.

The first method applies a voltage-limited constant current, ranging from C/2 to 1C for 2.5 to 3 hours, thus bringing the battery up to 100% charge. A lower charge current can also be used, but will require more time.

The second method is similar but it requires monitoring the charge current. As the battery charges, the voltage rises, exactly as in the first method. When it reaches the programmed voltage limit, which is also called the float voltage, the charge current will begin to drop. When it first begins to drop, the battery is about 50% to 60% charged. The float voltage continues to be applied until the charge current drops to a sufficiently low level (C/10 to C/20) at which time the battery is approximately 92% to 99% charged and the charge cycle ends. Presently, there is no safe method for fast charging (less than 1 hour) a standard Li-Ion battery to 100% capacity.

Applying a continuous voltage to a battery after it is fully charged is not recommended, as it will accelerate permanent capacity loss and may cause internal lithium metal plating. This plating can develop into an internal short circuit, resulting in overheating and making the battery thermally unstable. The length of time required is months.

Some Li-Ion battery chargers allow a thermister to be used to monitor battery temperature. The main purpose is to prevent charging if the battery temperature is outside the recommended window of 0°C to 40°C. Unlike NiCd or NiMH batteries, Li-Ion cell temperature rises very little when charging. See **Figure 2** for a typical Li-Ion charge profile showing charge current, battery voltage and battery capacity vs time.

### The Letter "C"

The letter "C" is a battery term used to indicate the battery manufacturers stated battery discharge capacity, which is measured in mAHr. For example, a 2000mAHr rated battery can supply a 2000mA load for one hour before the cell voltage drops to its zero capacity voltage. In the same example, charging the battery at a C/2 rate would mean charging at

1000mA (1A).

The letter "C" becomes important in battery chargers because it determines the correct charge current required and the length of time needed to fully charge a battery. When discussing minimum charge current termination methods, a 2000mAHr battery using C/10 termination will end the charge cycle when the charge current drops below 200mA.

**Determining Battery Float Voltage**

The main determining factor is the electrochemical potential of the active materials used in the battery's cathode, which for Lithium is approximately 4V. The addition of other compounds will raise or lower this voltage. The second factor is a trade-off between cell capacity, cycle life, battery life and safety. The curve shown in **Figure 3** shows the relationship between cell capacity and cycle life.

Most Li-Ion manufacturers have set a 4.2V float voltage as the best balance between capacity and cycle life. Using 4.2V as the constant voltage limit (float voltage), a battery can typically deliver about 500 charge/discharge cycles before the battery capacity drops to 80%. One charge cycle consists of a full charge to a full discharge. Multiple shallow discharges add up to one full charge cycle.

Although charging to a capacity less than 100% using either a reduced float voltage or minimum charge current termination will result in initial reduced battery capacity, as the number of cycles increases beyond 500, the battery capacity of the lower float voltage can exceed the higher float voltage. **Figure 4** illustrates how the recommended float voltage compares with a reduced float voltage with regard to capacity and the number of charge cycles.

Because of the different Li-Ion battery chemistries and other conditions that can affect battery life, the curves shown here are only estimates of the number of charge cycles and battery capacity levels. Even a similar battery chemistry from different manufacturers can have dramatically different results due to minor differences in battery materials and construction methods.

Battery manufacturers specify a charge method and a float voltage the end user must use to meet the battery specifications for capacity, cycle life and safety. Charging above the recommended float voltage is not recommended. Many batteries include a battery pack protection circuit, which temporarily opens the battery connection if the maximum battery voltage is exceeded.

Once opened, connecting the battery pack to the charger will normally reset the pack protection. Battery packs often have a voltage printed on the battery, such as 3.6V for a single cell battery. This voltage is not the float voltage, but rather the average battery voltage when the battery is discharging.

**Charger for Extending Battery Life**

Although a battery charger has no control over a battery's depth-of-discharge, discharge current and battery temperature, all of which have an effect on battery life, many chargers have features that can increase battery life, sometimes dramatically.

A battery charger's role in extending battery lifetime is mainly determined by the charger's float voltage and charge termination method. Many Linear Technology Li-Ion chargers feature a ±1% (or lower) fixed float voltage of 4.2V, but there are some offerings in 4.1V and 4.0V, as well as adjustable float voltages. **Figure 5** contains a list of battery chargers that feature a reduced float voltage that can increase battery life when used to charge a 4.2V Li-Ion battery.

Battery chargers that do not offer lower float voltage options are also capable of increasing battery life. Chargers that provide minimum charge current termination methods (C/10 or C/x) can provide a longer battery life by selecting the correct charge current level at which to end the charge cycle.

A C/10 termination level will only bring the battery up to about 92% capacity, but there will be an increase in cycle life. A C/5 termination level can double the cycle life, although the battery charge capacity drops even further to approximately 85%. **Figure 6** contains a number of Linear Technology chargers that provide either C/10 (10% current threshold) or C/x (adjustable current threshold) charge termination mode.

**Choosing What You Need**

Can you have both, a longer run time and longer battery life? With present battery technology and without increasing battery size, the answer is no. For maximum run time, the charger must charge the battery to 100% capacity. This places the battery voltage near the manufacturer's recommended float voltage, which is typically 4.2V ±1%.

Unfortunately, charging and maintaining the battery near these levels shortens battery life. One solution is to select a lower float voltage, which prohibits the battery from achieving 100% charge, although this would require a higher capacity battery to

| Product | Description | Float Voltage |
|---|---|---|
| LTC1730-4.1 | Pulse charger | 4.1V |
| LTC1731-4.1 | Linear Charger Controller | 4.1V |
| LTC1731-8.2 | 2 cell Linear Charger Controller | 8.2V |
| LTC1732-4.1 | Linear Charger Controller | 4.1V |
| LTC1733-4.1 | Linear Charger | 4.1V |
| LTC1734-4.1 | Linear Charger | 4.1V |
| LTC4050-4.1 | Linear Charger | 4.1V |
| LTC4064-4.0 | Linear Charger | 4.0V |
| LTC4008 | Switching Charger Controller | Adjustable |
| LTC1980 | Switching Charger Controller | Adjustable |
| LTC4089-1 | HV / High Efficiency Charger | 4.1V |

***Figure 5:*** *Battery chargers that provide a lower float voltage for increased battery life*

| Product | Description | Termination Method |
|---|---|---|
| LTC3550/-1 | Linear Charger & DC/DC Converter | C/x |
| LTC3552/-1 | Linear Charger & DC/DC Converter | C/x |
| LTC4001 | Switching Charger | C/x |
| LTC4054/X/L | Linear Charger | C/10 |
| LTC4058/X | Linear Charger | C/10 |
| LTC4061 | Linear Charger | C/x or adj. timer |
| LTC4062 | Linear Charger | C/x or adj. timer |
| LTC4063 | Linear Charger | C/x or adj. timer |
| LTC4068/X | Linear Charger | C/x |
| LTC4075 | Dual Input Linear Charger | C/x |
| LTC4075HVX | Dual Input Linear Charger | C/x |
| LTC4076 | Dual Input Linear Charger | C/x |
| LTC4077 | Dual Input Linear Charger | C/10 |
| LTC4078 | Dual Input Linear Charger | C/x |
| LTC4096/X | Dual Input Linear Charger | C/x |
| LTC4097 | Dual Input Linear Charger | C/x |

***Figure 6:*** *Battery chargers that feature minimum charge current termination method for increased battery life*

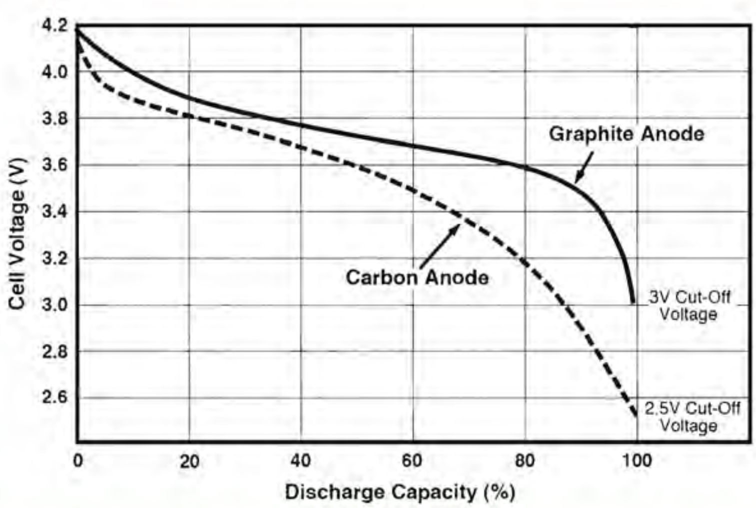


***Figure 7:*** *Li-Ion discharge voltage profile for different anode materials*

provide the same run time. Of course, in many portable products, a larger sized battery may not be an option.

Also, using a C/10 or C/x minimum charge current termination method can have the same effect on battery life as using a lower float voltage. Reducing the float voltage by 100mV will reduce capacity by approximately 15%, but can double the cycle life. At the same time, terminating the charge cycle when the charge current has dropped to 20% (C/5) also reduces the capacity by 15% and achieves the same doubling of cycle life.

### Output Voltage When Discharging

As expected, during discharge of a typical Li-Ion battery, the battery voltage will slowly drop. The discharge voltage profile vs time depends on a number of factors, including discharge current, battery temperature, battery age and the type of anode material used in the battery. Presently, most Li-Ion batteries use either a petroleum-based coke material or graphite. The voltage profiles for each are shown in **Figure 7**.

The more widely used graphite material produces a flatter discharge voltage between 20% and 80% capacity, then drops quickly near the end, whereas the coke anode has a steeper voltage slope and a lower 2.5V cutoff voltage. The approximate remaining battery capacity is easier to determine with a coke material by simply measuring the battery voltage.

### Parallel or Series Connected Cells

For increased capacity, Li-Ion cells are often connected in parallel. No special requirements are needed, other than the batteries should be the same chemistry, manufacturer and size. Series connected cells require more care because cell capacity matching and cell balancing circuitry is often required to assure that each cell reaches the same float voltage and the same level of charge.

Connecting two cells (that have individual pack protection circuitry) in series is not recommended because a mismatch in capacity can result in one battery reaching the over-voltage limit, thus opening the battery connection. Multicell battery packs should be purchased assembled with the appropriate circuitry from a battery manufacturer.

### Analysing the Factors

The lifetime of a Li-Ion battery is determined by many factors of which the most important are battery chemistry, depth of discharge, battery temperature and battery capacity termination level. Charging a battery to the manufacturer's suggested 100% capacity level will provide the stated number of full charge/discharge cycles. Applications requiring increased battery lifetime will benefit greatly by selection of a charger that allows charging to less than 100% capacity. This is achieved by selecting a battery charger that features a lower float voltage or one that terminates earlier in the charge cycle. ■

LUIGI AMADUZZI FROM FONDAZIONE UGO BORDONI IN ITALY AND MAURIZIO TINTI FROM THE UNIVERSITY OF BOLOGNA PRESENT THEIR IMPLEMENTATION OF A MICROWAVE RECEIVER WITH LOW-COST COMPONENTS

# IMPLEMENTATION OF A MICROWAVE DICKE RECEIVER

This article describes the implementation of a Dicke receiver with low-cost components. The equipment can be used to demonstrate the man-made emission of electro-magnetic fields in the microwave range or as educational radio astronomy receiver.It is well known that the most critical blocks of the equipment for the measurement of the electromagnetic radiation in the microwave range (e.g. the radio telescopes) are the receivers. It must have low noise so that the systems are very sensitive and, consequently, it is possible to measure very small field differences.

### The Use of LNBs

Expensive low noise amplifiers (LNA) are required for the implementation of front-ends in receivers (the section to which the receiving antennas are directly connected). In the case of high performance devices, they should be cooled to low temperatures.

For some years now such systems have been available in the consumer market, especially low-cost devices used for the satellite TV reception, namely LNBs (low noise blocks) with NF of 0.3dB. For our design we've used an LNB for satellite TV reception and a parabolic antenna.

