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# ELECTRONICS WORLD

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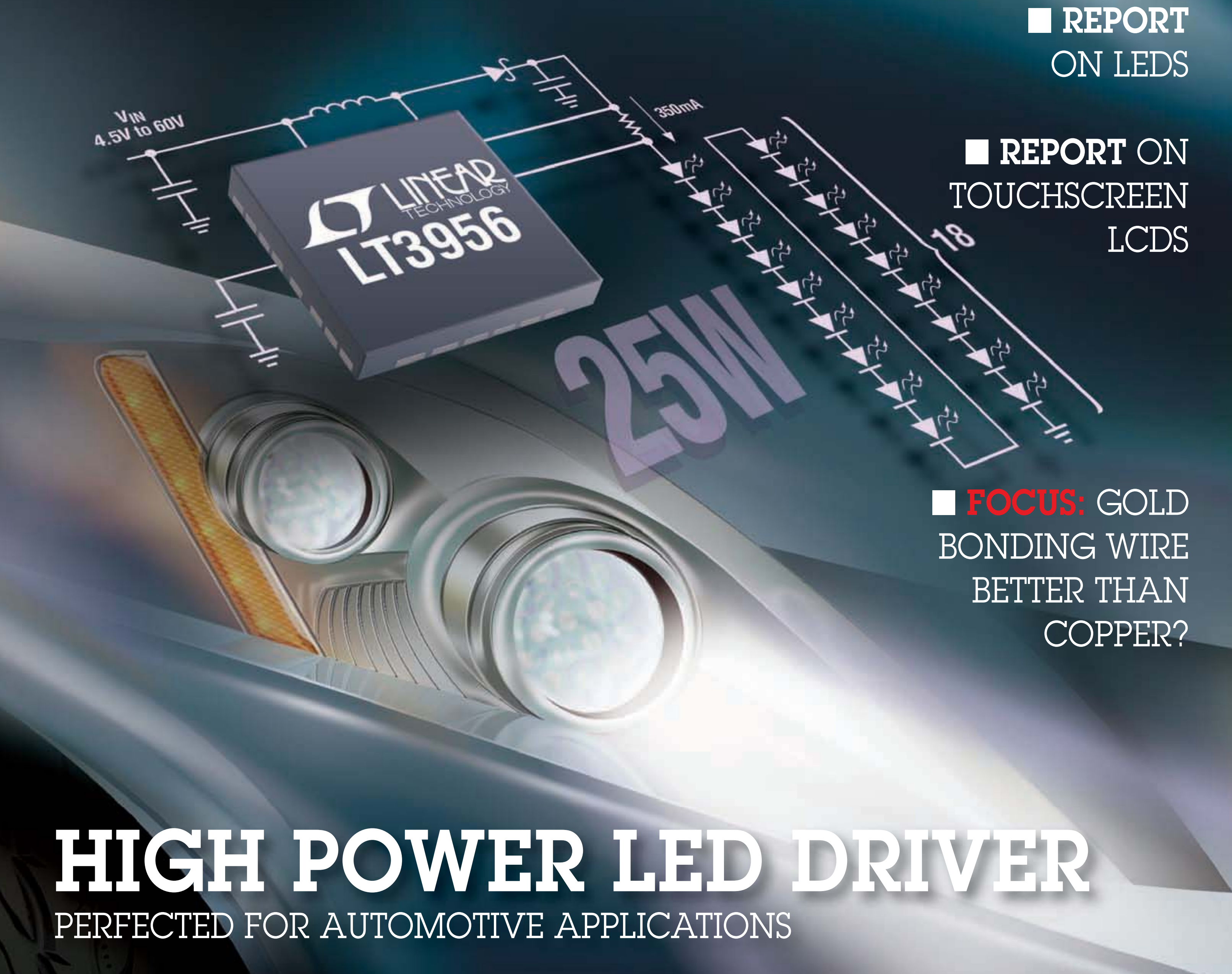


■ **REPORT** ON LEDS

■ **REPORT** ON TOUCHSCREEN LCDS

■ **FOCUS:** GOLD BONDING WIRE BETTER THAN COPPER?

# HIGH POWER LED DRIVER

PERFECTED FOR AUTOMOTIVE APPLICATIONS

**TECHNOLOGY**
ELECTRONICA 2010 TO PRESENT FUTURE MOBILITY CONCEPTS


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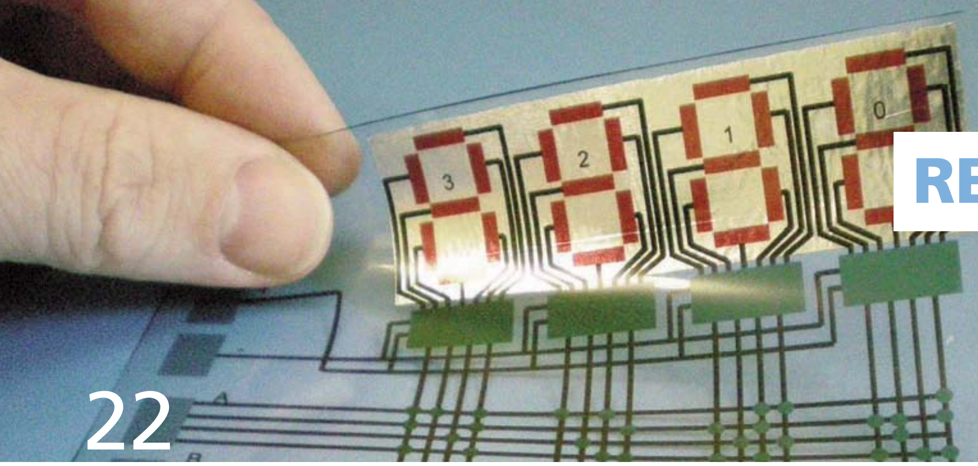
MAKE YOUR OWN OLEDS

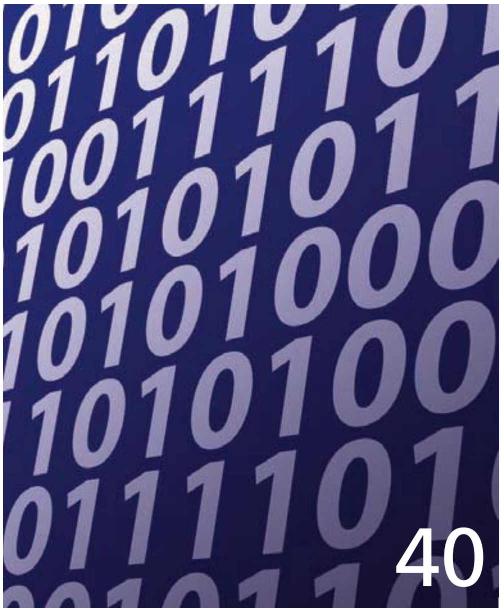
**AUDIO TUTORIAL**
BIT TESTING IN AUDIO APPLICATIONS

ALSO IN THIS ISSUE: THE TROUBLE WITH RF.... • AUDIO COLUMN • DESIGN




# REGULARS




# FEATURES



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# THE INTERNET OF THINGS and What Sits Behind It…

**BY DUNCAN ELLIS**

What this piece states is that networks are being prepared to deal with multiple services and quality requirements to allow for the 'Internet of Things' to operate without snags.

We are all well aware of how the Internet has connected billions of people around the world in a way never seen before. We have come to rely on this visible web for many areas of our lives, be it reading news online, listening to digital radio, streaming TV programmes or updating our social networks. So far, so commonplace.

What is less well known, however, is that running alongside the visible web we know so well from our daily lives is an equally pervasive 'invisible' web of connected devices – the Internet of things and machines. The Internet of devices is primarily used for machine to machine communication and is the equivalent of the autonomic nervous system; it keeps our environment healthy and functional. This part of the web performs monitoring, supervision and control – across the Internet.

As this network of interconnected appliances and devices grows, building the so-called 'Internet of Things', we anticipate a future where the machines that touch on our daily life will have much more of an impact on us.

The data traffic in this network happens "behind the scenes" as it is not about the human-accessed content and services, but rather machines communicating with other machines without human interaction (dubbed machine-to-machine-communication – M2M). An example of this could include cars being able to connect with the traffic lights they pass and each other to reduce accident rates and congestion. Alternatively, a damaged home printer could automatically notify the repair company and schedule its own service, with little or no interaction from its owner.

In the logistics sector, quick and automated processing of packages is already based on "talking" packages and appliances equipped with RFID tags, for example sharing information about destination and size. Similar processes can be applied to other fields in the future – there are countless applications of the 'Internet of Things' that can help automate and improve the many devices that surround us and ultimately make life all the more convenient.

Healthcare is another sector which can benefit greatly from this development. Remote patient monitoring is already becoming increasingly more sophisticated and prevalent due to the lower costs of wireless devices, the wide availability of broadband networks and the requirement for healthcare providers to find new ways to streamline patient care and costs. One possible application could be a heart rate monitor, notifying the hospital when certain pre-set levels are reached. Necessary steps to deal with the situation could then be set in place automatically, without the need of human interaction (increasing the dose of medication to an IV drip, for instance). In fact, ABI Research recently stated that the remote patient monitoring market is set to grow at a 77% compound annual growth rate, reaching nearly a billion US dollars by 2014.

The evolution, therefore, has already begun. Together with it, however, come certain network implications which have to be taken into account.

The exponential increase in the number of network-connected devices exchanging information will become a real driver for much more network bandwidth. In fact, the proliferation of networked devices changes the nature of the network by significantly raising the threshold of "baseline" Internet traffic. Operators struggling to cope with 3G or broadband growth will need to consider "intelligent" ways of growing the network without growing costs.

Further, networks must be prepared to deal with multiple services and quality requirements at the same time. The need to differentiate both high and low priority traffic will be just as important as to be able to dynamically adapt the network to changing capacity requirements on-demand and in real-time. It is these service-driven networks that will allow the flexible use of existing capacities without impacting the service quality.

The Internet of Things could greatly change our lives for the better, but it is essential that the right network is put in place to support these innovations.

> "THE INTERNET OF THINGS COULD GREATLY CHANGE OUR LIVES FOR THE BETTER"

**By Duncan Ellis, Director of Systems Engineering at Ciena**

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*The entire spectrum of automobile electronics will be shown at electronica 2010 in November*

# electronica 2010 to Present Future Mobility Concepts

The bi-annual electronics trade fair – one of the largest in Europe – electronica 2010, is focusing on a "three-pillar concept for automobile electronics" when it opens its doors to visitors this November in Munich, Germany.

The automotive part of the fair is the centerpiece of electronica this year and it's branded "the most important innovation platform for international companies in the automotive industry". Energy efficiency and environmental compatibility are two of the most important challenges facing the automobile industry. Automobile electronics can provide numerous solutions for future automobiles and, as such, it is one of the fastest growing markets in the automotive sector. Around 20% of exhibitors at electronica 2010 will show products from the automotive sector and present solutions for future mobility. In addition to the trade fair itself, the 'electronica automotive conference' and the Automotive Forum will also focus on this topic, thus forming the three-pillar concept of the trade fair for this area.

The Automotive Forum will examine the topics of e-mobility, safety and communication during different sessions. The forward-looking technologies will be described on all four days of the trade fair during short talks and podium discussions.

The 'electronica automotive conference' will be held in the Munich International Congress Center on November 8 and 9, 2010. The first day will feature talks on markets and strategies aimed at top managers from automobile manufacturers, automotive component suppliers and electronics companies. The focal point for the target group on the second day will be technical management technologies.

The automobile industry ranks among the world's most important and highest earning industries. Automotive electronics also plays a leading role in the electronics sector as a sub-segment. After a drop in turnover to $125bn in 2009, market researchers are anticipating an increase; market analyst house Strategy Analytics forecasts a figure of $244bn up to year 2017.

Further information on electronica 2010 is available from **www.electronica.de/en**

Scientists from Singapore A*STAR's Institute of Materials Research and Engineering (IMRE), University of Cambridge (UK) and Sungkyunkwan University (South Korea) have created metallic lines so thin and smooth that they can only be seen using powerful electron microscopes. Their line widths are just 7nm, and line width roughness, which are the variations in thickness along the line itself, stand at 2.9nm.

The ability to create such distinct lines and patterns on a sub-10nm scale level is essential in the further miniaturisation of electronic components. Rough, undefined patterns and lines results in poorly made, energy-inefficient devices. The process is very delicate and precise because of the scale at which the work is done.

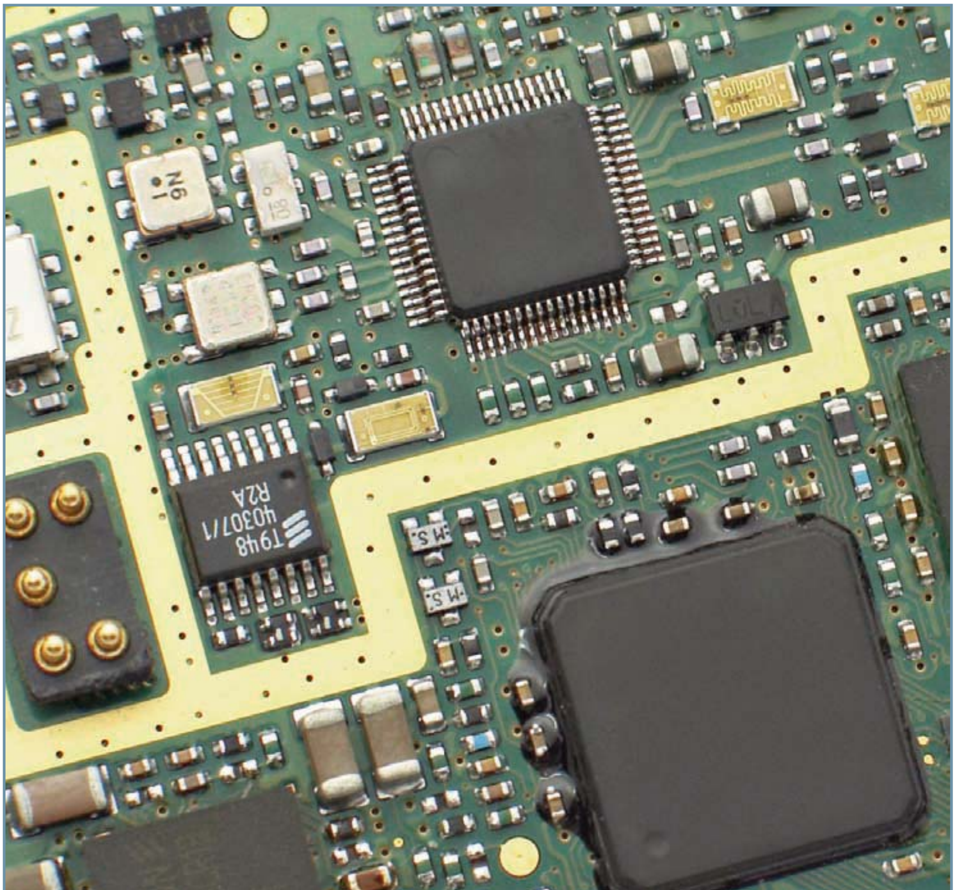
A UK company TeraView is offering an alternative to full body scanners currently being deployed at airports. Its scanner uses TeraHertz signals, which it claims, offers greater advantages over traditional X-rays and millimetre wave technology as it is particularly sensitive to certain substances. It distorts the contrast of the images it generates to quickly and simply highlight explosives (including PETN) on the body amongst clothing and other obstacles. This feature eliminates the invasion of passenger privacy as the 'low interest' aspects of images are not exposed in fine detail.