An LNB amplifies the input signal that fills a portion of the Ku band assigned to satellite TV, in the range of 11÷12.5GHz. With an internal local oscillator this band is converted into a convenient output intermediate frequency that is, generally, extended from 1 to 2GHz. The block's total gain is about 60dB and the pass-band is about 1GHz.

These considerable technical performances are at the root of our decision to use this device, even thought it suffers from a considerable gain-instability linked to the environomental temperature. Equally, the characteristics of the detector that is used in the follow-up stage also depend on the environmental temperature.

Stability of the whole system can be reached by modifying the LNB, in such a manner that the equipment works as a "Dicke receiver", where the output signal is a result of the difference between the antenna signal and the signal generated by the "reference load", and the received signal variations due to the thermal drift are largely cancelled.

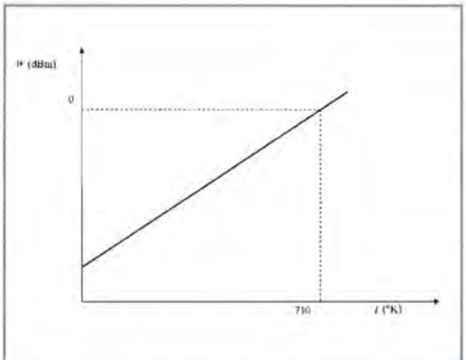

***Figure 1:*** *Received noise power (W) from the hot object in function of its temperature T*

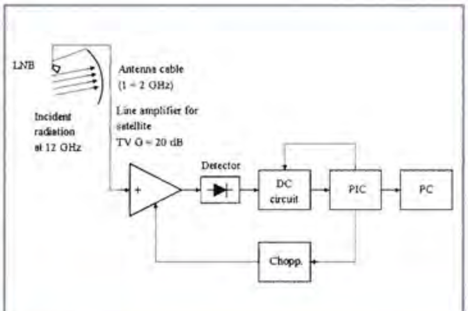

***Figure 2:*** *Block diagram of the reception system*

### Theory

From the LNB's signal-to-noise factor (S/N) indicated by the constructor (0.3dB) it is possible to calculate the minimum detectable temperature by the equipment. The noise figure $F$ corresponding to the noise S/N first indicated is:

$$F = 10^{\frac{0,3}{10}} = 1.07$$

It then follows that the receiver noise temperature $T_R$, determined from the front-end amplifier noise temperature, is:

$$T_R = T_{env}(F-1) = 20.\ °K$$

(we have considered the environmental temperature $T_{env}$ = 290°K).

If the equipment is used to measure man-made electromagnetic radiation, considering the thermal noise emitted by a wall (at a temperature of $T_{wall} \approx$ 290°K or 20°C) intercepted by the antenna beam in absence of a person, the system's temperature $T_{sys}$ is:

$$T_{sys} = T_R + 0.6T_{wall} \cong 195\ °K$$

(the paraboloid efficiency indicated by the constructor is 60%).Then, the minimum detectable temperature difference ($\Delta T_{min}$) is:

$$\Delta T_{\min} = 2\frac{T_{sys}}{\sqrt{B\frac{1}{f_c}}} = 0.058\ ^\circ\mathrm{K}$$

($B \approx 1$ GHz is the receiver pass-band and $f_c = 22$Hz is the cut-off frequency of the digital filter).

These calculations show the ease with which a hot body operating at 37°C in respect to the 20÷25°C temperature of the surrounding environment can be identified and selected by the antenna beam. In fact, in this case, the receiver must only detect and interact, with notable security margin, at an obvious system $\Delta T$ (the difference between the person's temperature and the background wall temperature) of the order of about ten degrees, therefore, more than the theoretical limits of a degree fraction that we have first calculated.

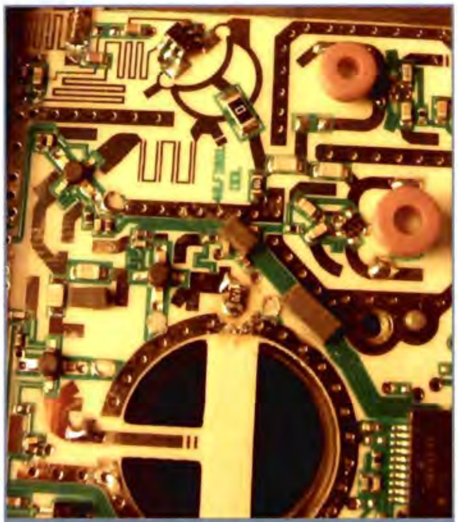

***Figure 3:*** *LNB modification. The SMD resistor is visible (in white), inserted in the place of one of the two dipoles*

Instead, if used as a teaching radio telescope, the background will be the Cold Sky emission. We can consider the temperature of the Cold Sky $T_{Sky} \approx 40$°K (for the presence of the atmosphere). As such, the system temperature is:

$$T_{sys} = T_R + 0.6T_{Sky} \cong 45\ ^\circ\mathrm{K}$$

then the minimum detectable temperature difference is $\Delta T_{min} = 0.013$°K.

Generally, it is possible to determine the temperature of a hot object with the Nyquist equation:

$$W = k \cdot T \cdot B$$

($k = 1.38 \cdot 10^{-23}$ J · °K$^{-1}$ = Boltzmann constant) by using the received noise power $W$ we can calculate its temperature

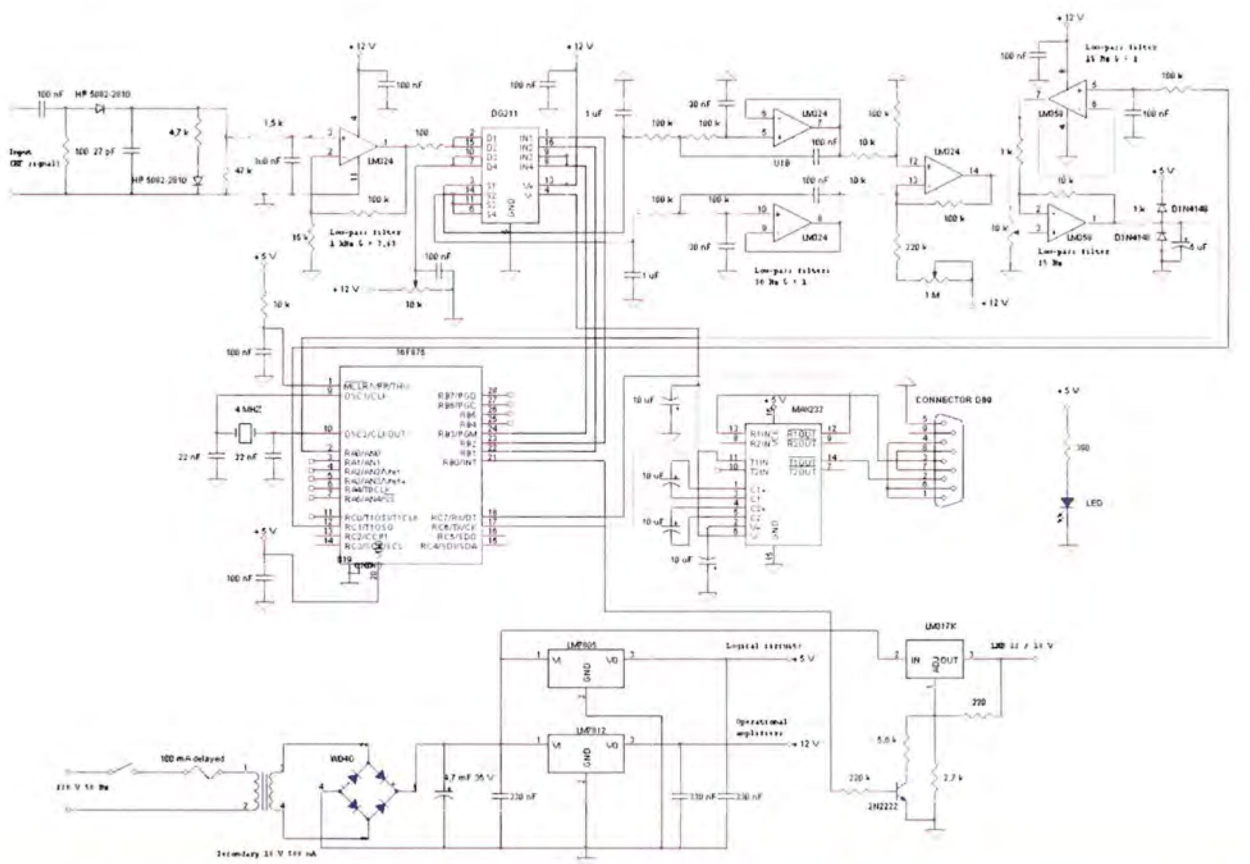

***Figure 4:*** *Electrical diagram*

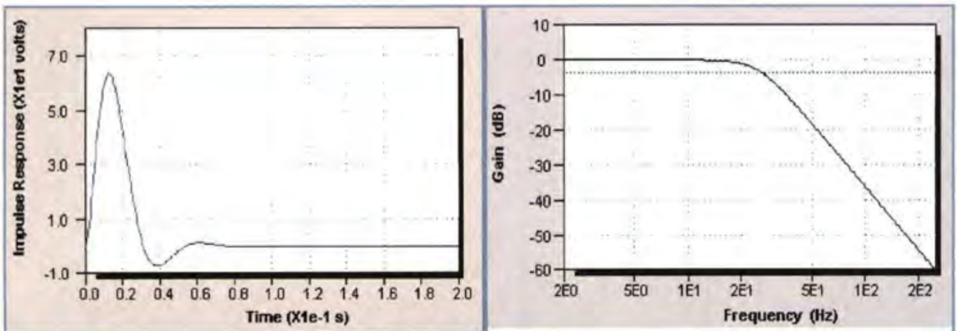


***Figure 5:*** *Impulse response (left) and amplitude diagram (right) of the analogue filter.*

$T$ ($B$ is the bandwidth of the LNB, about 1GHz). Because the LNB and the line amplifier gain is 80dB, considering a detecting block that can operate between –60dBm and 0dBm, it is possible to measure temperatures from 42°K (double of $T_{sys}$) to 730°K.

### Equipment Description

The level of noise power received by the LNB can be obtained by "detecting" the intermediate frequency signal with a diode. The noise level that allows a good operation of the diode is about 0dBm (1mW). This level is obtained by intermediate frequency amplification. This is achieved with a satellite TV line amplifier, a low-cost device from the consumer market. Its gain is 20dB and its pass-band is about 1GHz (900÷2300MHz). The intermediate frequency signal that comes out of the LNB has this band. The detector circuit, designed according to a scheme that provides the temperature compensation (ref: H. Eriksson R.W. Waugh, *"A Temperature Compensated Linear Diode Detector"*, Design Tip Agilent), has been mounted inside the metallic box of the line amplifier.

The LNBs available on the market are able to receive the horizontal and vertical polarisation of two orthogonal dipoles. The selection is controlled by the voltage value of the supply (12V vertical polarisation, 18V horizontal polarisation) through the antenna line. Since we are not interested in distinguishing the polarisation of the received radiation (we observe thermal noise sources that emit non-polarised radiation) for our application, we modified the used LNB by excluding one of the dipoles and substituting it with a resistor (that has in series a capacitor for the direct component block), matched with the input impendence of the front-end amplifier (50Ω). In this way, when the input that corresponds to the resistor is selected (by the supply voltage), the resistor acts as a reference noise source. **Figure 3** shows the modified LNB.

The LNB input is switched between the antenna and the reference load by a chopper (controlled by the PIC, see **Figure 4**) based on the LM317 voltage regulator, that provides the LNB with the supply voltages corresponding to the load and the antenna through the line amplifier. The LNB's chopper frequency must be selected between a reasonable lower limit (e.g. 10Hz), and the maximum switching frequency of the LNB. The minimum sampling period $T_S$ depends on the switching times of the components (rise and fall time of sample-hold and LNB):

$$T_s = 2T_{on-offSH} + 2T_{off-onSH} + 2T_{on-offLNB} =$$

$$2 \cdot 0.001 + 2 \cdot 0.001 + 2 \cdot 0.0028 = 0.0116\,\text{s}$$

This corresponds to a maximum chopper frequency of 86Hz.