Cambridge Consultants announced it has developed InCognito, a novel, low-cost 'spectral sensing' cognitive radio technology platform that will allow any radio product to transmit without interference over the so-called 'whitespace' frequencies recently vacated by the US digital TV switchover.

These highly desirable TV band frequencies easily penetrate walls, potentially extending the range of Home Area Networks (HANs) and enabling a range of novel new applications, such as reliable high-definition video streaming from a single access point to every room in a house. Innovative use of 'whitespace' radio will also make it possible to increase the accessibility of low-cost high speed wireless internet services, including those rural communities which are currently poorly served.

DuPont announced that it has achieved record performance in printed organic light emitting diode (OLED) displays, sufficient to enable future adoption of OLED television (TV). Using proprietary DuPont Gen 3 solution OLED materials, DuPont has for the first time demonstrated a solution-based manufacturing process in which OLEDs can be cost effectively printed while delivering the necessary performance and lifetime.

OLEDs are an inherently more sustainable display technology when compared with liquid crystal displays (LCDs). OLEDs have the potential for lower power consumption and eliminate the need for many of the LCD components, such as backlights and colour filters.



*Part of a circuit board*

# GOLD BONDING WIRE IN SEMI-CONDUCTOR PACKAGING

**Richard Holliday at the World Gold Council explains the main differences between copper and gold used in electronics manufacturing and the views of electronics manufacturers on this subject**

**GOLD HAS AN** extensive track record of use in industry over many decades. Over 400 tonnes of gold is used in a diverse range of industrial applications each year, accounting for over 10% of annual gold demand. A number of different industries manufacture an array of gold-based materials, components and chemicals that help produce, or are part of, thousands of products. These products significantly improve our everyday life and safety, and the competitiveness of scores of industries.

But it is the electronics industry that is most reliant on gold. In 2008 (before the economic downturn hit the semiconductor industry), nearly 300 tonnes of gold was estimated to be used in the electronics industry including packaging, platings, thick film pastes etc. This represents 8% of total gold demand. Of the 300 tonnes, approximately 140 tonnes a year of gold bonding wire is used by the semiconductor industry. Each year over 8 billion wires are bonded and used for integrated circuits, transistors and LEDs. Gold has an extensive track record of use for many decades and each year millions of electronic devices trust in gold bonding wire to deliver reliable performance.

There is undoubtedly substantial knowledge and experience of gold bonding wire, but why is gold the material of choice in the first place? The unique properties of gold make it ideal for use in bonding wire technology: outstanding corrosion resistance, high electrical conductivity and its ability to be easily drawn into the thin diameter wire used in the microelectronics industry.

> THE UNIQUE PROPERTIES OF GOLD MAKE IT IDEAL FOR USE IN BONDING WIRE TECHNOLOGY

There are, of course, detailed technical issues and considerations related to decisions in selecting bonding wire material. The most important factors that manufacturers look at when selecting bonding wire material are in-service product reliability, process yield and proven performance. Other key considerations are the stability of the wire bonding process, the compatibility of the material with other substrates and the cost effectiveness and reliability of the material.

With the rising price of gold, many companies are looking to ways to save costs. Some manufacturers are looking to switch to cheaper materials like copper particularly for high volume products with low margins, where reliability is not a concern. For example in China, there has been a switch to copper for high volume, low margin products such as toys. However, for many products quality and reliability cannot be compromised. WGC welcomed the results of a recent survey, conducted by SEMI, the global semiconductor industry association, which showed the semiconductor industry has serious reservations about the reliability and yield of copper bonding wire.

SEMI surveyed 46 leading semiconductor companies across the world to determine the extent of copper bonding wire programs in the industry and to identify the key issues and considerations related to decisions in selecting bonding wire material. Companies surveyed included both integrated device manufacturers (IDMs) and fabless semiconductor companies, with revenues totalling $137bn in 2008, representing 55% of the global industry, and included responses from 14 of the top 20 supplier rankings for 2008.

The results show that 59% of the companies surveyed do not use copper wire technology in their products, 41% use it in some products and none of the companies use it in the majority of products. Of the companies surveyed, 72% are considering the switch to copper wire for some new products, 13% are considering it for the majority of products and 15% are not considering switching. There were serious concerns about the move to copper usage, of which the main concerns were in-service product reliability, process yield and unproven historical performance.

This global survey does show that an increasing number of companies are considering using copper for some new products, this despite continued evidence that gold is more reliable. With this reported shift towards using copper in place of gold bonding wire in the semiconductor industry, it is important to clarify the extent to which this shift is actually taking place and find out what the industry thinks of copper as a replacement for gold. Currently, a balanced view of the merits of each metal are not being discussed and debated, and importantly, the total costs related to the whole supply chain not just the basic wire cost. According to some industry players, copper bonding wire can meet all the needs of the industry, yet the results of the survey suggest many people are not convinced that copper is the complete solution. There are serious concerns with the reliability and yield of copper wire. We believe this survey should stimulate the debate that has been notably absent up until now.

Technically speaking, what are the properties of gold that make it more reliable than copper? As previously mentioned, gold has many advantages as the material of choice for bonding wire including good corrosion resistance, high electrical conductivity and the ability to be bonded into position in an ambient environment. Gold also has an extensive track record of use for many decades and each year millions of electronic devices trust in gold bonding wire to deliver reliable performance, so there is substantial industry know-how on gold bonding wire.

INSTEAD OF SWITCHING TO COPPER SOME INDUSTRY PLAYERS ARE SEEKING ALTERNATIVE STRATEGIES FOR COST REDUCTION

Stable wire bonding production is achievable with gold wire. This because gold is softer and has a lower flow stress than copper so is less prone to bond pad cratering than copper and a robust second bond is achieved. As copper wire is harder than gold wire, bond pad modification is required for some applications.

Gold wire bonding also has larger process windows than copper – a high number of units per hour can be achieved with gold which allows higher productivity than copper and cost-effective assembly operations. Copper wire bonding is slower due to longer bond formation, resulting in lower units per hour production rates, and the costs for infrastructure and consumable gases used to protect the free-air ball in copper bonding need to be accounted for during the costing process. The costs associated with higher bonding temperatures and bonding forces also need to be considered.

Reliability and package testing are more difficult with copper; the use of normal decapping methods based on nitric or sulphuric acid to remove the thermoset plastic, thereby leaving the gold wire intact, can't be used with copper. Alternative laser decapping methods are costly and time consuming.

Copper's inferior corrosion resistance means copper wire has a limited 'floor life' compared to gold. This may result in increased scrapping of material and associated costs. There is also the significant added cost of potential in-service chip failure.

At the same time, gold is compatible with any substrate or lead materials (aluminium, gold, silver or copper), whereas copper may corrode more readily with epoxy moulding compounds commonly used with gold and some moulding compound suppliers may need to offer new formulations for use with copper wire.

Instead of switching to copper some industry players are seeking alternative strategies for cost reduction. Reducing the amount of gold consumed, whilst maintaining the inherent reliability of a gold bonding wire solution, is a viable strategy for cost reduction. Solutions include reducing the overall length of gold wire through optimisation of loop height, optimising bonded ball volume or design changes to minimise wire usage (for example, using thinner wires for signal wires and thicker wires for power wires). It is important that wire suppliers assist their customers to reduce the impact of the metal price on the overall cost of gold bonding wire technology.

In terms of cost it is also important to remember that when evaluating the costs associated with bonding wire selection it is recommended that the total cost – rather than just the basic wire cost – of a copper solution versus a gold solution is considered. There is much more to the story than just the cost per meter of gold versus copper bonding wire. ■

Myk Dormer

# Decoupling

**IF YOU HAVE** designed in enough of it, then it seems to be doing nothing.

Allow for an insufficient amount, then nothing works at all…

Amusing, but firstly: what do we mean by decoupling?

Put simply, decoupling components are the circuitry which prevents one section of a complex design from spuriously interacting with another. They are the (numerous) rail-to-ground capacitors which keep supply impedances low, the tiny ferrite beads on signal wires that reduce electromagnetic coupling, or the big inductor in the supply rail.

In general, decoupling circuitry consists of low-pass filter networks on supply rails or signal lines, consisting of low impedance capacitance to ground combined with series reactance (inductive or resistive) to block the passage of spurious signals or energy. Depending on the circuit path under question, different tradeoffs apply.

**"INADEQUATE DECOUPLING CAN GIVE RISE TO A WIDE RANGE OF PROBLEMS AND INSUFFICIENT DECOUPLING CAN RESULT IN REDUCED PERFORMANCE"**

Supply rails require the lowest possible impedance to ground at high and low frequencies (to maintain stage stability), combined with sufficient current carrying capacity (or minimal voltage drop) in the series elements.

Decoupling a signal line requires different tradeoffs: current handling is rarely an issue, but the overall ‘lowpass’ component must attenuate only the unwanted frequencies, while allowing the signal waveform to pass uncorrupted.

Inadequate decoupling can give rise to a wide range of problems: Amplifiers (both audio and RF) become unstable or pick up unwanted signals. Logic circuits conduct noise onto supplies and spuriously trigger as the rail voltage ‘glitches’, power supplies become noisy or unstable and EMI levels rise uncontrollably.

Low power radio modules are especially vulnerable. Insufficient decoupling can result in reduced performance. It can also result in operation outside the limits of the approval specification.

Receivers will suffer primarily from noise pickup. There is a lot of gain (over 100dB) in the signal path of even a simple radio. Interfering signals can enter the circuitry via the interface or supply connections and degrade circuitry otherwise protected by the (intended) signal filtering. Large interferers can degrade sensitivity and corrupt data-streams, but lower levels will still introduce spurious responses and degrade rejection performance.

Transmitters suffer from two different mechanisms: external noise will add (potentially illegal) spurious components to the RF spectrum, while the coupling back of the transmitter’s output signal to its input circuitry can cause instability or a form of severe modulation waveform distortion known as ‘recirculation’; the higher the output power, the greater the risk of this issue.

So what is to be done? Simply include more decoupling than you think you need – at the initial design stage.

Allow a rail-to-ground capacitor for every stage or IC, as close to the circuit as practical. Sensitive, or especially noisy, devices sometimes need two: a small RF decoupler and a much bigger low frequency part. Also, a low value resistor or an inductor (or low Q ferrite decoupling choke) in series with each stage’s supply feed is beneficial and makes isolating the stage during debugging or rework easier.

Signal paths can sometimes be decoupled with series ‘stopper’ resistors, which form a low-pass network with the input capacitance of the following stage, but small ferrite chokes are sometimes needed.

Be careful not to add too much capacitance to signal lines since, as well as attenuating the wanted signal, this can cause instability in logic or op-amp output stages, and always ensure a solid earth, otherwise the ‘decouplers’ just move the ground current loops about.

In the case of a wireless module I recommend:

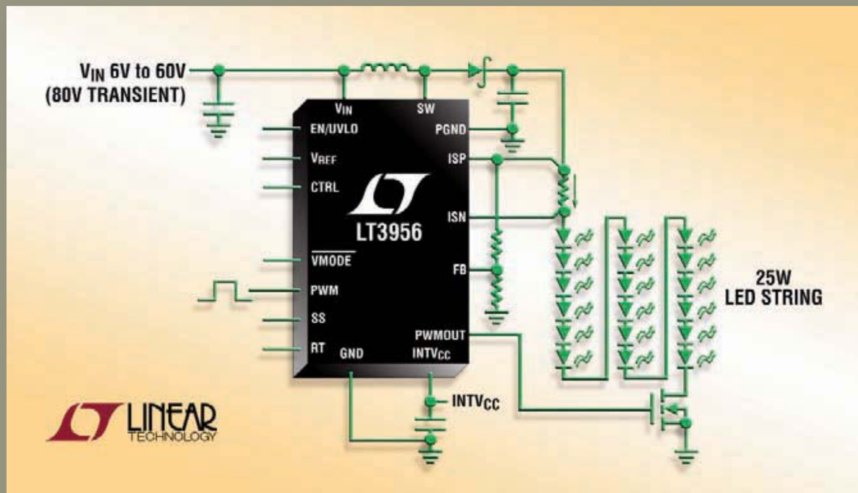
- An RF decoupler (something like 100pF) to ground and a series ferrite ‘EMI suppression’ choke on every interface pin. The 0603 parts are cheap and are small enough to have little impact on the layout.
- A low frequency decoupler (several tens of microfarads, electrolytic) on the power supply. If supplied from a switch mode power supply, a large value low ESR inductor in series may also be wise.
- Avoid locating the aerial too close to the module, or to the wires and tracks connecting to it. Keep PCB tracks short and direct, and use a good, solid ground plane.

Remember: it is much easier to bridge out or not fit ‘unnecessary’ decouples during the later iterations of a design (after your tests have proven that they are not needed) than it is to bodge and squeeze them in later, after the pre-production units have expensively failed an approval test. ■

*Myk Dormer is Senior RF Design Engineer at Radiometrix Ltd*
***www.radiometrix.com***

# LEDs Deliver More from Less

**Tony Armstrong**
Director of Product Marketing
Power Products
Linear Technology Corporation


## LEDS & AUTOS

LEDs continue to penetrate automotive lighting applications due to their long life and flexibility of use for body styling and interior design. It might come as a surprise to some people that this trend continues to gain momentum despite the fact that a LED's cost of implementation is greater than that of the incandescent light bulb. So, why would this be the case? The answer is surprisingly simple; the front of any vehicle looks like a face and how it looks has a profound effect on a potential buyer. LED lighting, used for the headlights, daytime running lights and turn signal indicators, allow for much greater design flexibility than that of either Xenon or incandescent light bulbs. This permits the body designers of an automobile's front end to do things that they could never do before. A good example of this design flexibility is readily illustrated by Audi's A-series automobiles that have their daytime running lights in a linear array underneath the headlights and turn signal indicators. If you have ever seen one in your rear view mirror, you'll know exactly what I am talking about.

Nevertheless, it is the headlight itself, which has been the elusive goal of LED adoption in an automotive environment. The main reason for this has been the thermal design aspects of the LEDs and their associated driver circuits. Unlike a traditional light bulb, which is basically a 'heater' and operates at high temperature, a LED and its driver circuit need heatsinking incorporated as part of their enclosure so that heat can be taken away from the LEDs. Clearly a LED driver's efficiency of conversion along with its associated power loss can have a significant impact on the thermal design aspects of the LED housing used in an automobile headlight configuration. All of these precautions are necessary because a LED's light output and operational lifetime are negatively impacted by exposure to high temperatures.

## LEDS & CAPABILITIES

A high power, or high brightness LED's light output has already exceeded the critical milestone of 100 lumens per Watt (lm/W). In fact, some manufactures are already claiming 200 lm/W in the laboratory. Clearly then, LEDs have surpassed an incandescent light bulb (15 lm/W for a typical 60W bulb) in terms of luminous efficacy. Or said another way, the amount of light output from a light source, measured in lumens, as a ratio of the amount of power consumed to produce it, measured in Watts. Even so, it is projected that by 2012, LEDs with 150 lm/W output will be readily available in the marketplace. Another added benefit is LED lifetime. Depending on how it is calculated, a white LED bulb has at least a 10,000-hour lifetime and some even claim up to 50,000 hours, while an incandescent bulb's life is around 1,200 to 1,500 hours. Furthermore, LEDs are "Green," since they do not contain any hazardous materials.

The cost of LED lighting has been coming down very quickly. The cost of individual white LEDs, several of which go into a LED bulb and make up much of the cost, have come down in price from about $5 a few years ago to under $1.00 in the last twelve months. Many LED industry analysts predict that over the course of the next twelve months LED bulb replacements for the incandescent light bulb will be priced at a level that will be acceptable for the consumer. Some LED manufacturers have already claimed that they have designed light-emitting chips that could power a LED bulb producing light comparable to the 75-Watt incandescent bulbs so commonly used in most private residences. This type of LED chip usually requires 12W to 15W of power in order to be able to output this amount of light.

Specifically in the case of cars, a headlight needs to have a light output of at least 800 lumens to be practical. Cree, a manufacturer of LEDs, has its XLamp XP-G series of LEDs, which it claims has the highest lumen density of any available lighting class of LEDs. Housed in their XP-family package, they can provide up to 400 lumens output at 1A and over 130 lm/W at 350mA. Thus, since a LED headlight will provide an energy benefit (they are typically 75% more efficient than the standard version), their use will reduce the level of fuel consumption on an annual basis. How much LEDs can actually save in fuel costs was evaluated in a 2008 study by the University of Michigan's Transportation Research Institute (UMTRI). In it, they studied the power consumption of exterior lighting on passenger cars by comparing a traditional system using 100% incandescent and halogen lighting sources with a 100% LED equivalent. The results showed light power savings of over 50% with an all-LED system. This not only saves in fuel cost for a petrol powered vehicle but it would reduce the vehicle's total carbon footprint by 1% to 2% per year.

## DRIVING A 25W HEADLAMP

A 25W white LED headlamp can now be configured using an array of 18 LEDs in series with 350mA of current passing through them to produce the necessary light output. However, a major obstacle is how to efficiently and simply drive such a configuration. One possible solution is to use the recently introduced LT3956 monolithic LED driver from Linear Technology. The LT3956 is a DC/DC converter designed to operate as a constant-current and constant-voltage regulator. It is ideally suited for driving high current, high brightness LEDs (see Figure 1).

The LT3956 features an internal low side N-channel power MOSFET rated for 84V at 3.3A and is driven from an internal regulated 7.15V supply. The fixed frequency, current-mode architecture results in stable operation over a wide range of supply and output voltages. A ground based referenced voltage feedback (FB) pin serves as the input for several LED protection features and also makes it possible for the converter to operate as a constant-voltage source. A frequency adjust pin allows the user to program the frequency from 100kHz to 1MHz to optimize efficiency, performance or external component size.

The LT3956 senses the output current at the high side of the LED string. High side sensing is the most flexible scheme for driving LEDs, allowing boost, buck mode or buck-boost mode configurations. The PWM input provides LED dimming ratios of up to 3000:1 and the CTRL input provides additional analog dimming capability.

Efficiency of conversion for the LT3956 can be in the 94% range, depending on the input voltage and operating frequency. This is illustrated in the efficiency curve shown in Figure 2.

This high efficiency of conversion allows for a more straightforward thermal design for the LED headlight housing since this LED driver does not contribute significantly to the heat generated by the LEDs themselves. In the example above, the LED driver has a power loss of 1.5W, which is dissipated as heat (25W * (1-0.94)). This has the added benefit of also saving on space and weight requirements.

## CONCLUSION

For a high power LED driver to be used in an automotive environment it must have some key attributes. Clearly, they must be capable of delivering sufficient current and voltage for the different types of LED configurations in a conversion topology that satisfies both the input voltage range and required output voltage and current requirements. However, they should also posses the following features:

a) Wide input voltage range
b) Wide output voltage range
c) High efficiency conversion
d) Tightly regulated LED current matching
e) Low noise, constant frequency operation
f) Independent current and dimming control
g) Wide dimming range ratios
h) Small compact footprint with minimal external components

Even with this list of performance characteristics, the LED being driven by the LED driver has to be capable of delivering the necessary lumens of light output from the lowest possible level of power without causing significant thermal design constraint. Fortunately for the headlight designer there exists both the high efficacy LEDs and the high performance LED drivers to realize what had previously been considered mutually exclusive: high values of light output from low levels of input power.

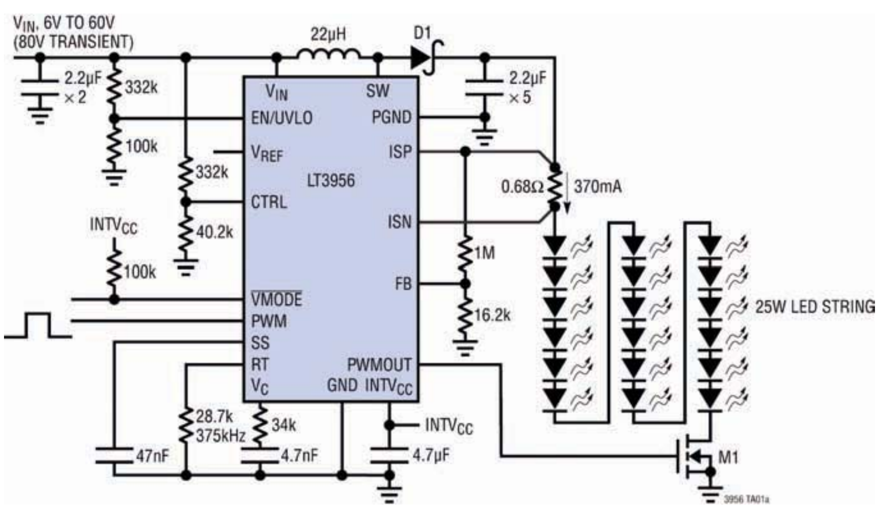



***Figure 1:*** *94% Efficient 25W White LED Headlamp Driver*

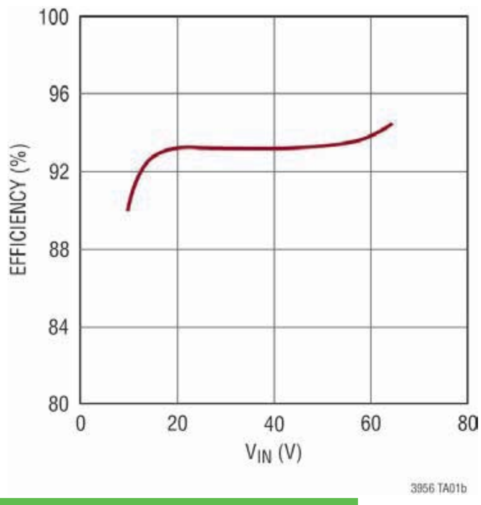



***Figure 2:*** *Efficiency vs. $V_{IN}$ for the LT3956 Circuit Shown in Figure 1*

**Jacques Le Berre**, director of marketing and business development, on NXP's SSL2103 LED driver, discusses the changes in lighting technology, with specific references to the developments in dimmable LED lamps. This article explains the related issues and provides examples of tradeoffs to be considered

# Dimmable LED Based LAMPS

**IN RECENT YEARS**, the lighting world witnessed a revolution with the emergence of LED based lighting. Across retail outlets in both Europe and the US, old incandescent lamps are now difficult to find or simply banned. The lower power range of the Compact Fluorescent Lamps (CFL) now has to compete with the new player in the lamp replacement market. The LED technology is permanently improving, making LEDs brighter and much more powerful every day. Added to their efficiency, these features make them ideal for use in lighting.

An incandescent lamp will produce around 10 lumens per Watt, while LED manufacturers claim performance up to 100 lumens per Watt. However, targeted form-factor and maximum operating temperatures prevent the full potential of LEDs. As a result, best performing LED replacement lamps reach today an efficacy of 50 to 60 lumen per watt. Therefore, LEDs are close to challenge the CFL lamps on the efficacy criteria (note: CFL lamps are ranging from 60 to 70lm/W with limited improvement potential).

Ecological issues are also becoming more and more relevant to the public. With a heightened awareness of global warming and climate change, the idea of saving resources and energy is becoming a major feature in many marketing strategies.

The decrease in the fuel consumption of cars over the last ten years and the ban of incandescent lamps perfectly illustrate this trend. Governments around the world have all set a timetable to phase out incandescent lamps. Some public initiatives provide relaxed taxation or financial help for ecologically friendly "ECO" products.

LED's intrinsic benefits perfectly match the public expectation for a safe, energy efficient and environmentally-friendly lighting solution. LEDs offer many other advantages, such as high dimmability, excellent life spans and a small form-factor. They open up opportunities where form, colour, life span and cost matter.

Replacing conventional light sources (fluorescent lamps, CFL, halogen or other incandescent lamps) by electrically, mechanically, optically and thermally compatible LED solutions is a revolution on its way. Hospitality, office and residential lighting markets call for quality LED retrofit lamps. While the cost of these solutions remains a major hurdle, further technical issues require attention:

- Electrical compatibility with the infrastructure in place, especially in the case of wall plug dimmers.
- The form-factor must be equivalent to an Edison type lamp.
- The conducted heat from the LEDs must be dissipated.

### Dimmer Compatibility

Until now, control equipment for lamps in homes, hotels and offices were created only for incandescent lamps. The best way to provide a dimming functionality is to use 'mains phase cut' dimmers. These dimmers are logically developed to power an incandescent lamp. In electrical terms, an incandescent lamp behaves like a resistive load.

The electric equivalent load of the electronic light sources like CFL or LED lamps is no longer purely resistive. This makes a considerable difference in the way the dimmer works. Using an inappropriate load can lead to an unsatisfactory functioning of the system. It can create some very

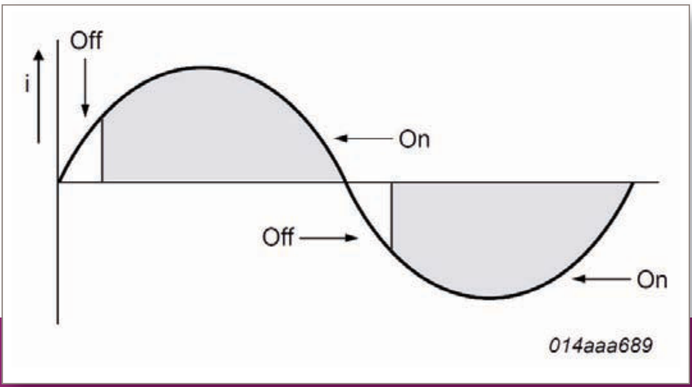



***Figure 1:*** *Leading edge – dimmer maximum on*

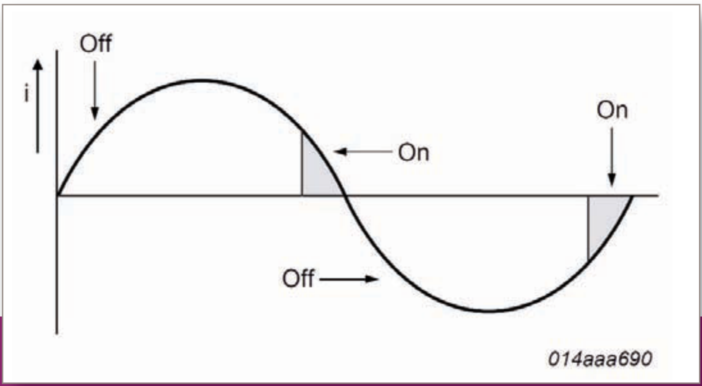



***Figure 1:*** *Leading edge – dimmer minimum on*

*Figure 3: Trailing edge – dimmer maximum on*

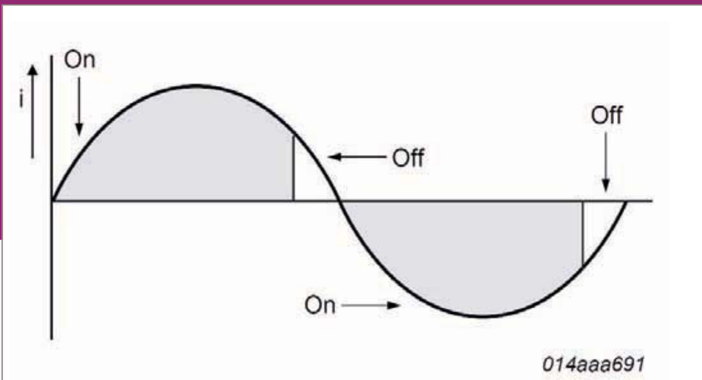
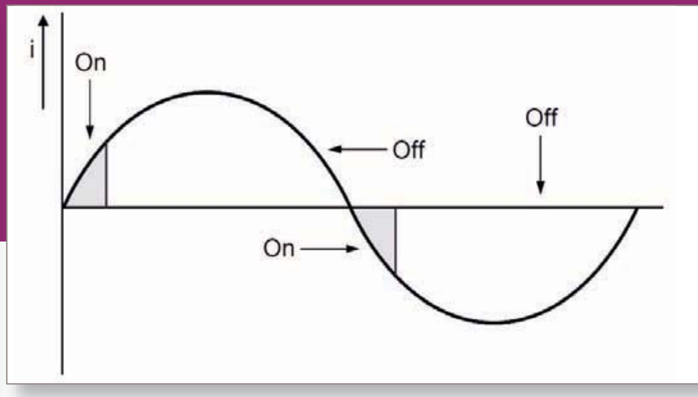



*Figure 4: Trailing edge – dimmer minimum on*




unpleasant flickering of the light or even damage the lamp or dimmer. This may create dissatisfaction resulting in a slower adoption of LED based solutions.

Dimmers are still quite expensive and difficult to install. Offering quality solution compatible with the installed base of dimmers is therefore a must to safeguard the announced roll out of LED lighting.

There are different types of phase cut dimmers, but they all use the same principle, i.e. cutting a part of the mains sine wave during each period. This is achieved using a switch. When this switch is conducting, a supply is delivered to the load (the bulb). When it is off, no supply is delivered. By adjusting the conduction time, the total delivered energy is modulated.

There are two types of dimmers: leading edge and trailing edge types, see **Figure 1**.

With leading edge dimmers, the phase is cut at the beginning of the mains half period. After a time corresponding to the dimming position, the switch is put to "on" and the supply is delivered until the end of the half period. After crossing zero, the same operation repeats, see Figure 1 and **Figure 2**.