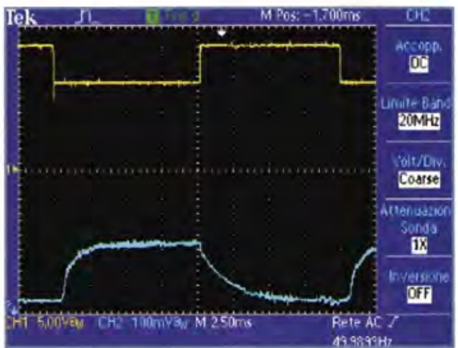


***Figure 6:*** *LNB supply (top), the detector output (down)*

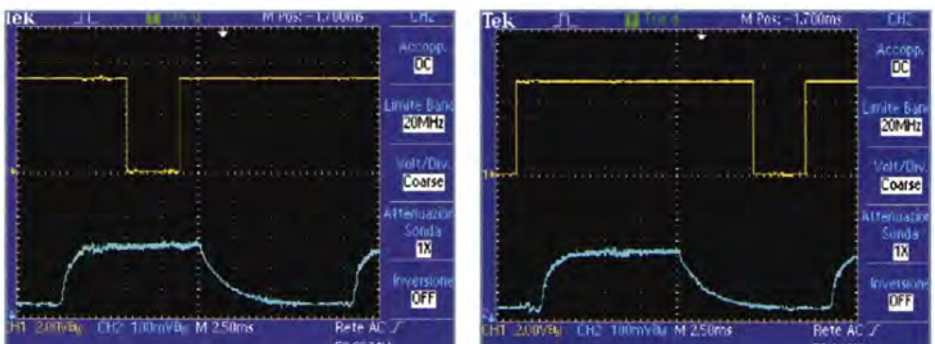


***Figure 7:*** *Switch closing - horizontal polarisation (left, up trace), switch closing - vertical polarisation (right, up trace), detector output (down trace)*

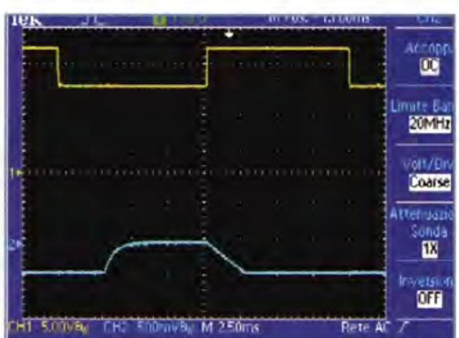


***Figure 8:*** *LNB preamplifier Vgs and Vds.*

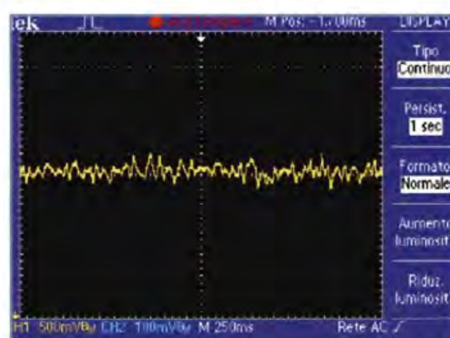


***Figure 9****: Input PIC16F876A AD converter (without signal).*

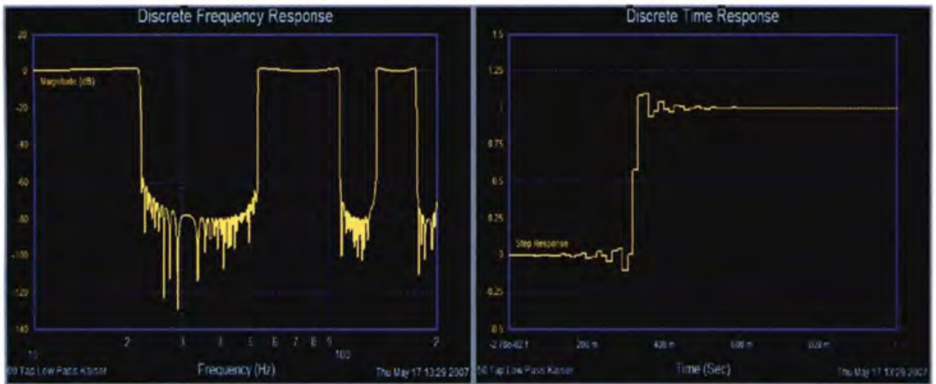

***Figure 10:*** *Digital low-pass filter 22Hz (FIR - Kaiser, 50 cells)*

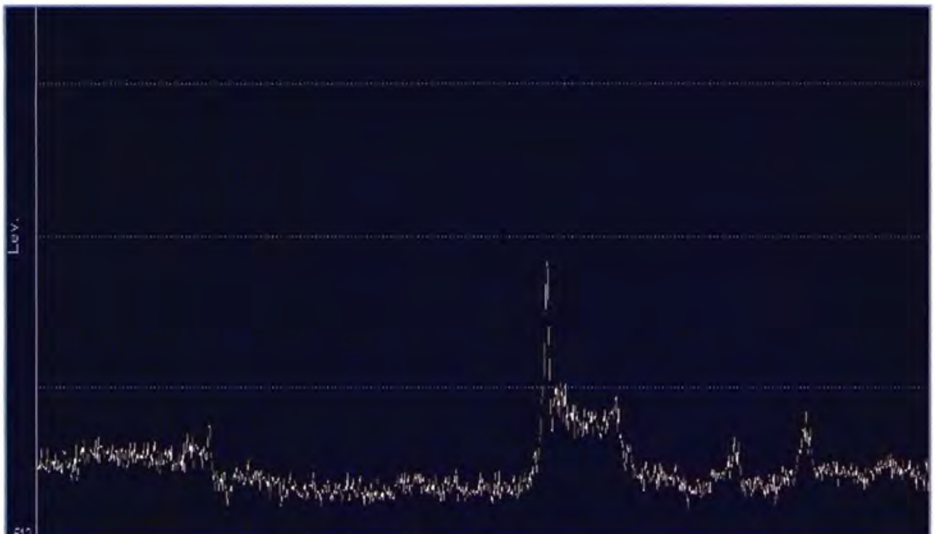

***Figure 11:*** *The output signal acquired and shown on the PC monitor*

The detector DC output transits through a series of filters. The first is an active low-pass filter that amplifies the signal (G = 8) and limits the band signal between DC and 1kHz. The signal is then switched by the DG211 analogue switch (sample-hold) in two separate channels. The first channel is for the antenna signal, the second channel is for the reference signal.

The analogue switch is controlled by the PIC, synchronous with the signal that controls the chopper.

The two signals are then limited in the band interval between 0 and 25Hz by two Sallen-Key filters with gain 1.

Subsequently, a differential amplifier with gain 10 makes the difference between the antenna signal and the reference signal. Filters and differential amplifier are implemented with the quadruple operational amplifier LM324. Because the signal level received by the antenna is always higher than the signal received by the reference load, we subtract from the output signal the offset voltage adjustable by the PWM output of the PIC. In this manner the amplitude variations are always in the acquisition interval of the PIC (0÷5V); the LM358 double operational amplifier implements these functions.

In order to obtain a third order filter, the analogue signal is further filtered by an RC band-pass filter with a cut-off frequency of 25Hz. Then it goes to the


***Figure 12:*** *The implemented receiver (left), the teaching radio telescope operating at Villa Griffone (right)*

PIC for acquisition.

Due to the sensitivity of the equipment, it is possible to start a software correction integrator that can cancel the thermal drift: for every sampling (if the sample is higher than a fixed threshold) we increase the variable; if the sample is lower we decrease it. Every *N* samples, if the variable is higher than zero, we increase by one bit the output of the PWM; if it is lower than zero we decrease it by one

$$T_i = \frac{N \cdot n\_levels}{f_{sample}}$$

The integration time $T_i$ is:
$n\_levels = 2^{n\_bit}$
*n_bit* = num of bit of PWM
As *n_bit* = 10, it follows that *n_levels* = 1024.
The PIC16F876A generates the control signals of the chopper and switch, and generates the PWM signal that controls the offset. The PIC also acquires the analogue signal that is subsequently sent to the serial port by the MAX232 interface adapter at 19200bit/s.

The analogue and digital section and the chopper are mounted over a printed circuit and fitted, with the radio frequency section, in a standard plastic box.

The gain of the first low-pass filter is fixed at about 8; the value of the resistor that is in parallel at the output of the detector must be selected for the best compromise between the signal amplitude and minimum slope. The resistor, which determines the detection coefficient of the diode, must be of value that will avoid the saturation of the follow-up operational amplifier, when the measured radiation power is at a maximum.

**Sources of EMI**

The man-made sources of electro-magnetic field that emit inside the reception band of the equipment (e.g. line frequency, lighting discharge tube, etc) cause the detection of a signal due to a beating between line frequency and chopper frequency. It is difficult to filter out this frequency.

The simplest solution is to synchronise the LNB chopper frequency with the line frequency; the result is a DC level that can be suppressed by the offset voltage. The synchronisation is implemented drawing the line frequency voltage from the secondary of the transformer of the receiver and sending it to the PIC via the 4N35 photo coupler.

The higher harmonics of line frequency (100Hz, 150Hz) can be reduced with the insertion of a notch filter at these frequencies. Good results are obtained but are not sufficient for the needed sensitivity.

We can also insert in the PIC a digital filtering function, but the maximum number of operations that can be carried out by the PIC limits the filter order to a too low a value to obtain an appreciable result.

The most suitable solution is to implement a digital filter in the acquisition and visualisation program that is executed in the PC.

For the digital filter implementation you can use many free programs or commercial programs in the trial version which can generate a C source code; one of those we have used (http://www.filter-solutions.com from Nuhertz) has the features shown in **Figure 10**. This filter samples the signal at 73Hz and cancels the line frequency and its harmonics, leaving a low frequency band from DC to 22Hz.

**Conclusions**

The equipment described in this article can be used to detect the microwave emission from a person moving through the beam using the offset automatic regulation (algorithm implemented in the PIC program) and can be used as teaching microwave "total power" radio telescope. In this case, the measure of the electromagnetic radiation emitted by the observed source may be referred to the radiation emitted by the Cold Sky which represents the "background".

This is obtained by sending, from the PC, a special command that sets the output to a null value (like as a manual offset control). In this way, when the antenna is pointed at the "stellar source", the performed measurement can be referred to the temperature of the Cold Sky.

Due to the reduced dimension of the parabola that influence its angular resolution, only the biggest radio sources in the sky are visible (Sun, Moon, Milky Way etc) and can be measured by referring to the Cold Sky as we did in Villa Griffone, Italy.

# The Software

```
// necessary files inclusion....

#include <strings.h>
#include <delays.h>

// note: TIME_SAMPLE= (Ti*Fs)/1024

#define TIME_SAMPLE          800
#define TIME_SCALE           100
#define ANT_INVERTITA        1
#define PWM_LEVEL            256

// global variables statement

int     PWM_mean,               // >0
down correction <0 up correction
        PWM_offset;             //
actual offset value
BYTE    i;              // index
unsigned int
        AD_val,         // actual
conversion value AD
        take_sample,            //
filtering step
        chopper,        // I/O
management step
take_offset,            // offset step
        scale_out;              // n.
pass out of scale
BYTE    str[32];

void UserInterrupt()
{
        if((PIR1 & 0x01)==1) {      //
expired timer
                // polarisation switching
                switch (chopper) {
                        case 0 :

CK_POL=0;               //
POLARISATION SWITCH (ZERO)

TMR1H=0xEC;     // 1.3 ms

TMR1L=0x77;

break;
                        case 1:

POL_ZERO =0;    // switch OPENING for
zero

TMR1H=0xFC;
```

```
                                        TMR1L=0x52;     // 3.5
ms here decrease up to 1 ms
                                        break;
                                case 2:
                                        POL_ZERO =1;    // switch
CLOSING for zero
                                        TMR1H=0xFC;
// 1ms
                                        TMR1L=0x27;
                                        take_sample++;  // all
switch closed -> take sample
                                        break;
                                case 3:
                                        CK_POL=1;
// switch POLARISATION (MEASURE)
                                        TMR1H=0xEC;     // 1.3ms
                                        TMR1L=0x77;
                                        break;
                                case 4 :
                                        POL_MIS=0;
// OPEN switch for measure
                                        TMR1H=0xFC;
                                        TMR1L=0x53;
                                        break;
                                case 5 :
                                        POL_MIS=1;
// CLOSE S&H of measure
                                        TMR1H=0xFC;
// 1ms
                                        TMR1
                        }
                        if(chopper !=5)
                                chopper++;
                        else
                                chopper=0;
                        PIR1 &=0xFE;            // Clear TMR1
interrupt flag
                }
  }

  void UserInitialise()
  {
        // I initialise the variables
        AD_val=512;
        PWM_mean=0;
        chopper=0;
        take_sample=0;
        take_offset=0;
        PWM_offset=512;

        // AD converter initialisation
        ADCON0=0x41;                    // oscillator /8
        ADCON1=0x82;                    // right aligned 5
channels

        // TIMER1 initialisation
        TMR1H = 0xFC;
        TMR1L = 0x17;
        PIR1 &= ~(1<<TMR1IF) ;          // irq TIMER 1
ENABLING
        PIE1 |= 0x01;
        T1CON = 0x01;                           // it uses clock /4,
enables

        // general IRQ enabling
        INTCON |=(1<<GIE)|(1<<PEIE);
        Wait(1000);
        TMR2=4;                                 // predivisor
loading
        T2CON|=(1<<TMR2ON);

        // initial zero research (PWM_LEVEL)
        do {
                while (take_sample==0);
                ADCON0 |=(1<<GO);       // start conversion
                while(ADCON0 &(1<<GO)); // wait end
conversion
                AD_val=(((int)ADRESH<<8)+(int)ADRESL) &
0x03FF;
                if(AD_val <PWM_LEVEL)
                        PWM_offset—;
                if(AD_val > PWM_LEVEL)
                        PWM_offset++;
                SetPWM2Volts(PWM_offset);
                take_sample=0;
        } while (AD_val !=PWM_LEVEL);
        scale_out=0;
  }

  /************ EXAMPLE :MAIN() *****************
  void main(void){
        ........
        while(1) {
                .....
                UserLoop();
                ......
  }
  ************************************************
/

  void UserLoop()
  {
        // measure cycle beginning
        k++;
        // voltage measure execution
        if(take_sample) {   // only if IRQ signals that we must
execute the conv. and transm.
                ADCON0 |=(1<<GO);               //
conversion beginning
                while(ADCON0 &(1<<GO));         // end
conversion waiting
                AD_val=(((int)ADRESH<<8)+(int)ADRESL) &
0x03FF;  // 10 bit ADC value reading
                sprintf(str,"%04d ",AD_val);
                i=0;
                // string transmission to
```

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Here are just a few of our controller and driver modules for AC, DC, Unipolar/Bipolar stepper motors and servo motors. See website for full details.

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Drive any bi-polar stepper motor using externally supplied 5V levels for stepping and direction control. These usually come from software running on a computer.
Supply: 8-30Vdc. PCB: 75x85mm.
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**Most items are available in kit form (KT suffix) or assembled and ready for use (AS prefix).**

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Here are just a few of the controller and data acquisition and control units we have. See website for full details. Suitable PSU for all units: Order Code PSU445 £8.95

### 8-Ch Serial Isolated I/O Relay Module

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Assembled Order Code: AS3108 - **£64.95**

### Computer Temperature Data Logger

4-channel temperature logger for serial port. °C or °F. Continuously logs up to 4 separate sensors located 200m+ from board. Wide range of free software applications for storing/using data. PCB just 45x45mm. Powered by PC. Includes one DS1820 sensor.
Kit Order Code: 3145KT - **£17.95**
Assembled Order Code: AS3145 - **£24.95**
Additional DS1820 Sensors - **£3.95 each**

### Rolling Code 4-Channel UHF Remote

State-of-the-Art. High security. 4 channels. Momentary or latching relay output. Range up to 40m. Up to 15 Tx's can be learnt by one Rx (kit includes one Tx but more available separately). 4 indicator LED 's. Rx: PCB 77x85mm, 12Vdc/6mA (standby). *Two and Ten channel versions also available.*
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Assembled Order Code: AS3180 - **£54.95**

### DTMF Telephone Relay Switcher

Call your phone number using a DTMF phone from anywhere in the world and remotely turn on/off any of the 4 relays as desired. User settable Security Password, Anti-Tamper, Rings to Answer, Auto Hang-up and Lockout. Includes plastic case. Not BT approved. 130x110x30mm. Power: 12Vdc.
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Individually control 12 on-board relays with included infrared remote control unit. Toggle or momentary. 15m+ range. 112x122mm. Supply: 12Vdc/0.5A
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### ATMEL 89xxxx Programmer

Uses serial port and any standard terminal comms program. Program/ Read/ Verify Code Data, Write Fuse/Lock Bits, Erase and Blank Check. 4 LED's display the status. ZIF sockets not included. Supply: 16-18Vdc.
Kit Order Code: 3123KT - **£24.95**
Assembled Order Code: AS3123 - **£34.95**

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# TEMPERATURE INSENSITIVE GM-C INTEGRATOR WITH TUNABLE TIME CONSTANT

A new voltage-mode (VM) active-C integrator with advantageous features of temperature insensitiveness and electronic tunability time constant is presented here. The circuit is free from the realisability condition and has low sensitivities. The circuit employs a grounded capacitor, which suits the IC fabrication process.

Tunable integrators are applicable to accomplish signal processing tasks (state variable and biquads filters, switched capacitor filters etc), process controller design, waveform generation and calibration circuits. By employing components with large spread, the time constant can be enhanced to the desired value. However, IC technology has its limitations vis-à-vis employment of large value components as these cannot be economically fabricated. Thus, it is not feasible to incorporate the components whose magnitude exceeds the permissible limits imposed by IC fabrication.

We are proposing a simple integrator configuration using three OTAs and a grounded capacitor. The time constant is electronically tunable through the ratio of transconductances of the OTAs, which is highly stable against temperature variations. The configuration is free from realisability conditions.

Taking port relations of OTA, a routine analysis of the integrator shown in **Figure 1** operating in voltage-mode yields:

$$\frac{V_o}{V_{in}} = \frac{gm_1 gm_2}{sCgm_3} = \frac{1}{s\tau} \qquad (1)$$

$$\text{where} \quad = \frac{KC}{gm_1} \qquad (2)$$

$$\text{and } K = \frac{gm_3}{gm_2} \qquad (3)$$

It is clear from **Equation 1** that the circuit is inherently free from the realisability conditions leading to the realisation of ideal integrator. From **Equations 2** and **3**, it is seen that the time constant $\tau$ can be controlled by $gm_3$ and/or $gm_2$, which are in the form of ratio thereby showing stability against temperature variations.

For an integrator, the active and passive sensitivities are:

$$S^{\tau}{}_{C,gm3} = -S^{\tau}{}_{gm1,gm2} = 1$$

**Simulation Results**

To verify the theoretical analysis, the proposed integrator as shown in Figure 1 has been realised with a macro model of CA3080 to implement OTA. **Figure 2** shows the typical results for the integrator. The rectangular waveform $V_{in}$ with 5V peak-to-peak at 8kHz was applied to the integrator circuit with the following setting: $gm_1$ = 0.01mS, C = 1nF, $gm_2$ = 0.3mS and $gm_3$ = 0.01mS. The output is a triangular waveform with 5V peak-to-peak.

**M F Rather**
**India**

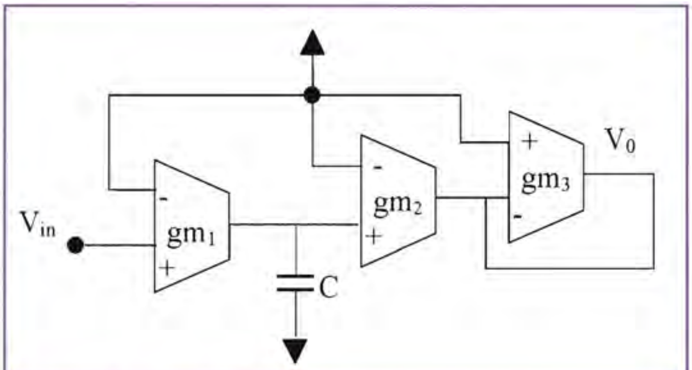



***Figure 3**: Proposed integrator*

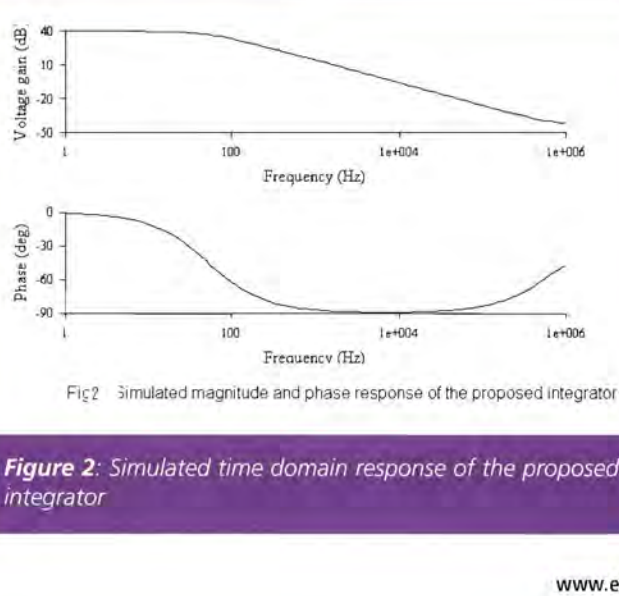



Fig2 Simulated magnitude and phase response of the proposed integrator

***Figure 2**: Simulated time domain response of the proposed integrator*

# OFF-LINE TEMPERATURE CONTROLLER WITH ISOLATED SENSOR

This is a design for a temperature controller that is powered by the mains voltage, yet has a temperature sensor that is isolated from high voltage by means of a transformer. It does not require a power supply transformer for its operating power. It also has a circuit to limit inrush current when turned on.

The temperature controller is used to reduce the standby temperature of a soldering iron in order to extend the useful life of the tip of the iron. It can be used for other purposes as well.

This control unit is powered from the mains supply but the temperature sensor is isolated and thus safe to mount close to the heating element. The controller was designed to reduce the temperature of a soldering iron while it is cradled on its base. The temperature sensor is mounted above the heating element of the iron. Reducing the iron's temperature while it is idle extends the life of the tip and heating element. The circuit is presented as a concept and can be adapted to your requirements. Component values pertain to mains power of 110 Volts. For 230V operation all the power components need to be different.

### Circuit Operation

Mains power is applied to a bridge rectifier that charges filter capacitor C1 through a 150-Ohm resistor to reduce the inrush current. After half a second the PIC16F819 turns on power fet Q1 to short out the inrush resistor. C1 is now charged to 150 Volts.

The controller then applies full power for two minutes to warm up the iron and then switches to a temperature control mode with PID control. PID control measures the iron's temperature and compares it to a set point (the voltage from potentiometer P1).

When the actual temperature is too low compared to the set point a corrective signal is sent to the power controller (Q2) in the form of a pulse width modulated signal. The amount of corrective signal is proportional to the error signal (difference between set point and actual measured temperature).

An integral (the 'I' in PID) component is added that increases the power to the iron gradually as long as the error signal indicates a demand for heat. PI control alone results in overshooting the desired temperature. To compensate for that the time derivative of the measured temperature signal is calculated and when the actual temperature rises too fast then the energy into the iron is reduced. The time derivative is simply the difference between two temperature samples 2 or 3 seconds apart.

The power mosfets are driven from a gate driver (IC 1A and 1B) that provides level switching from 5V to 10V. The inputs are pulled to gnd by R7,11 while the PIC is in reset mode. Transistor Q3 is driven in a cascode manner and it needs to withstand 150 Volts for half a second during inrush.