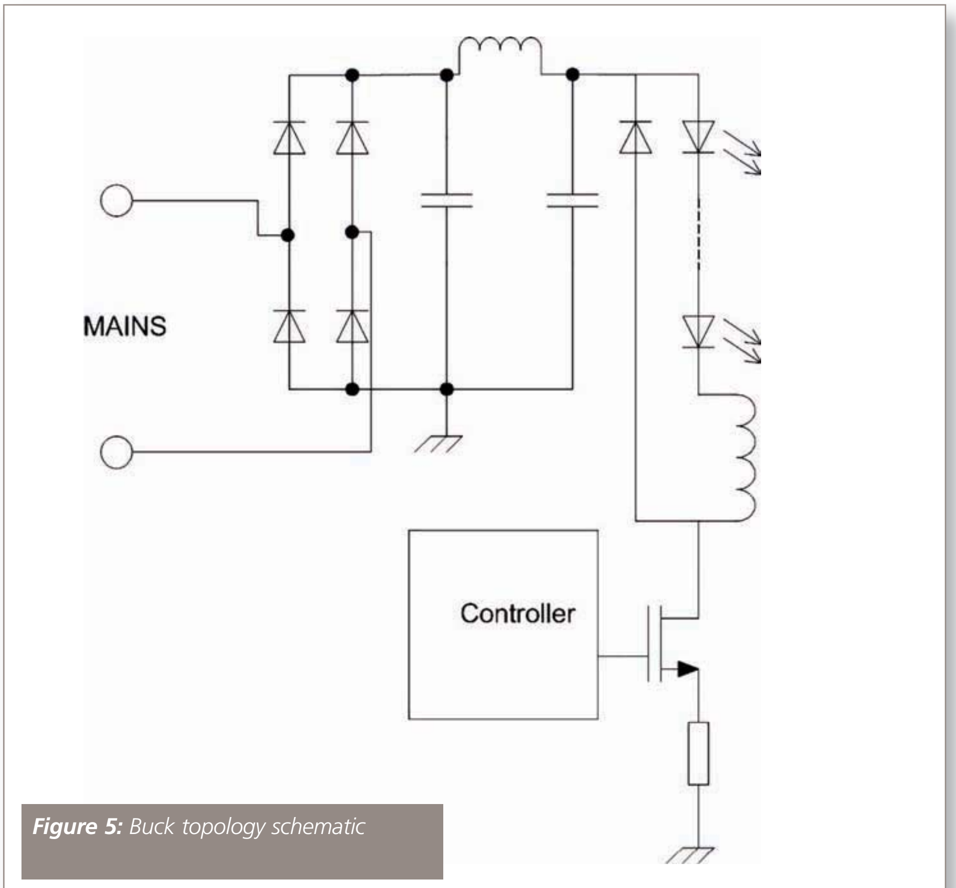



*Figure 5: Buck topology schematic*

With trailing edge dimmers, the switch is set to "on" at the beginning of the half period, and closed after a time corresponding to the dimming position. It stays off until the end of the half period. After crossing zero, the same operation repeats, see **Figure 3** and **4**.

To achieve phase cutting, two technologies are mainly used: TRIAC switches or transistors switches. TRIAC dimmers are always leading edge dimmers. Transistors dimmers can be "leading" or "trailing" edge dimmers.

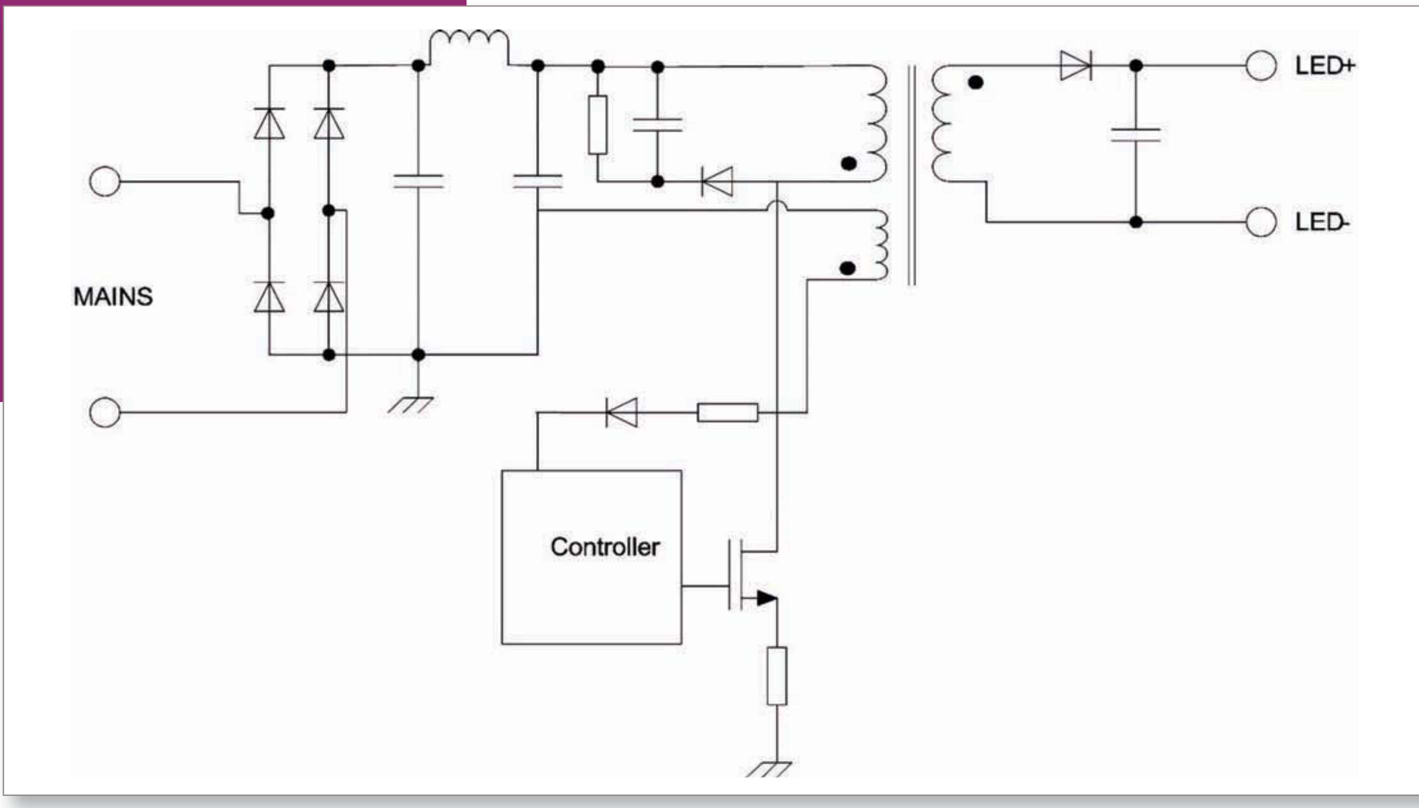
The issue with TRIAC dimmers is that they required special conditions to work correctly: A TRIAC can be opened by activating its gate and, after it is activated, a minimum current needs to be present to hold the TRIAC open. This current is called the "latch current" and must be applied for some time to keep the TRIAC conducting.

Once the device has been latched, a continuous current must flow through the device. This is called the 'holding current'. If this current is removed or decreased, the TRIAC will switch off.

To be dimmer compatible, an LED-based lamp will have to sink the hold current needed for the dimmer. For instance, if a 6W LED lamp (roughly equivalent to 40W incandescent bulb) is used with a dimmer designed for a minimum load of 10W, some extra circuitry will be needed to provide a sufficient hold current. In this case, the efficiency of the bulb will decrease but the benefit will still be high compared to 40W. Moreover, an LED lamp without this circuitry will not operate correctly. There is a variation in the hold current over all dimmers.

As a conclusion, the larger these extra losses are, the greater the dimmer compatibility. The difficulty in designing a

**Figure 6:** *Flyback topology schematic*




dimmable application is to find a compromise between efficiency and dimmer compatibility.

The NXP SSL2101 (and derivative SSL2102) has two integrated bleeder switches controlled by the IC. By connecting external resistors, two different bleeding currents can be set. The IC offers greater flexibility in the choice of current and helps to optimize dimmer compatibility. In the SSL2103 (the controller only version of SSL2101), the integrated bleeder switches are removed. They can be replaced by low cost external bipolar switches (still driven by the IC) for higher bleeding current levels. Also, the internal Mosfet to operate the converter is removed, and can be corrected externally to enable a specific tuned solution.

## Form Factor versus Topologies

Fundamentally LEDs are current driven. The quantity of light they emit is roughly proportional to the current flowing. Based on that, different topologies can be used to drive them from mains. One of the key targets in the choice of the topology is the form factor of the final application. Small power (< 15W) LEDs lamps are mainly addressing retrofit markets. This means that the shape of the bulb must be equivalent to classical existing lamps.

The three following topologies are representative of current available products:

### *LEDs in series with a resistor*

The LEDs are connected in series with a resistor directly to the mains. This topology is the simplest. As soon as the mains voltage goes higher than the sum of the forward voltage of the diodes, LEDs start conducting. The maximum LED current will be determined by the resistor value as in:

$$I_{peak} = \frac{V_{mains\_max} - n \cdot V_f}{R}$$

where n is the number of LEDs and $V_f$ their forward voltage.

This solution is simple, but very inefficient. As an example, consider a 12W application with a maximum current of 500mA in the LEDs. The global forward voltage will be 24V. For 220V (AC) mains, the necessary resistor value is 574 Ohms. This resistor will dissipate 143W @ I = 500mA. Of course we could consider using low current diodes, but their $V_f$ will be much higher for the same power. As a direct consequence of this, the open time would be much smaller and some flickering would occur.

### *Buck topology*

The buck topology is one of the most efficient topologies. A basic schematic is shown in **Figure 5**.

When the switch is on, the current flows through the coil of the LED and light is emitted. To control the value of the current, a sense resistor is put in series with the ground. The voltage across this resistor is sensed and when it reaches the Over Current Protection (OCP) value, the switch is closed. The energy stored in the coil is then discharged in the free-wheel diode and the LEDs.

This topology has two main advantages:

- First, the efficiency is very good, especially for low power applications (below 10W). LED lamps for general lighting using this kind of topology often claim efficiency values higher than 90%.
- The second advantage is the form factor. The global form-factor of the application is very important for the retrofit market because the final shape of the product must be comparable to classical incandescent or halogen products. Buck topology does not use transformers or optocouplers, and so the coil can be relatively small, especially if the switching frequency is set relatively high.

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The topology also has two main disadvantages:

- The main drawback of this topology is that it does not provide any galvanic isolation. For thermal reasons, the LEDs are often placed on a metallic heat-sink. In such a case, galvanic isolation may be mandatory for safety reasons.
- The second drawback is that the LEDs are connected in series with the coil. There is a compromise between the global forward voltage of the diodes and the maximum losses in the converter. If there is a big difference between input and output voltage, efficiency will drop.

### *Flyback topology*

For the flyback topology, the coil is replaced by a transformer and LEDs are connected to the secondary side as shown in **Figure 6**.

When the switch is on, a current flows through the transformer and the diode on the secondary side is blocked. When the switch is off, the secondary diode starts conducting and a current flows through the diodes, emitting light.

The main advantage of the flyback topology is that LEDs are connected on the secondary side of the transformer. The compromise between the number of LEDs and the efficiency is no longer relevant because one can select a winding ratio. Galvanic isolation is now possible, the safety of the unit is improved and the VCC generation is simpler. An auxiliary winding can be added to the transformer that will generate the supply to the controller.

The main drawback of this topology for the retrofit market is the physical size of the application. Transformer – and potential optocoupler in the case of feedback – occupy a large amount of space. Some controllers, like the SSL210x family, are compatible with both buck and flyback topologies. Depending on the requirements, and when safety and good thermal dissipation are required, a very compact buck application can be produced or a flyback can be used if the LEDs are higher power or there is galvanic isolation. To make a smaller form-factor, both the SSL2101 & SSL2102 have integrated power switches.

### Dimming

LEDs are easily dimmable. Their emitted light is almost proportional to the supplied current. By reducing the average current, the light output can be reduced. However, having a dimmable topology is more complex and different techniques must be used like PWM dimming, frequency modulation or $I_{peak}$ modulation.

- With PWM dimming, the momentary current sent to the LEDs has only two values: 0 or $I_{max}$
  - When PWM = 0, $I_{leds}$ = 0A
  - When PWM = 1, $I_{leds}$ = Imax

By adjusting the duty cycle of the PWM signal, the average LED current can be changed. This technique requires the converter to act like a fast switchable current source. The aim of this technique is to accommodate high currents and maintain accurate control. Switching losses can be high, especially for deep dimming.

- With frequency modulation, the maximum LED current is not changed but the frequency of the converter is adapted. In other words, the amount of energy sent to the LED at each cycle of the converter is the same but the number of cycle per second is modulated. The problems of frequency modulation are the audible noise generated if the minimum frequency becomes too low, or it will give considerable switching losses if the maximum frequency becomes too high. These factors can make deep dimming difficult.
- In the case of $I_{peak}$ modulation, the frequency of the controller is constant but the open time of the power switch is modulated. As a result, the maximum current $I_{peak}$ in the LEDs are changed. In other words, the number of cycles per second is constant but the quantity of energy sent to the LEDs at each cycle is reduced. To achieve deep dimming using this technique, very small pulses are needed. This is not advised because of the switching losses.

Some controllers, like the SSL 2101 and its derivatives (SSL2102/03), combine frequency and $I_{peak}$ modulation. The drawbacks of each method are minimal. At full power, the switching frequency can be optimized to limit switching losses. During dimming, reducing Ipeak and frequency at the same time avoids an open time being too small and frequencies being too low. As a consequence, dimming below 1% can be achieved.

### Lifetime

An extended lifetime is a major advantage of the LED, with a claimed life of 50,000 hours. This value is much higher than the equivalent CFL lifetime, and far exceeds the lifetime of a conventional incandescent lamp. However, LEDs cannot be used alone (as described above) and they need other components to drive them. In the semiconductor industry, the standard for a lifetime test is 1000 hrs. Depending on the working temperature of the final application, some coefficients are applied to estimate the lifetime of components. This 1000-hour test is certainly not sufficient in guarantying an estimated lifetime. An extended lifetime test must be done to guarantee that a controller will have a lifetime compatible with the lifetime of the LED.

The SSL210x product family has passed the 8000 hours lifetime test at 150°C junction temperature. Depending on the actual junction temperature in the final application, the estimated lifetime can be extrapolated towards 45,000 hours at 115°C or 75,000 hours at 105°C. These values support the claim that the "SSL210x product family matches the lifetime of the LEDs".

### The Lighting Minority

Currently LED based lamps are still, in terms of numbers, in the minority of the general lighting market. Nevertheless the ramp-up in the market has started and LED solutions will certainly become more and more dominant in the coming years.

This article has discussed several aspects of dimmable LED lighting applications. Buck and flyback topologies are the two main used topologies. The buck topology offers a very compact and efficient solution for low power applications, and flyback, with its intrinsic galvanic isolation, is still the best way to provide a safe and versatile system.

Dimmer compatibility and dimming range are two challenging features. Balancing the choices surrounding these issues will make the difference between successful and unsuccessful products.

Currently, NXP provides the SSL 210X family to cover all possible dimmable applications for the retrofit market so the optimum solution for each design can be obtained. ■

**Pierre Mars**, VP of Applications Engineering for CAP-XX Ltd, compares light energy and photo quality from predominantly 5-megapixel camera phones using both xenon flash and standard battery-powered LED flash, and demonstrates how high-power LED flash is now possible using the latest white LEDs powered by a supercapacitor

# Comparison of Xenon and High-Current LEDs for CAMERA-PHONE FLASH

**MANY CELL PHONES** have compromised on size and/or cost of their flash solution by providing either a small xenon flash or a low-to-medium-current LED photo light, both of which provide insufficient light energy for an acceptable photo in low-light conditions such as in restaurants, bars and other places where people socialize, see **Figure 1**.

***Figure 1:*** *Photo taken in very low ambient light using a small xenon flash (5MPx LG KU990 camera phone). The girl is only 2m from the camera, but only her silhouette is visible*

## Light Power vs Light Energy

The key to a good picture in low ambient light is to produce enough light energy from the flash during image-capture time to illuminate the subject adequately.

Light energy is the total amount of light received by each pixel in the camera sensor. People often wrongly assume that light power – or the flash brightness – is key, because it's what attracts our attention, but it's the light energy that counts.

Light energy is the area under the curve of light power over time. Assuming light power is constant during the flash pulse, as is the case for LED flash, then you calculate light energy by multiplying light power (in lux) by duration of the flash exposure (in seconds). A good picture ideally requires 10-15 lux.secs of light energy.

- Xenon flash has excellent light power, up to several hundred thousand lux, but a very short flash duration, typically 50-100µsec.
- LED flash delivers lower light power, but over a longer flash exposure to generate more light energy. Powered by a supercapacitor, LED flash can now generate up to several hundred lux with a flash pulse of up to ~100ms.

Therefore, a xenon flash needs 1000 to 2000 times the power of the LED flash to deliver the same light energy.

## Camera-Phone Solutions Tested

In this study, we measured light power over time for:

- Xenon: SonyEricsson K800i, LG KU990, Nokia N82 and Samsung G800, all with 5-megapixel cameras but with varying size storage capacitors.
- Standard battery-powered LEDs: Nokia N73 (3.2-megapixel camera) and N96 (5-megapixel camera).
- Supercapacitor-powered LEDs: Using the power architecture called BriteFlash, developed by CAP-XX, which combines a LED flash driver IC, supercapacitor, battery and WLEDs.

Integration of the area under the curves of light power over time shows the light energy available to fill pixels in the camera sensor, enabling an objective comparison of the solutions.

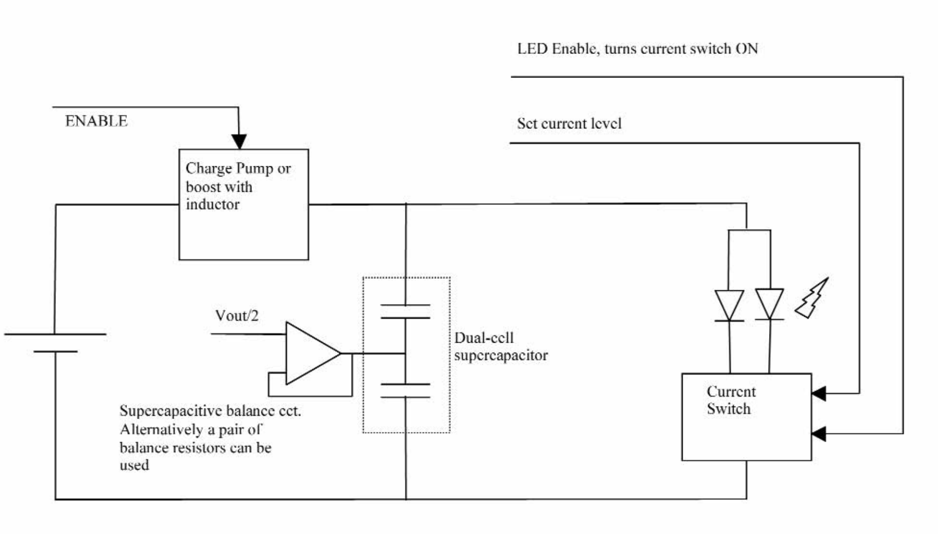



***Figure 2:*** *High-power LED flash supercapacitor solution block diagram*

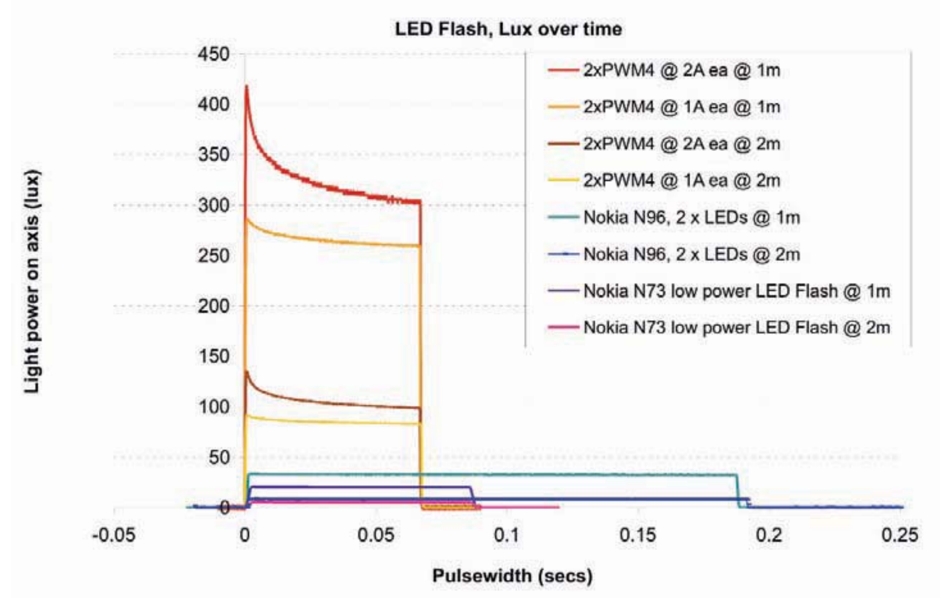



***Figure 3:*** *Light power over time for four xenon sources*

## Supercapacitor-Based LED BriteFlash Power Architecture

A supercapacitor can power high-brightness WLEDs drawing > 1A at 5V. This overcomes the limitations of low-current LED solutions outlined above, and enables a thin-form LED flash solution which can deliver comparable light energy to a xenon flash.

When using a supercapacitor to support LED flash, the battery only needs to supply average power to recharge the supercapacitor between flashes, while the supercapacitor provides the high-peak LED current (> 1A per LED) during the flash pulse. The flash driver's boost converter charges the supercapacitor to 5.5V, enabling it to drive the LED flash. **Figure 2** shows a block diagram of a typical flash driver using a supercapacitor.

Most major power IC vendors have released or are sampling supercapacitor-optimized LED flash drivers that integrate the functions in Figure 2, saving development time, board space and component cost.

Those already released include the AAT1282 from AnalogicTech, the CAT3224 and NCP5680 from ON Semiconductor, the LM3550 from National Semiconductor and the XRP6840 from Exar.

An I2C interface allows users to set Flash and Torch currents. Depending on the IC, a total LED flash current of up to 10A is possible. The supercapacitor has sufficiently high energy (high C) and high power (low ESR) to supply the LED current for the duration of the flash pulse with little or no contribution from the battery. The battery charges the supercapacitor between flashes.

## Limitations of LED Flash

There are many demands on cell-phone batteries, so designers want to avoid drawing more than 800-1000mA from LED flash used currently in mobile phones. The standard flash driver IC is a boost converter in current-control mode.

Assume the battery voltage is 3.6V, the LED forward voltage = 3.8V and the boost converter efficiency is 85%. For an 800mA battery current, the LED current = 0.8 x 3.6/3.8 x 0.85 = 650mA and LED power = 2.4W. At this current, a typical high-current LED will only provide 10-11 lux at a distance of 2m (for a Luxeon Flash PWM4), which only delivers 10/15 = 0.67lux.secs when capturing an image at 15 frames/sec.

In a xenon flash, an electrolytic capacitor is pre-charged to 330V, which then discharges across a xenon-gas-filled tube to produce an intensely bright flash. The high energy stored at 330V is a safety concern, and the electrolytic capacitor is bulky for thin-form-factor camera phones and digital cameras.

## Comparison Between Xenon and LED Flash

***Light power over time:***

**Figure 3** shows light power over time from the xenon sources at 1m and 2m respectively. The key points are:

- Light power from xenon flash is very intense, with the Samsung G800 delivering 300,000 lux peak power at 1m.
- Flash energy is traded off against the size of the electrolytic storage capacitor, described below from largest to smallest:
- The SonyEricsson K800 has 2 x 14µF, 330V electrolytic capacitors in parallel, for a total of 28µF, to produce ~220,000 lux peak power and a pulsewidth of ~100µs.
- The Nokia N82 has a 20µF, 330V electrolytic capacitor and

generates peak power of 160,000 lux with a similar pulsewidth.

- The LG phone uses a very small 10μF electrolytic and only generates 50,000 lux with a pulsewidth of ~50μs.

**Figure 4** shows the light power over time for the LED flash sources. To demonstrate the BriteFlash approach, we used the latest high-power LEDs from the Philips Luxeon range. The graphs show results for two high-current LEDs with optic at 1m and 2m distance. The supercapacitor drives the LEDs at 1A and 2A each, i.e. 2A or 4A total for 2 LEDs.

Key points from Figure 4 include:

- LEDs can deliver approximately constant light power for long flash pulses, allowing designers to use a CMOS sensor rolling shutter and no mechanical shutter. The supercapacitor-powered LED BriteFlash example delivered over 300 lux from 1m using two LEDs powered at 2A each.
- The Nokia N96 with standard LED flash delivered 32.5 lux from 1m, or approximately one-tenth of the supercapacitor solution with 2 LEDs @ 2A each.
- The Nokia N73, with a lower-power standard LED flash, barely registered on this scale. Its 1W of electrical power only delivered 16 lux from 1m, compared to > 300 lux from the two high-power LEDs driven at 2A each.

**Figure 5** shows how light is captured by a CMOS sensor with a rolling shutter. A frame is made of N lines, each with M pixels. Each pixel of a line is reset and then sometime later is read. The voltage read from each pixel is proportional to the light energy that has accumulated from the time the pixel is reset to the time it is read. That light energy is the light power integrated over that time (**Figure 6**).

When all pixels in the N lines have accumulated light energy for the same period of time, a frame has been captured. As shown in Figure 5, this occurs in a period of twice the frame interval. If the frame rate is 15 frames/s, then the image is captured in 2 x 1/15 = 2 x 66.7ms = 133ms. Each line has captured light energy

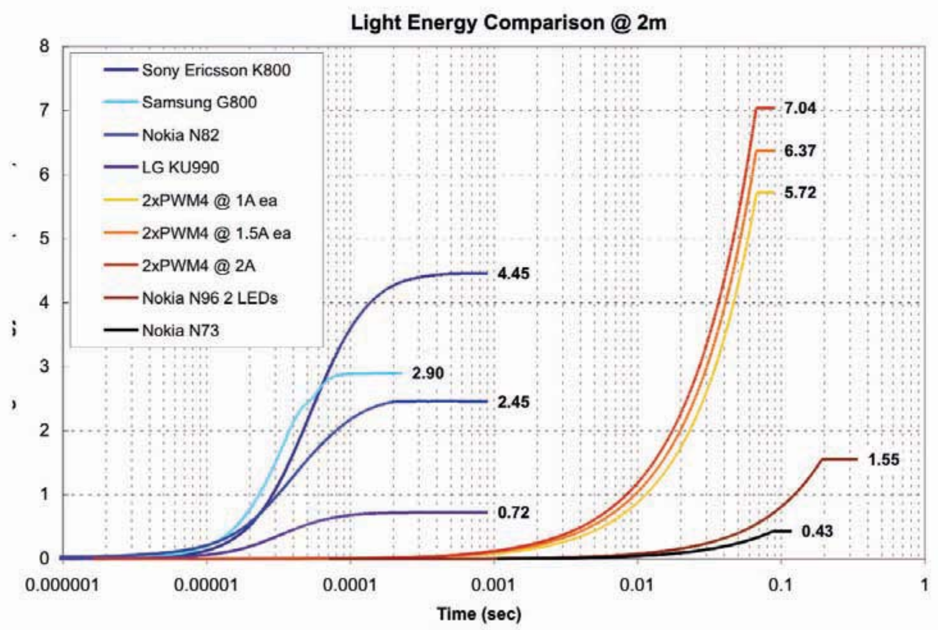



***Figure 4:*** *Light power over time for LED flash*

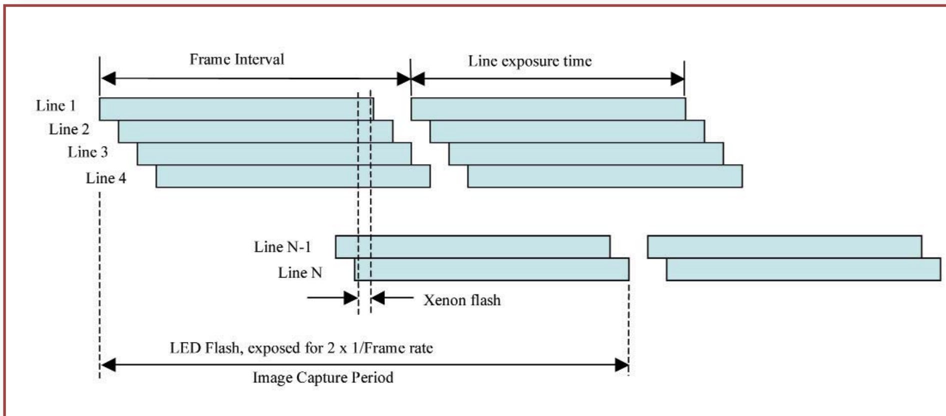



***Figure 5:*** *Light capture in a CMOS sensor*

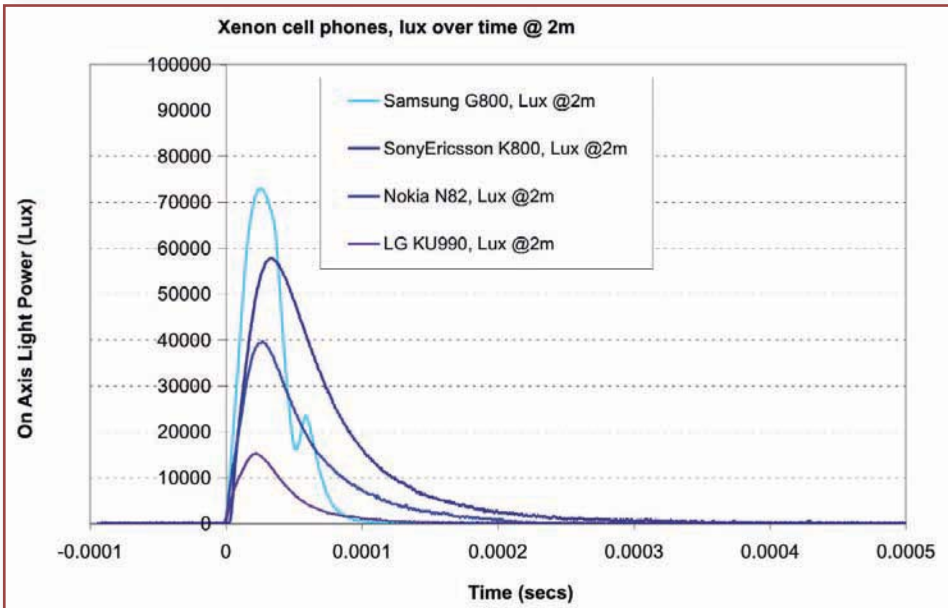



***Figure 6:*** *Light energy @ 2m for xenon and LED flash*

***Figure 7:*** *Photo taken in the same conditions as Fig 1, but this time using a Nokia N73 modified with a supercapacitor to drive 3 x LEDs at 1A each for a total flash power of 12W. We can now see the girl clearly instead of her silhouette*

(integrated light power) for 66.7ms.