Sensing the temperature is done by measuring the forward voltage drop of a silicon diode through a very small transformer. One output from the PIC puts out a 10kHz square wave through a dropping resistor and the voltage fed through D3 is proportional to the forward voltage of the sensor diodes which drops with increase in temperature. Diode D3 is a germanium point contact diode but a Schottky diode should work as well. R14 and C7 smooth the sensed voltage for stable readings.

As controller any microcontroller will do that has two analogue inputs and a PWM output. The power switching stage consists of Q2 which has a source resistor, in case you want to see the load current or add over current protection.

R5 and C5 absorb inductive voltage spikes and D4 also helps to limit voltage overshoot on the drain of Q2. D1 is a 50V Zener diode but this can be omitted if R2 is increased in value. Because C1 boosts the rms voltage from 110 to 150 Volts, the duty cycle is limited to 60% to give the same rms power. If C1 is omitted the PIC must output a PWM duty cycle of 0 to 100% to Q2. This design can be adapted for use on 230V.

The circuit board was small enough to fit into a double gang metal electrical outlet box. The mains switch and receptacle is one unit.

**Robert Bliek**
**Canada**

## Component List

| | |
|---|---|
| Q1 | IRF630 |
| Q2 | IRF840 |
| Q3 | ZVP 4424A mosfet but a pnp high voltage transistor also works |
| D1 | 1.5KE51A |
| D2 | 1N5363 30V Zener diode |
| D3 | Germanium or Schottky diode for low forward drop |
| D4 | 1N4937 fast diode |
| Dsensor | 2 anti-parallel Si diodes 1N4148 |
| BR | Bridge rectifier 2A or 4 diodes like 1N5408 |

(if the inrush circuitry is omitted then 4 x 1N5408 is a more robust choice)

LM7810 is a 3-terminal voltage regulator

78L05 is a TO-92 3 terminal voltage regulator

P1 is a potentiometer between 10 to 100kOhm

C1 220uF 200V but can be omitted. See text.

| | |
|---|---|
| C2 | 470uF 35V |
| C3 | 100uF 15V |
| C4 | 25uF 15V |
| C5 | 10nF 250V |
| C6,7,8 | 0.1uF 50V |
| R1 | 150 Ohm, 10W |
| R2 | 6.8kOhm or around 10kOhm if D1 is omitted |
| R3 | 120kOhm |
| R4 | 4.7kOhm |
| R5 | 120 Ohm, 2W |
| R6 | 4.7kOhm |
| R7, R11 | 47kOhm |
| R8, R12 | 3.3kOhm |
| R9 | 10kOhm |
| R10 | 1kOhm |
| R13 | 4.7 Ohm |
| R14 | 1MOhm |
| IC1 | UCC 27324 dual non-inverting gate driver |

# LIGHT BY MICROWAVE COOKING ...JUST ADD A PINCH OF SALT

## By Chris Williams, UKDL

I must start this month's column by declaring an interest – as well as being Director of UKDL, I am also a Director of Ceravision Ltd, a small UK company that has developed a disruptive lighting technology that may revolutionise many of the world's higher power lighting designs as we move through 2008 into the rest of this century.

The technology that Ceravision has created has the ability to convert electrical energy into light. Nothing original in this, you might think – converting electrical power into light is what the humble incandescent light bulb does, albeit not very efficiently. The key to the Ceravision system is in the efficiency of the two-stage process used to create light.

Firstly, electrical energy at the available supply level (can be anything: 240VAC, 12VDC etc) is used to power a self-oscillating microwave power source. This power is generated at the nominal frequency of 2.4GHz and it is then transmitted via a suitable antenna structure into a metalised dielectric waveguide, usually square, rectangular or circular in shape. Being a dielectric structure, at an operating frequency of 2.4GHz, this allows compact dimensions to be used.

The waveguide contains a hole into which an electrodeless quartz bulb containing a noble gas and carefully selected metal halide salts are placed. The microwave energy transmitted into the waveguide induces a very high frequency, high density alternating electrical field into the quartz bulb, ionising the noble gas and forming a plasma channel. The heat from this plasma channel then causes the metal halide salts to vaporise and the light creation process commences in earnest.

The process of forming a plasma channel and vaporising metal halide salts is common to every type of Metal Halide High Intensity Discharge lamp. These are commonly used in electronic projectors, car headlamps, and many other commercial and professional lighting applications.

The idea of using microwave energy to

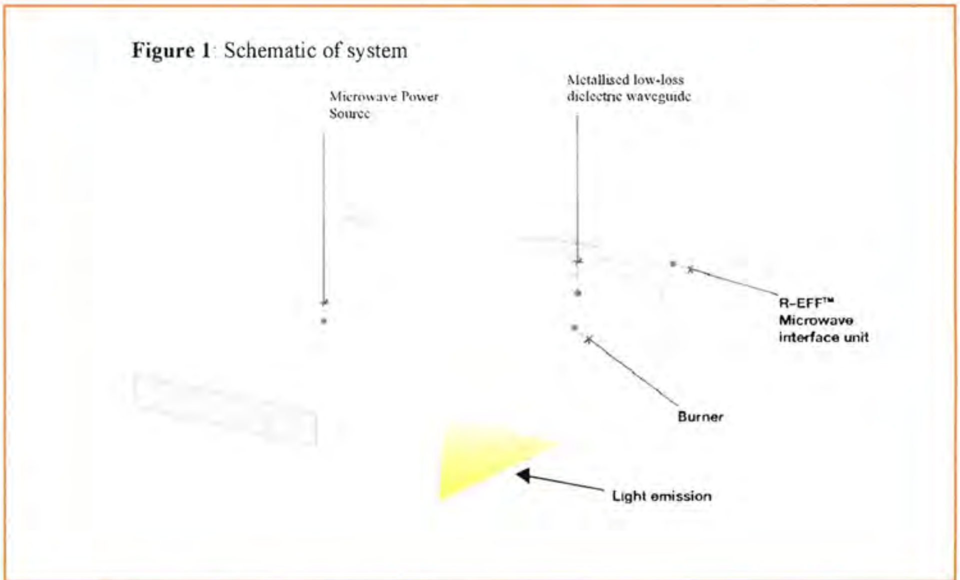



*Figure 1: Schematic of the Ceravision system*

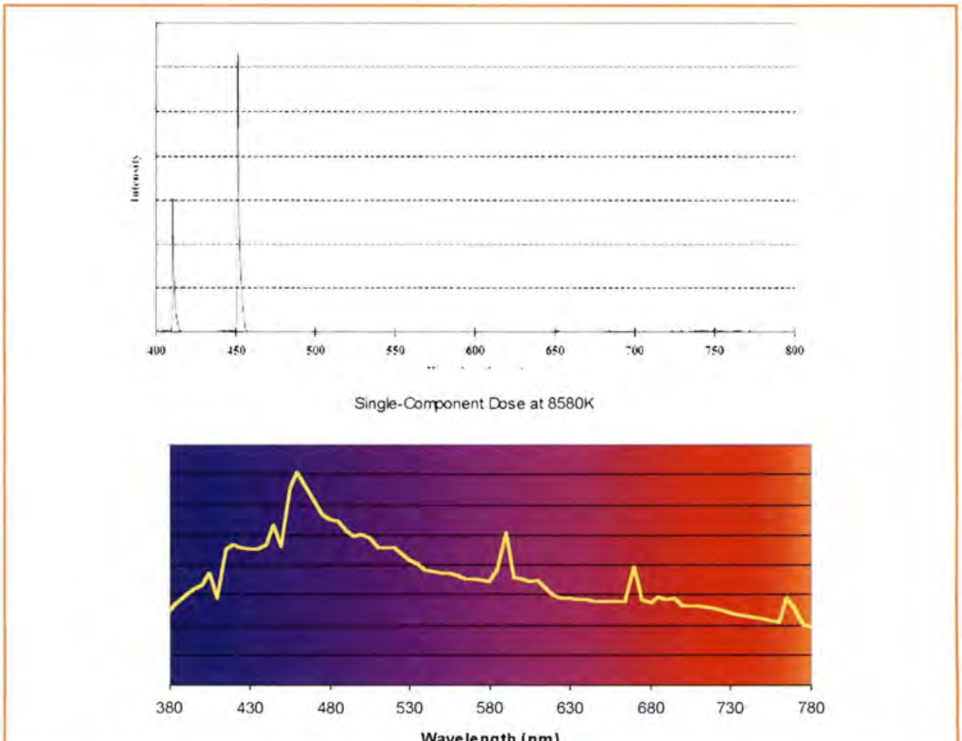



*Figure 2: The upper graph demonstrates line spectra emission from burner placed in air-filled waveguide cavity, and the lower graph demonstrates molecular excitation from burner placed in dielectric waveguide*

***Figure 3:*** *The benchtop demonstrator of the Ceravision Continuum 2.4 light source. For more details see www.ceravision.com*

stimulate the creation of a plasma channel is not new – many of the larger lighting companies have been attempting to do this for many years, with the first demonstration of microwave powered lighting having occurred more than 50 years ago.

Where Ceravision has succeeded – and others have failed – is to translate the principles of microwave excitation of a metal halide lamp into a commercially viable system.

The key to this achievement lay in the invention of what is casually referred to by the company as the "Microwave Interface Unit". The historic stumbling block for companies operating in this technology space has been the need to cope economically with the quirks of microwave engineering. The main problem is the bulb itself, called a 'burner" in the industry, which has an effective electrical impedance approaching infinity in the "off" state, and an effective impedance approaching zero in the "on" state. The power source that drives this wide dynamic impedance range has to swing from an almost "open circuit" to a "short circuit" condition, and maintain efficient power transfer in the process. This is difficult to do at audio frequencies; look at the "protection circuitry" designs that are commonly used in high power audio amplifiers to protect the output stages if we accidentally unplug the speakers, or manage to short-circuit the terminal directly.

Historically, the commercial problem has been that this protection circuitry is expensive when implemented at microwave frequencies. Good though a new lighting system may be, it is difficult to sell if it costs three times the price of the technology it is trying to replace.

Enter Ceravision with their Continuum 2.4 range of products. This system uses a very simple, novel, low-cost component between the power source and the waveguide assembly that allows 100% of the energy from the power source to be transmitted into the dielectric waveguide, yet prevents less than 0.1% of the incident power from being reflected back from the waveguide towards the power source when the burner is "on". This patented component has eliminated the need for any feedback circuitry from the waveguide itself to "monitor" the operation of the burner, and has drastically simplified the circuitry within the power source itself.

The result is a commercially viable, simple, high-reliability light source that will be in mass production during 2008.

In addition to the simple benefit of low-cost manufacture, serendipity steps in to offer users a brand new set of advantages when looking to adopt this light source. Conventional metal halide lamps operate under "atomic excitation", whereby the heat generated in the plasma channel causes the

**THE HISTORIC STUMBLING BLOCK FOR COMPANIES OPERATING IN THIS TECHNOLOGY SPACE HAS BEEN THE NEED TO COPE ECONOMICALLY WITH THE QUIRKS OF MICROWAVE ENGINEERING**

molecules of the metal halide salts to break down into their constituent atoms when the salts are vaporised. This results in the light emitted comprising the atomic spectra of the individual component elements. Within Ceravision's Continuum 2.4 products, the field strength intensity and very high operating frequency present within the waveguide induces a "molecular excitation" of the metal halide salts, and not just atomic excitation.

In this process, the complete molecules are stimulated to emit light, resulting in many more frequencies of light being generated, and a broad spectral output being created. **Figure 2** demonstrates this. In the first graph, a simple burner containing Indium Bromide as the metal halide salts is excited to emit light within a conventional air-filled cavity. This exhibits lower electrical field intensity than the Ceravision Continuum 2.4 system, and results in conventional atomic excitation as shown by the measured line spectra. The same bulb was then excited to emit light by being placed in the Ceravision Continuum 2.4 waveguide assembly. The resulting molecular excitation is shown in the second graph. This stunning improvement in the quality of light output means that using simple burner chemistry, it is possible to accurately simulate daylight.

The benefits continue in the areas of quality and reliability. By removing the need to have metal electrodes within the quartz envelope of the burner, the main cause of device contamination and reduction in quality of light is eliminated. The temperature of the plasma channel is of order several thousands of degrees Centigrade, and when operating with metal electrodes, the tips of the electrodes are subject to erosion.