An LED flash can provide constant illumination for the entire image-capture period and can, therefore, be used with a rolling shutter. To control the exposure, the LED current (and hence light intensity) can be set based on the ambient light measured. Alternatively, the line exposure time can be reduced. The frame rate will remain the same, but each line may only collect data for say 20ms instead of ~67ms.

A xenon flash only lasts a fraction of a millisecond. Therefore it must strobe in the few milliseconds when all N lines are capturing light (see Figure 5). However, ambient light is still captured by each line in the period outside the xenon flash pulse. To prevent this ambient light from overexposing the image, a mechanical shutter is necessary.

Figure 6 shows light energy for the xenon and LED flashes at 2m from the detector. The chart has a logarithmic timescale so the very short xenon and longer LED flash pulses can be displayed on the same graph. Figure 6 is the integral of the light power charts shown in Figures 3 and 4, and reflects the total light energy a CMOS sensor would capture.

The light energy for the xenon flashes is read from the final value shown on the chart, ranging from ~ 0.7-4.5 lux.secs, all of which would be captured by the CMOS sensor within the period labelled "Xenon flash" in Figure 5.

Light energy for the LED flashes is read from the chart for a given exposure time of a line in a CMOS sensor. For example, at 2m, the 2 LEDs @ 2A BriteFlash example delivered 3.4 lux.secs over 30ms and 7 lux.secs over 67ms exposure.

Points to note from Figure 6 are:

- The supercapacitor-powered LED BriteFlash example (2 LEDs powered at 2A each):
  1. Delivered 58% more light energy over 67ms (CMOS sensor frame rate of 15/sec) than the SonyEricsson K800, the best-performing xenon phone which includes a 28μF storage capacitance.
  2. Delivered 187% more light energy with a rolling shutter over 67ms (sensor frame rate of 15/sec) than the Nokia N82 xenon flash with a 20μF storage capacitance.


***Figure 8a:*** *Light energy @ 2m for xenon and LED flash*

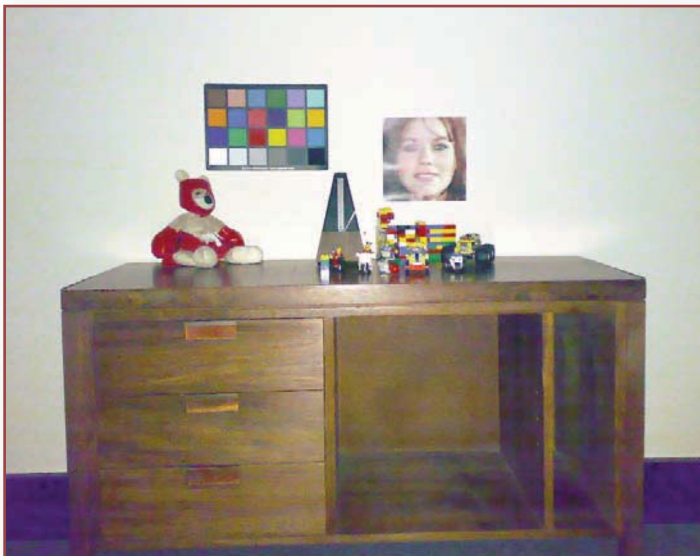


***Figure 8a:*** *The same scene as Figure 8a shot with a Nokia N73 modified with a supercapacitor to drive 3 x LEDs at 1A each for a total flash power of 12W. The colour chart shows much better colour rendition than Figure 8a and the metronome arm shows less blur from a faster exposure*

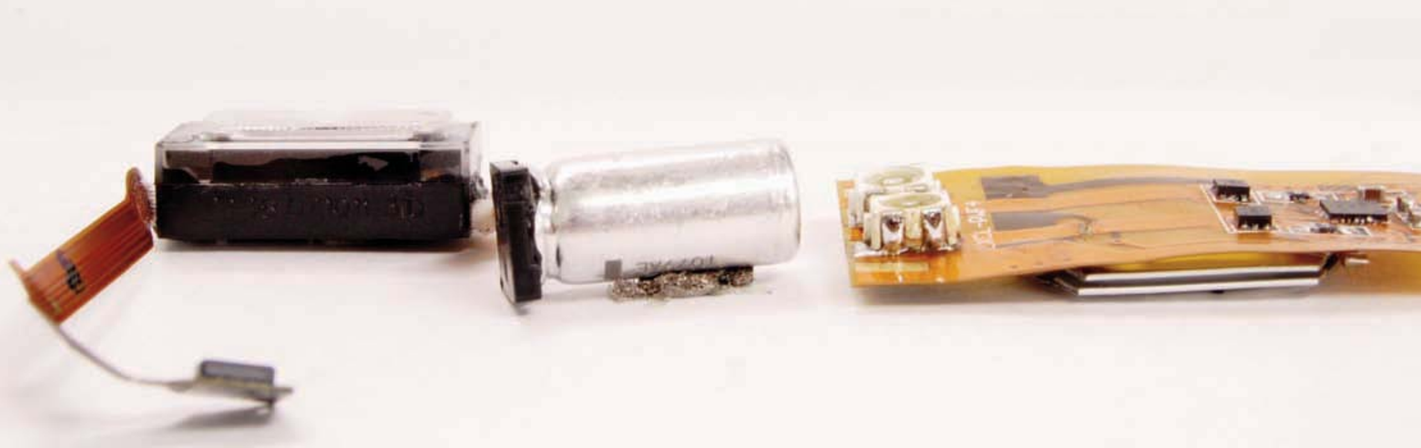


***Figure 9:*** *The Nokia N82 phone's xenon flash module + electrolytic capacitor (left) compared to a LED flash module (right), which uses an HA230 supercapacitor (on the underside) and the ON Semiconductor NCP5680 flash driver to drive high-current Philips Lumileds LEDs*

3. Over only 17ms, delivered 2.7 x the light energy delivered by the LG xenon flash with a 10μF storage capacitor – i.e. enough light for a photo of much higher quality. This is short enough (1/60th of a second) to eliminate blurry photos if the photographer's hand shakes. Like xenon, this solution would also require a mechanical shutter.
4. Similarly, over 33ms, delivered approximately 50% more light energy than the Nokia N82 xenon flash, enabling high-quality photos with a short exposure time and a mechanical shutter.

- The N96 standard LED solution only delivers 1/10th of the light energy over 67ms of 2 supercapacitor-powered LEDs @ 2A each.
- The standard low-current LED flash, using the Nokia N73 with a 90ms flash pulse as the example, generates much less light energy than the other solutions, only 8% of that produced by 2 high-current LEDs with a 67ms flash pulse.

**Figure 7** shows a photo taken under the same conditions as Figure 1. Figure 7 used a Nokia N73 modified by CAP-XX with a supercapacitor to drive 3 x LEDs at 1A each for a total flash power of 12W. We can now see the model, instead of her silhouette.

**Figures 8a** and **8b** compare the photo quality between a Nokia N96 with standard LED solution and a Nokia N73 modified with a high-power LED BriteFlash solution.

## Comparison of Solution Size and Energy Density

The key advantage of LED flash over xenon in camera phones is size. Electrolytic capacitors prevent slimline camera phones, demonstrated in **Figure 9** which contrasts the Nokia N82's xenon flash module + electrolytic capacitor (left) with a LED flash module with driver (right), including two high-power LEDs with integrated optic, and an HA230 supercapacitor.

This LED flash solution in Figure 9 can deliver 4A for 133ms, or a 67ms line exposure for a camera running at 15 frames/sec with a rolling shutter. Figure 6 shows this solution delivers 7 lux.secs at 2m from the subject compared to 2.5 lux.secs for the Nokia N82 xenon solution shown in Figure 9.

**Table 1** compares energy density of the electrolytic capacitors in the SonyEricsson K800 and Nokia N82 with the CAP-XX HA230 supercapacitors. These provide high C (0.425F) and low ESR (110mΩ) in a small 18mm x 20mm x 3.4mm package.

Of key concern to handset designers is total solution volume. Figure 9 shows how the BriteFlash solution is considerably smaller and thinner that the xenon module. ■

| | Electrolytic Capacitor<br>Sony Ericsson K800 | Electrolytic Capacitor<br>Nokia N82 | CAP-XX HA230<br>Supercapacitor |
|---|---|---|---|
| Capacitance | 2 x 14μF = 28μF | 20μF | 0.425F |
| Energy storage | ½ x 28μF x (330V2 –100V2 ) = 1.4J | ½ x 20μF x (330V2 –100V2 ) = 1.0J | ½ x 0.425F x (5.5V2 –4.5V2 ) = 2.0J |
| Dimensions | (2) x 7mm dia. x 18mm long | 7.7mm dia x 18mm long | 18mm x 20mm x 3.4mm |
| Volume | 1.76cc (effective) | 1.07cc (effective)2 | 1.22cc |
| Energy density | 0.785J/cc | 0.927J/cc | 1.634J/cc |

***Table 1:*** *Comparison of energy density for electrolytic capacitors*

**Stephen Clemmet**, CEng MIET, in this article explores OLED technology and structure, and describes how to make a proof-of-principle kitchen chemistry OLEDs

# The NEXT GENERATION of Electronics

**ORGANIC LIGHT** emitting diodes (OLEDs) are an example of the next generation of electronics that comes under the heading of Printed Electronics. Printed electronics are devices that can be fabricated on to flexible materials, such as plastic and thin metal foils.

OLED TV displays have a resolution that is unsurpassed by technologies such as liquid crystal displays (LCDs) or thin-film transistor displays (TFTs) that are found in laptops and mobile phones. The resolution is so good that razor-sharp film quality images can be played on mobile phone size screens. This is more than a technological advancement; it is a revolutionary technology change. OLEDs create new and exciting product types that were once the preserve of science fiction.

The term 'organic electronics' means that the device's molecules are bound together using carbon atoms. Conventional electronics are based on materials such as copper or silicon.

Light emissions from organic materials were first demonstrated by professor A. Bernanose in 1953, at the Nancy-Université in France. The first OLED device was created by Dr C. Tang and Dr S. Slyke of Eastman Kodak in 1985. Since that time, there has been considerable research and developments in OLED material science and applications.

The market value for OLED technology is projected to be worth $16.7bn by 2017. Of that figure OLED TVs are estimated to be worth $7.8bn. The entire field of printed electronics has a forecasted market-value of $30bn by 2017.

There are a series of changes to putting an OLED together. The first is cost. Vapour disposition chambers for making OLEDs cost upwards of $200,000 and sputter coaters upwards of $20,000. Secondly, 95% of the materials used are wasted during OLED fabrication. Materials coat the internal walls of the deposition chamber. In the case of spin coating, the material is flung off the substrate all together. For the 5% of material that is where you want it, the product yield of properly working devices is no more than 60%.

Also the larger the OLED area is, the greater the probability of a device being faulty. For an A6-sized OLED, the yield is approximately 0%.

## How To Make An OLED

The world of OLED manufacturing is focused on novel materials that use high-vacuum thin-film fabrication technologies. This does lend one to believe that getting even a toehold on OLED technology is impossible without at least $1,000,000 to spend. This is very true for any in-depth material science research. Though it's not true for those that wish to step on the bottom few rungs of the OLED ladder, or develop applications.

It's quite possible to make a working OLED for less than £50 and to experiment with the chemistry. Here's how using an OLED science kit that is available from E2M Technology.

This is what you need to do:

1. Using double-sided sticky tape, stick an ITO coated glass slide (ITO facing up) to a de-vaned fan (de-vaned to prevent a draft over the device).
2. Clean the ITO of grease and dirt using an alcohol swab, then use a hair dryer set to approximately $60^0$C to drive off any water vapour.
3. Spread an amount of PEDOT:PSS over the entire surface of the ITO glass. Switch the fan on so that the centrifugal force creates a thin, even coat across the slide. Bake the slide in an oven at $60^0$C for a couple of hours to drive off the water content. For very simple OLED devices, this layer can be omitted. The OLED device will still work.
4. Switch the fan on and place drop of emissive material on the centre of the slide. The centrifugal force will instantly spread it out across the slide.
5. Switch the fan off, then add an amount of gallium-indium (Ga:In) that is the area of OLED that you want to light up. This should be no more than 5mm diameter. Small devices are more reliable.
6. Attached wires to the ITO anode and Ga:In cathode.
7. Encapsulate the entire device using a resin.
8. Apply a voltage to light the device.

Experiment with steps 1-4 until you are satisfied with the result. The ITO glass can be cleaned with acetone (nail varnish remover). Do not use an abrasive to clean the ITO glass. Step 5 uses the metal alloy, which is expensive, so practice with the previous steps to ensure a good working OLED device.

A first device will emit and orange light for a few minutes. With a little practice it is possible to make a device light for several hours and be comparable with the light intensity that is found on many electronic items with conventional LEDs.

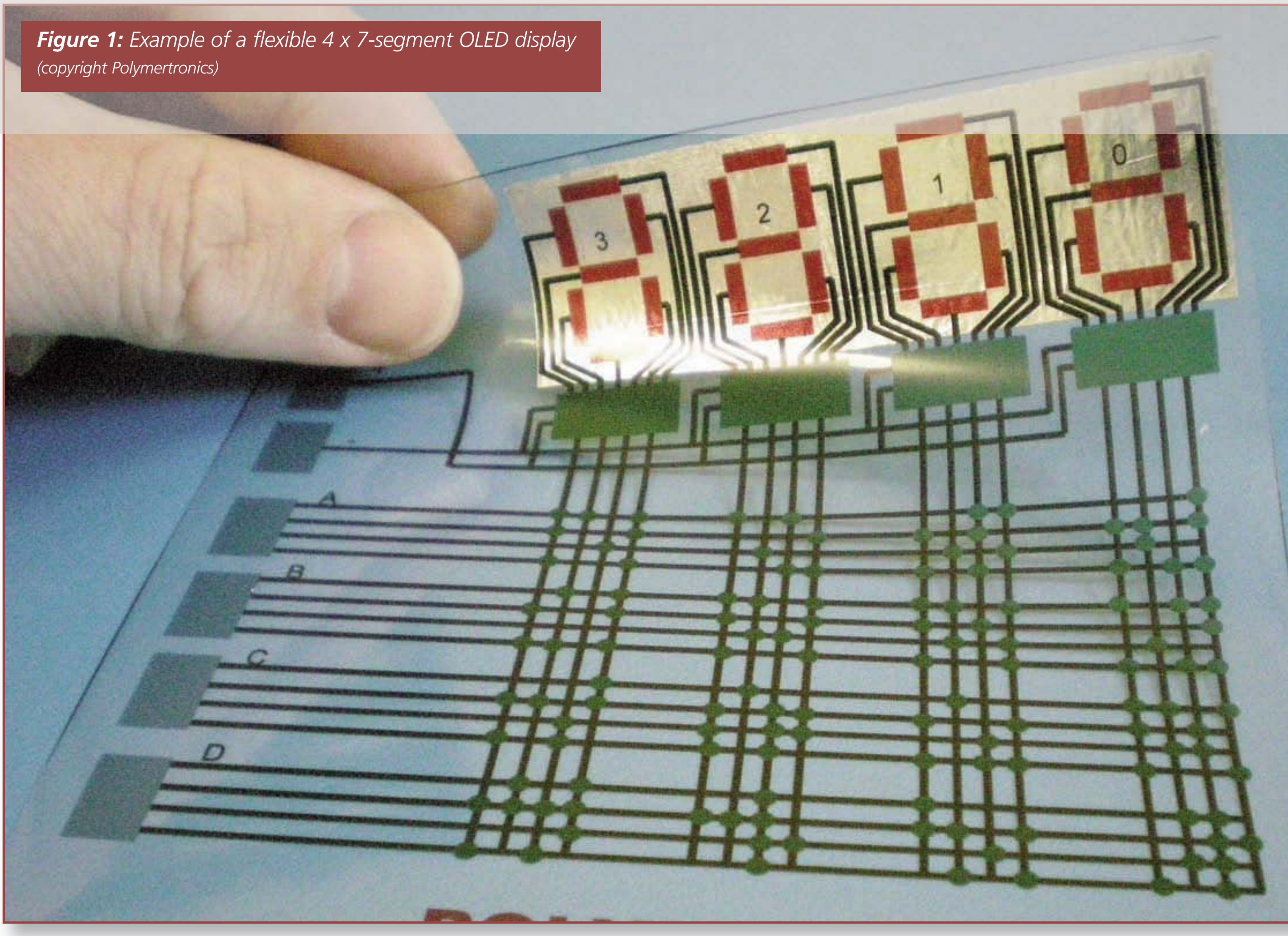



***Figure 1:*** *Example of a flexible 4 x 7-segment OLED display (copyright Polymertronics)*

Applying 3-10Vdc is adequate for testing a device lights. Applying a dc voltage for a long time will result in the device heating, which will degrade the device. If the applied voltage is pulsed with either a square wave, or pulse width modulation, the operational lifetime of the device can be extended for up to 100 hours. Pulsing the light at 75Hz is fast enough for the human eye not to notice the flicker. Further performance improvements can be made by using an electronic capacitive charge pump as the voltage source.

To increase the reliability of the OLED, the substrate must be clean, free of water molecules and free of any dust particles. The organic portion is no more than 200nm thick, so it doesn't take very much to cause a short circuit between the anode and the cathode. Water vapour is a known killer of OLEDs, so care must be taken to ensure none is present during device manufacture.

## How OLEDs Work

When a DC voltage is applied across the anode and cathode, there is a flow of electrons from the cathode to the anode. As an electron leaves the anode for the positive terminal of the power source, they leave an absence of electrons in the anode. This absence is termed a 'hole'. The holes move through the anode and conductive layers to the conductive-emissive layer interface. There the holes combine with electrons from the cathode. This process is called recombination and it occurs at the boundary between the conductive layer and the emissive layer. It is by recombination that light is emitted. The process repeats itself for as long as a voltage is applied.

The choice of materials used when making an OLED is very important. For the device to emit light, the OLED's molecules in the organic portion (conductive and emissive layers) require a minimum amount of electrical energy. The amount of energy required is called its 'work-function'.

To prevent heat being dissipated, the organic portion's work-function must be small, i.e. easy to make the material fluoresce. The difference in word-function between the anode and the cathode must be at least that of the work-function of the organic portion.

For the anode, the choice is simple: indium tin oxide (ITO) is the only sensible candidate. ITO has a very low resistivity (less than $100\Omega/cm^2$), it is transparent and it can be deposited (by sputter coating) on to glass, or on to polyethylene terephthalate (PET) plastic. PET is flexible, so is a common substrate for flexible OLED devices. For convenience, ITO can be bought already coated on substrates.

The organic conductive layer improves the electronic efficiency

**Figure 2:** *The structure of an OLED*

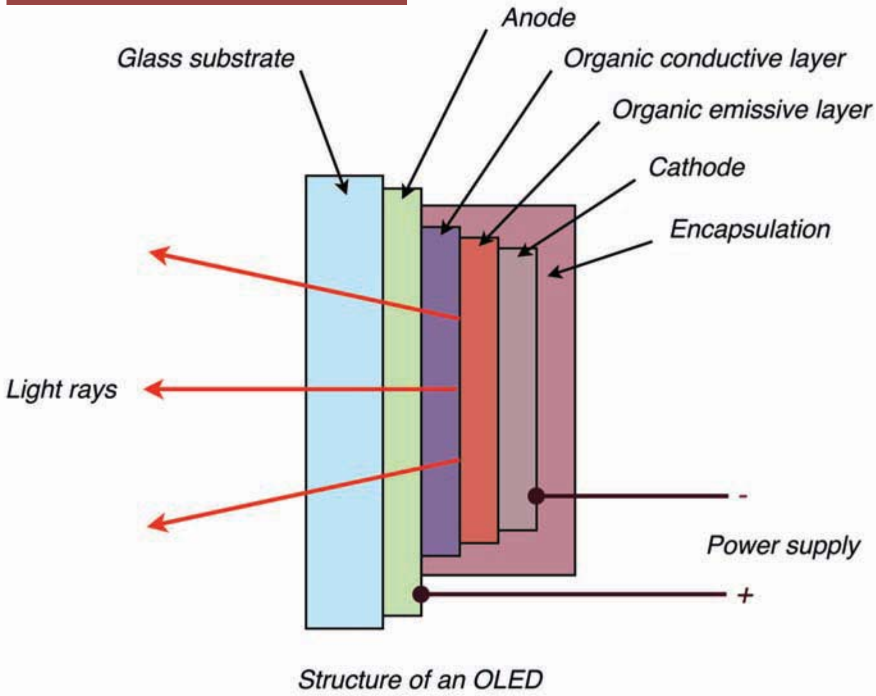
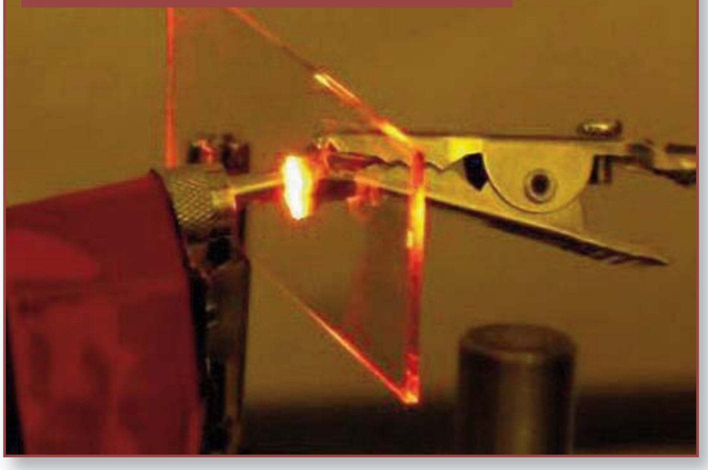



**Figure 3:** *A working proof-of-principle OLED*
*(copyright Polymertronics)*



and reliability of the device.

A commonly used material is poly(3,4-ethylenedioxythiophene)-poly(styrenesulfonate) (PEDOT:PSS). It is possible to fabricate OLEDs without the conductive layer. If so, the emissive layer is deposited directly onto the ITO glass. The emissive layer when on ITO can result in tiny holes in the layer. These are called 'pin holes' and become localized hotspots when the device is on. A device can still work even with pin holes.

The organic emissive layer material depends on the colour of light that you want to emit.

Derivates of poly[2-methoxy-5-(2'-ethyl-hexyloxy)-1,4-phenylene vinylene] (MEH-PPV) are the usual choice. For making proof-of-principle OLEDs, ruthenium compounds work very well. Ruthenium is very easy to spin-coat ruthenium compounds on to ITO and PEDOT:PSS. Ruthenium is available as crystals from chemical suppliers where upon it can be processed under laboratory conditions. Alternatively it can be bought as a ready-togo fluid from E2M Technology Limited.

The cathode material has to be a metal to reflect the light out through the ITO glass. The choice of metal is predominately dictated by the required word-function of the cathode. The cathode's work-function must be at least the sum of the anode's work-function plus the organic portion's work-function. This limits the choice of materials.

Aluminium is often used, having a suitable work-function. Surprisingly gold does not work, having a too high work-function. For experimentation purposes, the metal gallium-indium (Ga:In) is extremely good. It has a low work-function and is a liquid above $16^0$C.

For device longevity, encapsulating the device is important. This keeps water vapour out of the device and it also protects it from physical damage. Encapsulation can be a glass layer, or it can be a resin. Resins and plastic substrates are permeable to oxygen molecules over many months. Oxygen and water ingress limits the shelf-life and operational-life of OLEDs, even for commercial devices.

## Things To Try With The OLED

There are a range of experiments that can be conducted having made a working OLED:

1. Vary the spin coater speed to observe the effect on the OLED.
2. Make different sized OLEDs.
3. Measure the power per unit of an OLED.
4. Compare OLED versus LED technologies:
   i. Power consumption.
   ii. Light emissive waveband.
   iii. Light intensity.
   iv. Viewing angle.
5. Develop and compare OLED electronics drivers:
   i. DC sources.
   ii. Charge pumps.
   iii. Pulse width modulation drivers.

OLEDs and plastic electronics are an exciting new technology that has applications beyond high-resolution mobile phone screens. This article has scratched the surface of printable electronics. It is though improbable that plastic electronics will replace conventional electronics. They do though facilitate new technology product opportunities. ■

# Touchscreen EVOLUTION

**Binay Bajaj,** Senior Product Marketing Manager for Touch Technologies at Atmel Corporation goes into the basics of touchscreen technology, the associated sensor design and what to look for when selecting a touchscreen controller

**WITH THE ARRIVAL** of the Apple iPad and a host of competing tablets launched this year, the market for 5"-13" large-format touchscreen devices is set to explode. The explosive growth in personal computing has already unleashed a flurry of activity among device manufacturers, who are actively porting touchscreen technologies to large-format hardware.

However, moving from small screens and simple touch-enabled applications to a new paradigm, where hands and fingers are the primary tools for interacting with full-scale computers, is not necessarily a straightforward transition. Manufacturers need to rethink the way that touchscreens will be used by consumers and address a new and more demanding set of requirements.

To cite just one example, "multi-touch" capabilities chiefly consist of a few finger strokes on today's five-inch screens. What will they mean on a 12-inch or 40-inch device, or when multiple users are interacting simultaneously using both hands?

## Basics of Touchscreen Technologies

Large or small, the success of any touchscreen device is a function of the technology choices made in designing it, the most important being projected capacitance technology, sensor design and driver chip.

Today's devices overwhelmingly use capacitive touchscreens, which operate by measuring small changes in capacitance – the ability to hold an electrical charge – when an object, such as a finger, approaches or touches the surface of the screen.

However, all capacitive touchscreens are not created equal. Choices in the capacitive-to-digital conversion (CDC) technique and the spatial arrangement of the electrodes that collect the charge determine the overall performance and functionality the device can achieve.

Device manufacturers have two basic options for arranging and measuring capacitance changes in a touchscreen: self-capacitance and mutual-capacitance. Most early capacitive touchscreens relied on self-capacitance, which measures an entire row or column of electrodes for capacitive change. This approach is fine for one-touch or simple two-touch interactions. But it presents serious limitations for more advanced applications, because it introduces positional ambiguity when the user touches down in two places. Effectively, the system detects touches at two (x) coordinates and two (y) coordinates, but has no way to know which (x) goes with which (y). This leads to "ghost" positions when interpreting the touch points, reducing accuracy and performance.

Alternatively, mutual-capacitance touchscreens use transmit and receive electrodes arranged as an orthogonal matrix, allowing them to measure the point where a row and column of electrodes intersect. In this way, they detect each touch as a specific pair of (x,y) coordinates. For example, a mutual-capacitance system will detect two touches as (x1,y3) and (x2,y0), whereas a self-capacitance system will detect simply (x1,x2,y0,y3), see **Figure 1**.

The underlying CDC technique also affects performance. The receive lines are held at zero potential during the charge acquisition process, and only the charge between the specific transmitter X and receiver Y electrodes touched by the user is transferred. Other techniques are available, but the key advantage of the CDC is its immunity to the noise and parasitic effects. This immunity allows for addition system design flexibility; for example the sensor IC can be placed either on the FPC immediately adjacent to the sensor, or further away on the main circuit board.

## Sensor Design

Electrode pitch, a key parameter in sensor design refers to the density of electrodes – or more specifically, (x,y) "nodes" – on the touchscreen, and to a large extent determines the touchscreen resolution, accuracy and finger separation. Naturally, different applications have different resolution requirements. But today's multi-touch applications, which need to interpret fine-scale touch movements, such as stretching and pinching fingertips, require high resolutions to uniquely identify several adjacent touches.

Typically, touchscreens need a row and column electrode pitch of approximately 5mm or less (derived from measuring the tip-to-tip distance between the thumb and forefinger when pinched together). This allows the device to properly track fingertip movements, support stylus input, and with proper firmware algorithms, reject unintended touches. When the electrode pitch is in-between 3 to 5mm, the touchscreen becomes capable of supporting input with a stylus with a finer tip – a boost in accuracy that will allow the device to support a broader range of applications.

At the core of any successful touch sensor system is the underlying chip and software technology. As with any other chip design, the touchscreen driver chip should have high integration, minimal footprint and close to zero power consumption along with the flexibility to support a broad range of sensor designs and implementation scenarios. Any driver chip will be measured by the balance of speed, power and flexibility it achieves.

## Supersizing the Touchscreen

The considerations described above apply to any size touchscreen device. But what are the specific considerations for moving to large-format devices? Manufacturers will find that the key requirements for modern touchscreen technologies – multi-touch support, performance, flexibility and efficiency – become even more critical when users adopt larger screens.