This evaporated metal can either combine with the metal halide salts, modifying the chemistry and thereby changing subtly the colours of the light being emitted, or it can be deposited onto the walls of the burner itself. In conventional burners, both effects may happen, so the colour of a burner may start changing as soon as it is operating, and the brightness of the burner will slowly reduce as the glass envelopes is coated by the eroded metal. The need for glass to metal seals at the point where the electrodes enter the glass body is also a potential cause of failure due to mismatch of thermal coefficients of expansion.

Getting rid of the electrodes eliminates these problems and can hugely extend the operating life for the light system. Operating lifetimes in excess of 10-25,000 hours can be readily predicted with a microwave-powered system, compared with 1500 to 5000 hours from conventi

Perhaps the key conclusion to take away this month is that whilst the bulk of the technical press coverage on high-efficiency lamps is exclusively centred around LEDs and compact fluorescent lamps, there *are* alternative new technologies available, and these technologies will compete head-on with the old and new alike in their target application areas. I am very pleased to say that the world will not become solely dependent on LEDs and CFLi's. Wherever you need a *lot* of lumens from a very small bulb, then the Ceravision light source may be the perfect solution.

*Chris Williams is Network Director at the UK Display & Lighting Knowledge Transfer Network (UKDL KTN)*

Microchip continues to provide innovative products that are smaller, faster, easier-to-use and more reliable. PIC microcontrollers (MCUs) are used in a wide range of everyday products from washing machines, garage door openers and television remotes to industrial, automotive and medical products. While some designs such as Switch Mode Power Supplies (SMPS) are traditionally implemented using a purely analogue control scheme, these designs can benefit from the configurability and intelligence that can only be realised by adding a microcontroller.

**NOTE:** The tips 'n' tricks presented here assume a 3.3V supply. However, the techniques work equally well for other supply voltages with the appropriate modifications.

## TIP 1: USING A PIC MICROCONTROLLER FOR POWER FACTOR CORRECTION

In AC power systems, the term Power Factor (PF) is used to describe the fraction of power actually used by a load compared to the total apparent power supplied. Power Factor Correction (PFC) is used to increase the efficiency of power delivery by maximising the PF.

The basis for most Active PFC circuits is a boost circuit, shown in **Figure 1.**

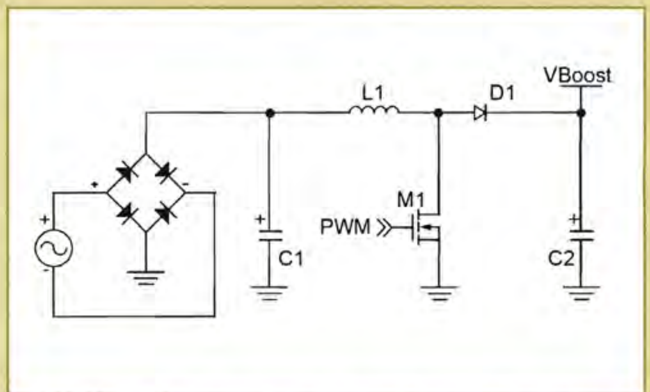



***Figure 1:** Typical power factor correction boost supply*

The AC voltage is rectified and boosted to voltages as high as 400VDC. The unique feature of the PFC circuit is that the inductor current is regulated to maintain a certain PF. A sine wave reference current is generated that is in phase with the line voltage. The magnitude of the sine wave is inversely proportional to the voltage at VBoost.

Once the sine wave reference is established, the inductor current is regulated to follow it, as shown in **Figure 2.**

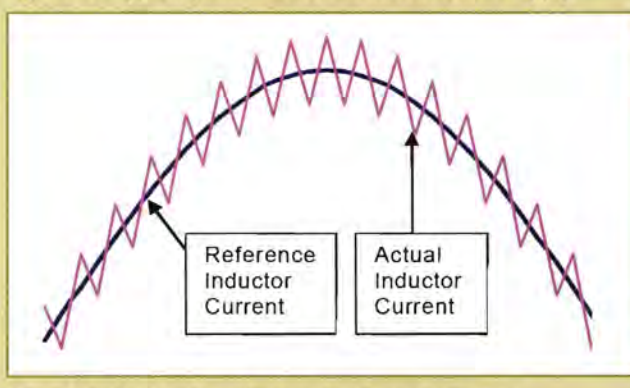



***Figure 2:** Desired and actual inductor currents*

## TIP 2: TRANSFORMERLESS POWER SUPPLIES

When using a microcontroller in a line-powered application, such as the IR remote control actuated AC switch described in TIP 3, the cost of building a transformer-based AC/DC converter can be significant. However, there are transformerless alternatives which are described below.

### Capacitive Transformerless Power Supply

**Figure 3** shows the basics for a capacitive power supply. The Zener diode is reverse-biased to create the desired voltage. The current drawn by the Zener is limited by R1 and the impedance of C1.

Advantages:
- Significantly smaller than a transformer-based power supply
- Lower cost than a transformer-based or switcher-based power supply
- Power supply is more efficient than a resistive transformerless power supply.

Disadvantages:
- Not isolated from the AC line voltage which introduces safety issues
- Higher cost than a resistive power supply because X2 rated capacitors are required.

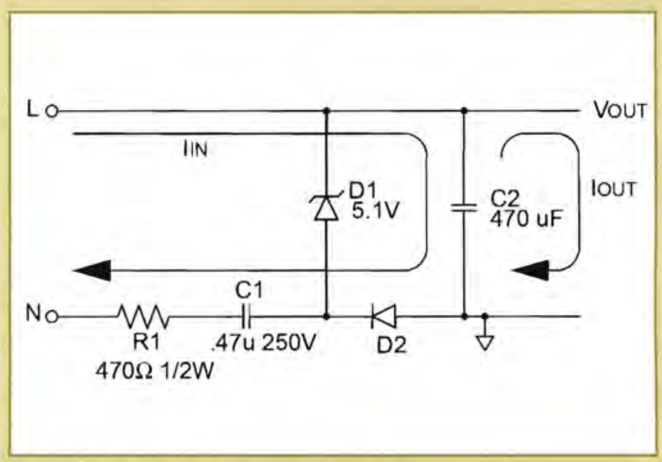



***Figure 3:** Capacitative power supply*

### Resistive Power Supply

The resistive power supply works in a similar manner to the capacitive power supply by using a reversed-biased Zener diode to produce the desired voltage. However, R1 is much larger and is the only current limiting element.
Advantages:
• Significantly smaller than a transformer-based power supply
• Lower cost than a transformer-based power supply
• Lower cost than a capacitive power supply.
Disadvantages:
• Not isolated from the AC line voltage which introduces safety issues
• Power supply is less energy efficient than a capacitive power supply
• More energy is dissipated as heat in R1.

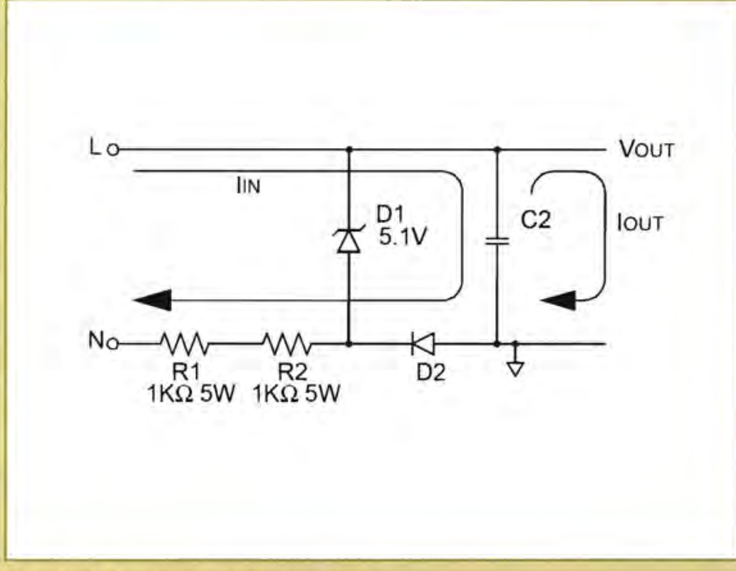


***Figure 4:** Resistive power supply*

## TIP 3: AN IR REMOTE CONTROL ACTUATED AC SWITCH FOR LINEAR POWER SUPPLY DESIGNS.

Many line-powered applications (audio amplifiers, televisions, etc) can be turned on and off using an infrared remote control. This requires that some components be energised to receive the remote signals even when the device is off. Low current PIC microcontrollers are best in this application. **Figure 5** shows an example circuit layout.

The PIC10F200 has several features that make it ideally suited for this type of application:

• Extremely low operating and standby current (350μA operating, 0.1μA when asleep)
• Input/output pins with configurable pull-ups and reset-on-change capability
• High sink/source ability (+/-25mA) allows driving external devices, such as the IR receiver, directly from the I/O pin
• Ability to use a low-cost resistive power supply
• Small form-factor (SOT-23 packaging).

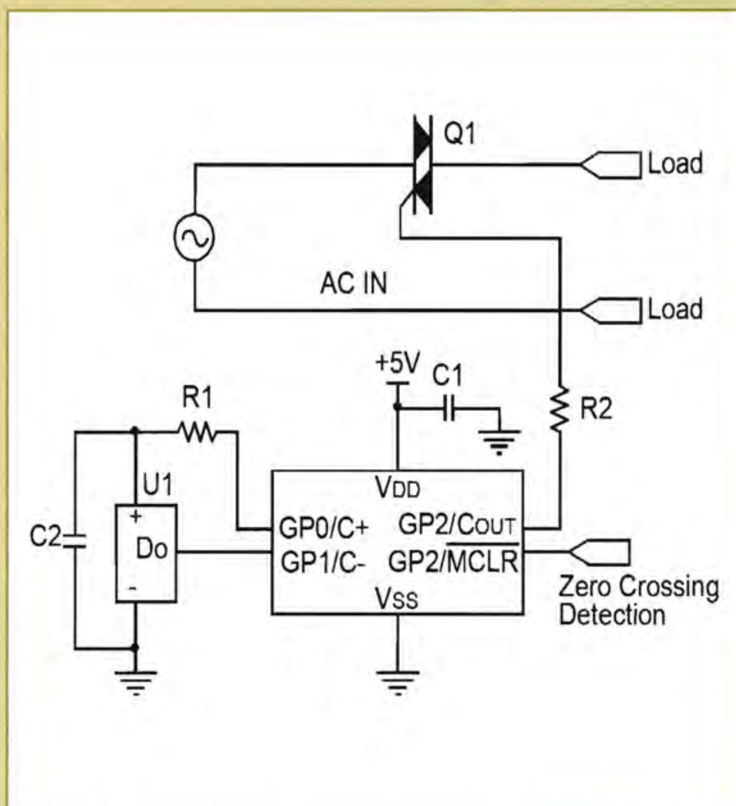


***Figure 5:** PIC MCU infrared receiver schematic*

## TIP: ONE MOSFET AND ONE RESISTOR TRANSFORM UNIDIRECTIONAL CURRENT SENSE AMP INTO BIDIRECTIONAL

*By Glen Brisebois, Linear Technology*

There are some excellent little unidirectional high side current sense amplifiers, but that "unidirectional" can sometimes be a problem. It means two things: you can't sense negative current and you can't accurately sense all the way down to zero current. This design idea shows how to use a single MOSFET and a single resistor to solve both problems.

**Figure 1** shows the normal operating mode of the LTC6101. The current to be sensed passes through $R_{SENSE}$, creating a sense voltage. The amplifier imposes this sense voltage across R1, forcing a current through its internal FET and, therefore, an output voltage across R2. The gain from sense voltage to output voltage is R2/R1 and the overall transimpedance gain of sense current to output voltage is $V_{OUT}/I_{SENSE} = R_{SENSE} * R2/R1$.

R3 exists in order to cancel the effects of bias current for improved accuracy. The circuit works very well down to the point where the output clips at 0V out. It cannot sense the opposite direction of current and can accurately gain up applied input sense voltage only down to its own offset voltage, which may be positive or negative.

**Figure 2** shows the bidirectional upgrade. The addition of MOSFET Q1 (with some gate bias of 3-5V) and resistor R4 creates an output bias reference voltage $V_{BIAS}$ (depending on Q1's $V_{GS}$). It also forces a matched current ($V_{BIAS}$/R4) into the drain to apply an accurate input voltage across R3 (upgraded to 1% from Figure 1). This input voltage is now the new null point. That is, with $V_{SENSE}$ = 0mV, the currents though both left and right legs is identical and the output voltage referred to $V_{BIAS}$ is 0V. Any applied sense voltage (from a current though $R_{SENSE}$) will induce an output voltage with the same gain as previously. But it can be positive or negative with respect to $V_{BIAS}$, supporting either direction of current flow. That's a lot of additional functionality for a MOSFET and a resistor!

Note, however, that effective input offset voltage is now dependant on the 1% resistors and will typically be worse than that achieved by the unaided LTC6101.

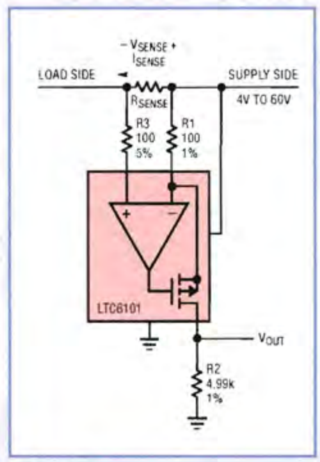



*Figure 1*

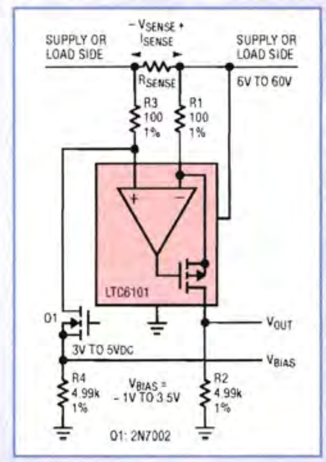



*Figure 2*

## Win a Microchip PICDEM 2 Plus Demo Board


**Electronics World is offering its readers the chance to win a Microchip PICDEM 2 Demonstration Board. This board now has an ICD port, LCD read-out, sounder and a temperature sensor. The enhanced PICDEM 2 Plus Demonstration Board provides designers with a tool for immediate programming and debugging Flash-based microcontrollers. The board is supplied with software loaded on a PIC18F452 microcontroller to demonstrate the device's features and peripherals. The program also sets up the microcontroller as a real-time clock and measures the local temperature, both of which are displayed on an LCD display. A PWM signal is sent directly to the Piezo sounder. There is an active RS-232 port and on-board Serial EEPROM and there is ample room in the generous prototyping area for project development work. A second Flash-based microcontroller with its own demonstration program, the PIC16F877, is also included.**

**Source code is provided allowing users to understand and dissect the programming algorithm. Additionally, users with an MPLAB® In-Circuit Debugger 2 can take advantage of the Flash-based microcontroller's in-circuit debugger capability by cutting, pasting, rewriting or adding to the program.**

**The PICDEM 2 Plus Demonstration Board is available separately or as part of the MPLAB ICD 2 Evaluation Kit, which also includes a power supply, serial cable and USB cable.**
**If you would like to be in with a chance of winning Microchip's PICDEM 2 Plus Demo Board, log onto www.microchip-comp.com/ew-picdem2 and enter your details into the online entry form.**

# VOICE OVER IPV6

## DANIEL MINOLI
## NEWNES

An alternative title might be: "Everything you wanted to know about VoIP – and a lot about IPv6".

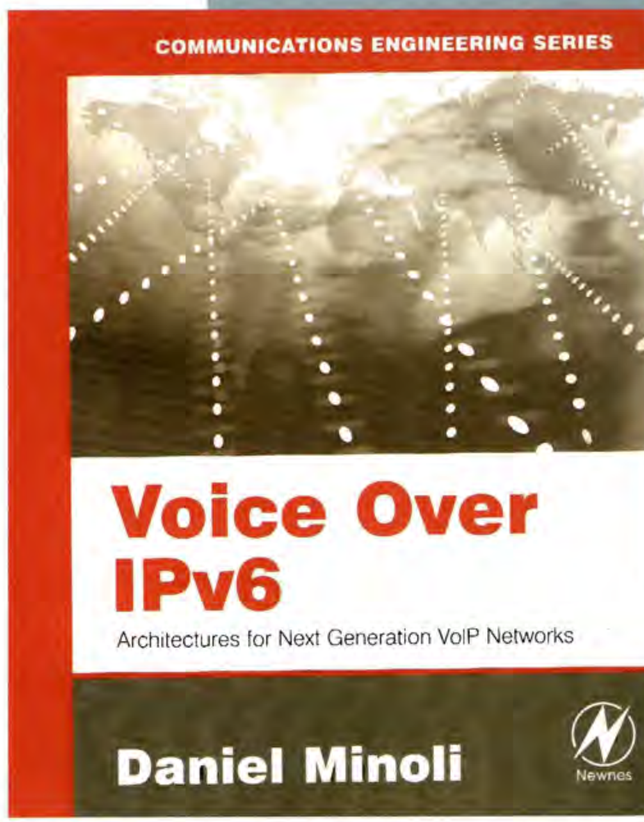
Voice over Internet Protocol (VoIP) is rapidly being adopted for communication on the growing digital network that is spreading throughout the world. Most of us are still using digital networks that implement Internet Protocol (IP) version 4 – IPv4. Its replacement, IPv6 has existed for more than a decade without widespread takeup (version 5 was a development that was not released for general use).

Version 4 defines a 32-bit address space and, for many years, the question was what to do when all addresses had been allocated – about 75% of them are currently in use. The answer was to be version 6 with a 128-bit address space.

**IT IS MINOLI'S THESIS THAT IPV4 AND NETWORK ADDRESS TRANSLATION OBSTRUCT THE PROTOCOLS NEEDED TO PROVIDE A GOOD VOIP SERVICE AND THAT IPV6 IS NEEDED BEFORE QUALITY VOICE PROVISION CAN BE WIDELY SUPPORTED**

However, the use of gateways/firewalls and network address translation (NAT) has largely removed the problem by allowing many local addresses to share a small number of global addresses. It is possible to run several computers each with its own local address but have them appear on the global network as a single IP address. In addition to an extended address range IPv6 provides several useful features such as mechanisms for providing quality of service.

It is Minoli's thesis that IPv4 and NAT obstruct the protocols needed to provide a good VoIP service and that IPv6 is needed before quality voice provision can be widely supported. To this end he describes the requirements of the voice service and how they can be provided in IP networks, both v4 with it limitations and v6 with its promise.




The book starts with an introduction to IPv6, to Voice over IP and to network architectures for voice systems. Two appendices to this chapter are provided, one listing basic IPv6 terminology and the other listing the reference material relating to IPv6, NAT and the session initiation protocol (SIP) most commonly used to make voice connections. This is an easily read and informative chapter which is well illustrated revealing, to my surprise, just how complex a set of protocols is involved.

Chapter 2 – *"Basic VoP/VoIP Concepts"* – covers deployment issues such as voice coding standards, signalling, SIP, numbering and wireless networks. I was surprised to learn just how many different standards have to be supported to cover legacy systems optimised for different capabilities. Although accurate and complete, there is so much technical detail to be conveyed and so many abbreviations used, that I found this chapter very hard to read.

Chapter 3 – *Basic VoIP Signalling and SIP Concepts* expands on Chapter 2. An 8-page overview is followed by a 50-page appendix giving a blow-by-blow account of a call using the session initiation protocol (SIP). Ominously, it ends with the sentence "Refer to RFC 3261 for a multitude of additional details"!

Chapter 4 – *Basic "Presence" Concepts* – has grown from a simple indication of availability to include Instant Messaging. It is also the basis 'publication' of other user characteristics such as alternate means of communication (e.g. "I'm in a meeting, use email"). A model of information suppliers, users and their 'agents' is also described and its implementation with SIP is detailed.

Chapter 5 – *Issues with Current VoIP Technologies* – explains why IP version 4, network address translation and firewalls do not provide the easiest environment for voice transmission. In the process it gives a good explanation of the NAT service and details why this presents difficulties for voice connections. Other issues are covered and detailed examples of session behaviour are given. This is another chapter packed with technical detail and abbreviations.

Chapter 6 – *Basic IPv6 Concepts* – provides a good introduction to version 6 of the Internet protocol but is probably more easily understood by those already familiar with the terminology of version 4.

Chapter 7 – *Using IPv6 to Support 3G VoIP* – indicates the ways in which IPv6 concepts may be used for VoIP traffic. It describes addressing, configuration, routing and route management. The final section, 7.6, reports briefly but positively the status of deployments and experiments in VoIPv6 making clear the advantages of IPv6 over v4.

Chapter 8 – *Issues Related to Transitioning to IPv6* – acknowledges that there will not be an instant switch-over from IPv4 and that the transition period will be lengthy (and that some IPv4 may continue to be used indefinitely). Techniques to allow the co-existence of both are described here.

There is an extensive list of references for those needing more detail and a comprehensive 16-page index assures its value as a reference book.

Overall this is a very comprehensive description of Voice over IP, its method of operation and requirements. Version 6 of the Internet Protocol is well described, in particular its features that support a better voice service.

VoIP and IP come with a vast number of specialised terms and abbreviations. Even to those familiar with networking terminology there is a lot that is new and that makes most sections of this book a hard read.

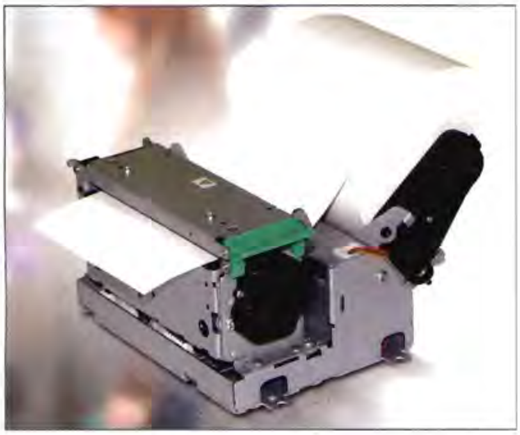
Network managers and those involved in planning for VoIP provision will find Chapter 1 and a few other sections useful but will probably not want all the detail provided elsewhere. Students and teachers will find that there is more than enough material for use as a textbook and many courses could be built around it.

I do not recommend attempting to read this book from cover-to-cover but taking it a little at a time; directed reading and topical research are easily carried out with the aid of the contents list and/or index.

Overall, I can recommend this book as a reference text for occasional use, but not for bedtime reading.

**Barry M Cook**

# The NP2411 and NP3411 Series Kiosk Printers



Printing 150mm/second, the NP2411 and NP3411 series of thermal printers from Nippon Primex are now available from DED. Designed with flexibility in mind, the NP2411 and NP3411 both feature a small footprint – perfect for the kiosk environment.

Ideal for printing in applications such as information kiosks and ticket issue, the NP2411 and NP3411 series feature an auto paper loading mechanism, jam free cutter on paper widths of up to 82.5mm, fully opening print head and a paper-low/paper-out indicator.

With dimensions of just 124.6mm wide x 123.5mm deep x 77.3mm high on the NP2411, both printers feature a 24VDC and come with drivers for Windows XP/2000/Vista and Linux CUPS and interfaces for USB and RS232C serial for ease of integration.

**www.ded.co.uk**

# VEAM Powerlock Connectors Ensure The Show Must Go On

ITT's VEAM Powerlock connectors, designed for field installation of power distribution systems, have been installed at the 02 Dome in London's Docklands, making life simple for touring riggers as each new show rolls through.

The Powerlock connector systems provide a very high level of safety and reliability and can handle the most severe operating conditions. Applications include three-phase motors, heavy industry, electric supply companies, generators, load banks, lighting distribution panels and in-house supplies, outdoor TV broadcasts, sporting events and concerts.

Powerlock connectors use a bayonet mating method and come in four standard formats: panel source, panel drain, line source and line drain. Source connectors are supplied with a male contact that incorporates a rigid finger-proof nose and a slot for the secondary locking pin. Drain connectors include a female contact with a spring-loaded finger-proof nose and an O-ring. Line or panel connectors support cable attachment or panel mounting, respectively.

All Powerlock series connectors are rated to 1000V (max) and are available in 400A and 660A versions. The range supports contact termination sizes from 35 to 300mm$^2$.

**www.itt.com**

# CRTtoLCD-8 Flat Panel Controller

Kontron's flat panel division expands its aFLAT series with the CRTtoLCD-8 flat panel controller. The Kontron CRTtoLCD-8 is the first product to have a wide range power supply (12-24 volt) and is specially designed to support industrial applications.

The flat panel controller is an interface, converter and scaler board between graphic sources and flat panels. The Kontron CRTtoLCD-8 is mechanically compatible with the other members of the Kontron CRTtoLCD family, providing a portfolio of flat panel controllers that offers scalable interfaces and performance.

In addition to RGB and DVI, the flat panel controller board offers composite and S-Video inputs for PAL/NTSC signals, providing comprehensive support for different video sources and providing all prevalent flat panels with the right signals. The Kontron CRTtoLCD-8 is ideally equipped for processing signals from IPCs and video cameras, which are becoming increasingly important for industrial and security applications. Other application areas include medical devices for endoscopy and minimally invasive surgery, POS/POI terminals and gaming machines.

Designed around the Genesis FLI5961chip, the Kontron CRTtoLCD-8 flat panel controller comes with 2 x 24 Bit LVDS support for up to two flat panels with a resolution up to SXGA.

**www.kontron.com/CRTtoLCD-8**

# BDM/JTAG Debugger Offers Higher Speed and Performance


The Abatron BDI3000, now available in the UK from Computer Solutions, is the latest generation of Abatron's popular range of BDM/JTAG debuggers, and offers higher speed and performance enhancements compared with earlier models.

Features of the BDI3000 include support for GDB debugging and flash programming for ColdFire, PowerPC, ARM, Xscale and MIPS processors. It will also support low-voltage processors down to 1.2V.

The BDI3000 provides high-speed links to the target CPU (up to 32MHz) and to the PC (via 10/100 Ethernet), resulting in very fast program downloads – up to 1500kbyte/s, depending on the CPU – and flash programming times limited predominantly by the CPU and flash memory characteristics. A typical programming speed is 220kbyte/s for the Xscale PXA250.

The same hardware is used for all supported targets and debuggers, allowing the unit to be used on subsequent projects, and features easy connection to the target system in a robust, EMC-optimised design.

All these performance enhancements have been achieved without an increase in the price of the unit.

**www.computer-solutions.co.uk**

# New Rigel Test Kit for Faster Safety Testing

The latest addition to the Rigel range of advanced electromedical test instrumentation is a special equipment package for EBME testing in line with the new IEC 62353 standard for medical devices.

The new Rigel 288 test kit links the new IEC 62353 compliant tester with a complete range of Bluetooth enabled test accessories designed to ensure that service engineers and biomedical engineering personnel can carry out recurrent and post repair testing on medical devices with maximum speed and efficiency.

The new handheld and lightweight Rigel 288 incorporates easy to follow menu driven instructions for simple operation and test control in manual, semi-automatic or fully automatic test modes.

As well as storing the results of electrical safety tests, the instrument also has the ability to record user defined inspections and measurements from specialist electromedical equipment such as Sp02, NIBP, ECG and other patient devices.

The highly portable and long life battery powered tester is equipped with Bluetooth technology for the wireless connection of bar code scanners, label printers and other accessories, allowing totally cable-free data transfer and safety labelling, without the cumbersome plugging and unplugging of leads and cords.

**www.rigelmedical.com**

# PRS10 Rubidium Frequency Standard – OEM Module

Available in the UK from Lambda Photometrics is the Stanford Research PRS10 10MHz Rubidium (Rb) disciplined frequency source with ultra-low phase noise, excellent stability and low aging rate. It is an ideal component for use in any OEM or end-use application requiring a stable precision low noise frequency standard.


Among its key features are the 10MHz output, very low phase noise (< -130dBc/Hz at 10Hz), time tags or phase-locks to a 1pps input, 72-hour Stratum 1 level holdover RS-232 interface for diagnostics, control and calibration, optional break-out connector board, 20-year Rb lamp life and a compact package (50x75x100mm) HWD.

Stanford's unique approach uses the 3rd overtone of a stress-compensated (SC-cut) crystal oscillator to produce an ultra-stable 10MHz output with very low phase noise (< -130dBc/Hz at 10Hz offset). The Rb lamp physics package provides a well defined gas transition reference frequency that is used to discipline the crystal oscillator.

The PRS10 has a very low aging rate (< 5 x $10^{-11}$/month). Additionally, the system can be phase-locked to an external source such as a 1pps GPS timing receiver, which eliminates the problem of long term aging and frequency offsets.

**www.lambdaphoto.co.uk**

## Portable Vibration Meter Show Offer


Monitran, developer and manufacturer of sensors for the measurement of vibration and displacement, is making its Portable Vibration Meter available for a discounted price of £395 during the three days of MAINTEC (11th, 12th and 13th March 2008).

The meter can be purchased from Monitran on stand F30 and, in addition to the discount of £200 off the usual price, the meter will come with two years' free calibration, as opposed to the standard one year. This equates to a further saving of £95.

In addition, Monitran's experts will be present at the MAINTEC show on stand F30 ready to give advice on vibration monitoring techniques and solutions.

The Portable Vibration Meter is easy to use, requires no connection to a PC and is ideal for routine systems checks. Typical applications include checking motors, gearboxes, fans, pumps and compressors.

Monitran's Portable Vibration Meter is lightweight (850g), compact (170 x 100 x 45mm) and is supplied with a probe, magnet, user manual, calibration certificate and batteries, all in a carrying case.

All prices quoted are exclusive of VAT.

**www.monitran.com**

## More Power to the Board

Amphenol Industrial Operations has developed three new compact, high amperage connectors for high current, single-point connections to printed circuit boards (PCBs). The new interconnection products, PowerBlok, RADSERT and PGY, employ the company's proprietary RADSOK technology to deliver more power to electronic board applications, whilst avoiding the heat and bulk problems associated with raising amperage.

Housed in a small package of 12.7mm x 12.7mm, PowerBlok provides up to 70A to a board. The component's backplane power interface uses compliant pins, which are press-fit into the board enabling a solid connection and an even signal flow.

Available in either a 2.4mm size carrying up to 35A or in a 3.6mm size carrying up to 70A, RADSERT offers the smallest footprint of Amphenol's new PCB line freeing up the most surface space for added design flexibility. A standard RADSERT is designed for a board thickness of 6.35mm +/-0.0635mm with custom sizes available for specific applications.

The PGY is an orthogonal card edge connector available in two sizes, 3.6mm carrying up to 70A and 5.7mm carrying up to 120A, delivering the highest amperage in the smallest package. Contact: s.allegra@amphenol-it.com

**www.radsok.com**

## Aircraft Battery Test System for Flight Line Support

Intepro Systems will be launching its new IBT700 battery test system for aircraft at the Aerospace 08 exhibition in Munich, April 15-17. Cyclic charge and discharge of Lithium Ion batteries is critical for the safe and reliable operation of these batteries, especially when used in fail-safe installations in aircraft.

The IBT700 has been primarily designed to test batteries by performing charge and discharge cycles while monitoring in real time key battery parameters including overall battery voltage, individual cell voltage and internal temperature (to prevent thermal runaway). The IBT700 may be supplied as single or dual modules for test cycling one or two batteries. Test results may be logged for future analysis and the system can also perform data transmission and interrogation of intelligent systems.

The Intepro IBT700 system will simulate a number of battery conditions for test purposes. These will include battery for flight, battery for storage or shipping, stored battery maintenance, decommission of failed battery, passive battery test and battery capacity measurement. Test routines are selected from a graphic user interface featuring drop-down menus.

**www.inteproate.com**

# Enhanced Performance, Low-Power ComboMemory Series

SST (Silicon Storage Technology) announced the 34WA series of 1.8V ComboMemory products, the latest additions to the firm's family of high-performance flash memory/RAM combination memory products.

The 34WA series supports functions and features new to SST's ComboMemory family, including burst-mode operation for faster performance and address/data bus multiplexing for a lower pin-count and smaller device footprint.

The products in the 34WA series use a very small semiconductor package, measuring just 6mm x 8mm x 1mm, making them the smallest address/data bus multiplex combination memory devices available on the market today. Their performance and space savings make these products ideal for the entry-level mobile handset market's need for high-performing, cost-effective, small form-factor mobile phones.

This series' products support burst-mode operation, which allows the data in the devices to be read at high speed, thereby increasing overall system performance. The devices also support address and data bus multiplexing to allow the sharing of I/O pins to reduce package pin-count and overall device size. The 1.8V operating voltage of the 34WA series devices leads to lower system power consumption

**www.sst.com**

# Cost-Efficient 2U Integrated ATCA Platform

Kontron showcases its AdvancedTCA 10GbE integrated platform, the OM9020, which elegantly resolves the price versus performance concerns of telecom equipment manufacturers who need to design non-redundant systems for edge and access applications used in data center, regional CO and enterprise networks.

As a two-slot, space-saving, 2U AdvancedTCA platform, the Kontron OM9020 realises its cost savings by eliminating the need for an AdvancedTCA switch board, which is replaced by an on-board Ethernet switch. This enables a Fat Pipe interconnect between the two slots via the backplane.

For external connectivity, the platform features two GbE/10GbE uplink modules that access the switching fabric and base interfaces, also via the backplane. Each module is hot swappable and is dedicated to one AdvancedTCA board. Moreover, the Shelf Manager has been replaced by a software implementation hosted on either Kontron AdvancedTCA board, and provides a cost-efficient Shelf Management solution to provide sensor data to the platform's System Alarm Panel.

The Kontron OM9020 comes pre-integrated with one very high density, multi-core processor board, the Kontron AT8030, featuring three Intel Core 2 Duo processors each with dedicated memory, a 10GbE fabric interface and one AdvancedMC slot for a SATA storage module.

**www.kontron.com/OM9020/**

# Carrier-Grade MicroTCA Integrated Platform


Kontron revealed the Kontron OM5080, a MicroTCA integrated platform that supports up to eight AdvancedMC modules. Kontron's latest open modular solution is ideal for telecom equipment manufacturers who need to design redundant systems without any single point of failure for edge and access applications used in data center, regional CO and enterprise networks.

The Kontron OM5080 represents a 2U off-the-shelf platform that achieves an industry-first by accommodating up to eight AMCs within the most space-efficient and cost-optimised design. The Kontron OM5080 realises its cost savings by implementing the MCH and Power Module functionality in a different way, specifically by using AMC carriers with integrated switches that provide Ethernet connectivity for 1GbE fabric or 10GbE fabric in combination with two uplink modules on the front. The 1GbE version provides a total of 8 x GbE uplinks on the front, the 10GbE version provides a total of 4GbE uplinks plus 2 x 10GbE uplinks. Thus, the system is very well suited for applications with high demands on traffic and throughput.

**www.kontron.com/OM5080**

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## REMOTE MANAGEMENT

# TTI named Kemet 'Charged' Distributor of 2007

TTI has been awarded the Kemet 'Charged' European Distributor of the year award for financial year 2007. This completes a 'Triple Crown' of Distributor awards in North America, Europe and Asia. This recognition has never before been achieved by a Kemet distributor. Kemet places a great deal of value on its distributor business, and its annual awards are based on a number of key factors - sales growth, market share, new product development, ease of doing business, and field and corporate relationships

Andrew Kerr, European Director of Passive Supplier Marketing at TTI said: "Kemet offers one the world's most complete line of surface-mount and through-hole capacitor technologies across tantalum, ceramic, aluminum, film and paper dielectrics. We are delighted to have been named as Kemet's European Distributor of the Year for a second consecutive year, and believe it reflects the value that our two companies place on building excellent partner relationships."

Graeme Dorkings, Director Distribution Sales of EMEA added: "TTI continues to operate a business model which delivers strong performance on all key criteria and this award truly demonstrates that their model works."

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