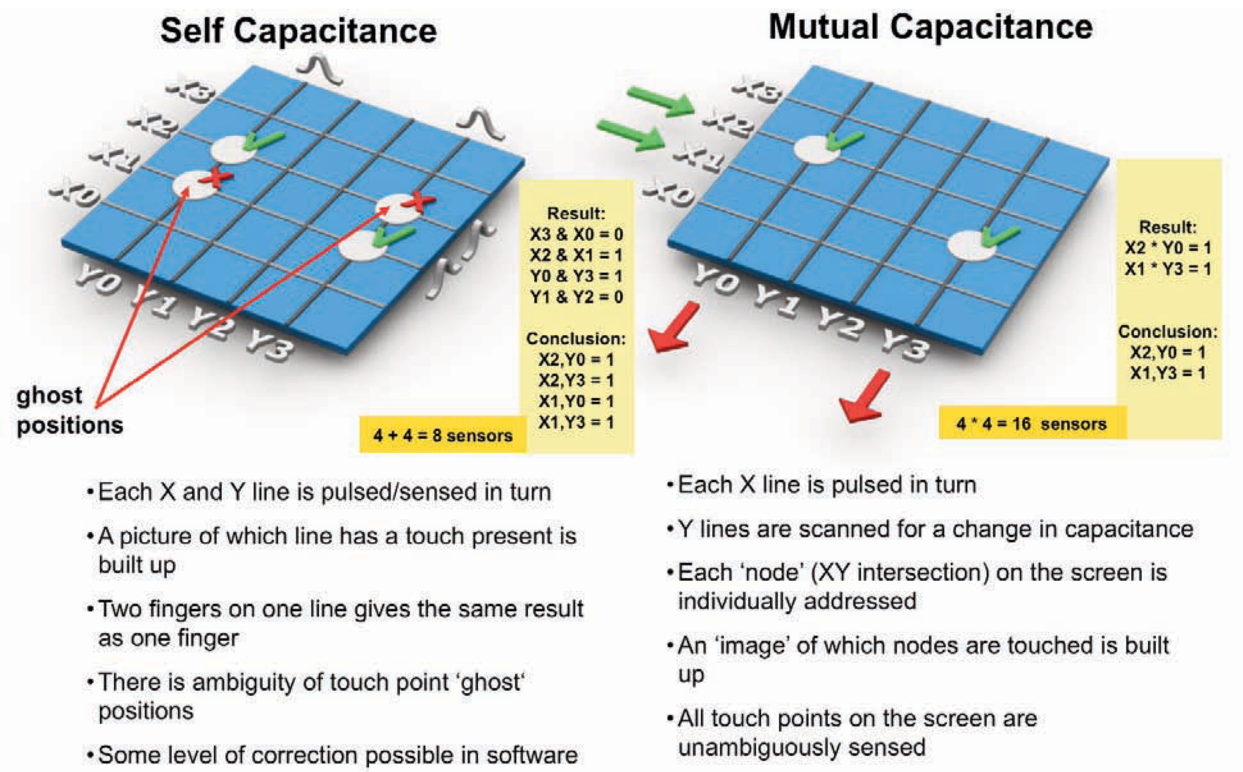



***Figure 1:*** *Self-capacitance versus mutual capacitance*

As large-format touch applications begin using four, five and 10 touches, it's important to consider not just how new applications might exploit these capabilities, but also how the controller chip will use this richer information to create a better user experience. For example, the ability to track incidental touches around the edge of a screen and classify them as "suppressed" is even more important on a large-format device than on a small one.

Just as a mobile phone's touchscreen needs to be able to recognize when a user is holding the phone or resting the screen against her cheek, so a larger-format system must account for the different ways that users will hold and use the device, for example resting the edge of the hand on the screen when using a stylus or resting both palms when using a virtual keyboard. And it's not enough to simply identify and suppress incidental touches; the device must track them so that they remain suppressed even if they stray into the active region. The more touches that a controller can unambiguously resolve, classify and track at once, the more intuitive and accurate the user experience can be.

## Achieving High Performance

Touchscreen performance is a function of five basic factors:

- Accuracy means the fidelity with which the touchscreen reports the user's finger or stylus location on the touchscreen. An accurate touchscreen should report touch position better than ±1mm.
- Linearity measures how "straight" a line drawn across the screen is. Linearity depends on sound screen pattern design, and should also be accurate within ±1mm.
- Finger separation describes how closely the user can bring two fingers together before the device recognizes them as a single touch.
- Response time measures how long it takes the device to register a touch and respond. For basic touch gestures such as tapping, the device should register the input and provide feedback to the user in less than 100ms. Factoring in various system latencies, this typically means that touchscreens need to report a first qualified touch position in less than 15ms. Applications such as handwriting recognition require even faster response.
- Resolution is smallest detectable amount of finger or stylus motion. It is important to reduce the resolution the fraction of millimeter level for a number of reasons: chief among them being the enabling of the stylus based handwriting and drawing applications.
- Signal-to-noise ratio (SNR) refers to the touchscreen's ability to discriminate between the capacitive signal arising from real touches and the capacitive signal arising from accidental noise. Capacitive touchscreen controllers measure very small changes in the row-to-column coupling capacitance and the way those measurements are performed has a strong influence on the controller's susceptibility to external noise. Large-format touchscreens are especially challenging in this regard, as one of the most significant noise generators is the LCD itself.

## Touchscreen Flexibility

Most of today's small touchscreens are designed to support a specific device and, often, specific software and applications. Emerging large-format touchscreens, however, will need to be much more versatile. For example, a paper-sized tablet device is a natural fit for handwritten input using a stylus. But to support that, the touchscreen needs a higher resolution than one intended for fingertip gestures on a five-inch screen.

By careful consideration of the above design criteria, engineers will be able to implement high quality, large format touchscreens for a wide variety of portable consumer electronics devices.

Atmel is at the forefront of the shift away from using the PC as the primary technical interface and toward the growing array of smart connected devices, consumer devices and communications. Having established its multitouch, maXTouch family of devices for use with touchscreens up to 5.6 inches in size, Atmel now continues to advance this industry leadership with the launch of maXTouch technology that can accommodate touchscreens up to 15.6 inches. ■

# Using Touch Screen LCDs In EMBEDDED Applications

**Professor Dr Dogan Ibrahim** of the Near East University, Cyprus, describes the basic principles and types of touch screen LCDs and gives an example to show how they can be used in microcontroller-based systems

**IF YOU ARE PLANNING** of replacing your mobile phone the chances are that you will get one with a touch screen. More and more consumer electronic products are now available with touch screen inputs. For example, electronic games, MP3 players, GPS receivers, mobile phones, PDAs, ATM machines, industrial control systems, remote control devices, point-of-sale (POS) terminals, advertisement show screens, information displays and many more similar products offer special screens where items are selected from a menu by simply touching the relevant part of the screen.

Perhaps the biggest advantage of a touch screen display is that it eliminates the need for a keyboard input, resulting in a cheaper and a lighter overall design. The user input facilities in such devices are usually provided in the form of soft keypads where the layout of a keypad is displayed on a touch screen panel, and required characters and numbers can be entered by simply touching the required key positions on the touch screen. Soft keypad also makes it easier to enter and edit data quickly.

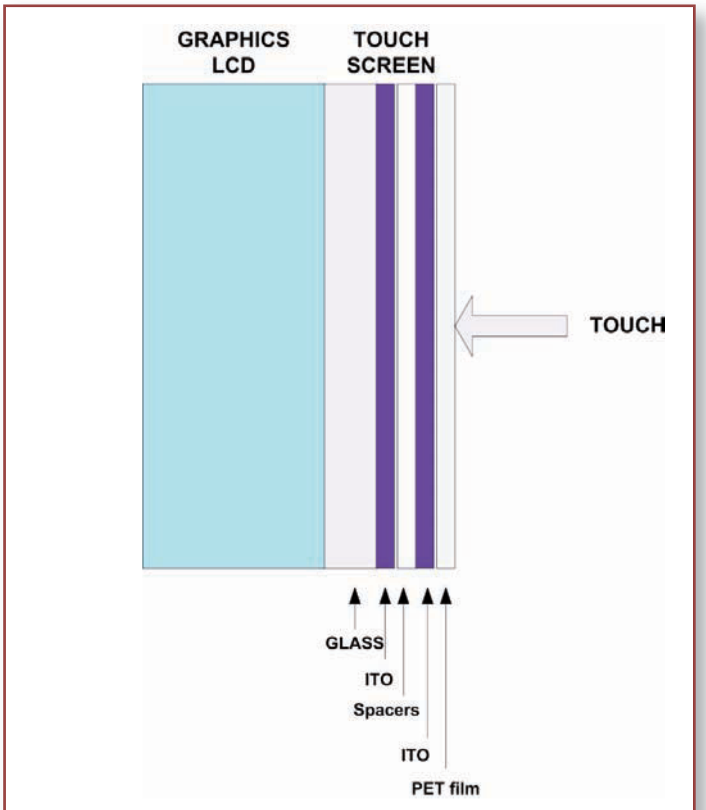



***Figure 1:** Resistive touch screens*

Another advantage of a touch screen display is that it is usually much quicker to navigate around the screen than using a keyboard or a mouse type inputs. Also, in some applications, such as GPS mapping and navigation, a desired geographical point can easily be selected by simply touching the desired point on the screen. It may take more time and effort to accurately select a point on a map using a keyboard and a mouse.

Touch screen displays are also used in most POS systems, for example in restaurants and in supermarket check-outs to select a purchased item from a menu quickly, easily and reliably. Perhaps the biggest advantage in such applications is the speed of making a correct selection.

One of the biggest disadvantages of touch screens is that the screen may get dirty and oily, and fingerprints can be accumulated on the screens after long usage by the finger and as a result, it may become less sensitive to a touch. Also, the screen can easily become scratched, especially if a hard object is used to touch and navigate through the screen. Touch screens can also cause stress on human fingers when used for more than a few minutes at a time, since pressure is required to make a selection. A touch device (e.g. a stylus) or fingernails can be used to prevent issues of direct touch. Another disadvantage is that a touch screen LCD display is usually more expensive than a standard LCD display. The choice of whether or not to use a touch screen display depends entirely on the nature of the application, the cost and the level of user experience.

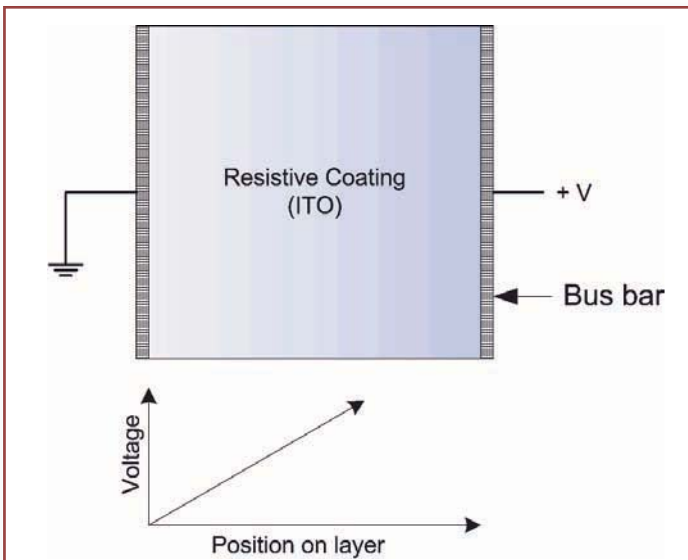



***Figure 2:** Voltage gradient in a screen layer*

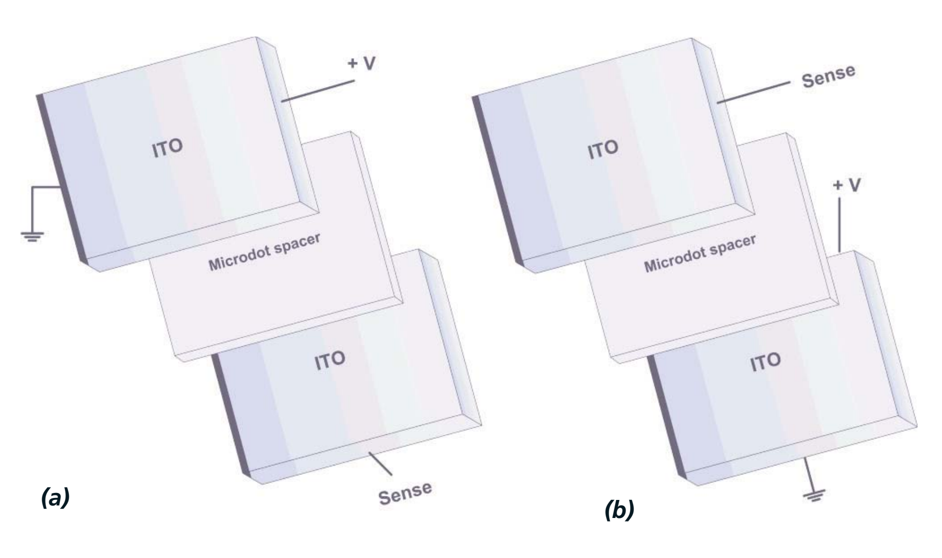



***Figure 3:*** *Determining the X and Y co-ordinates (4-wire)*
*(a) Determining the X co-ordinate; (b) Determining the Y co-ordinate*

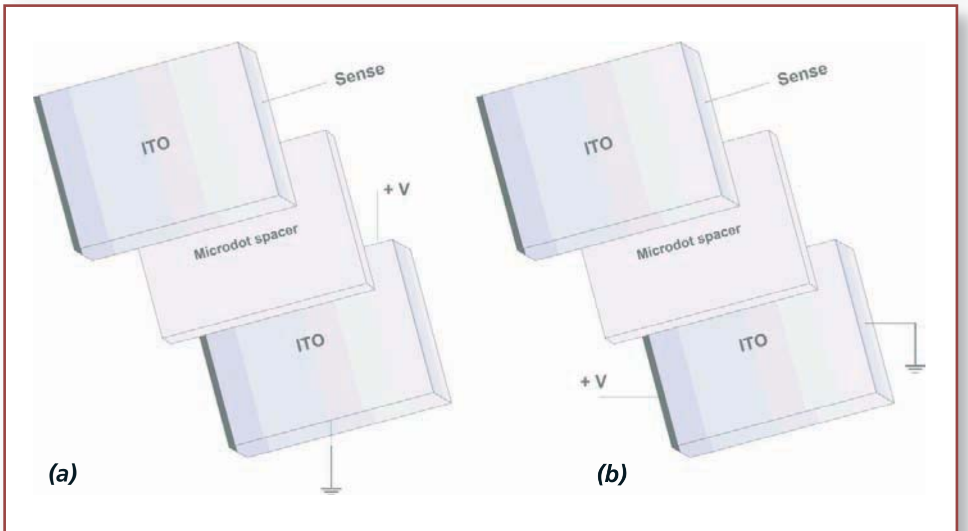



***Figure 4:*** *Determining the X and Y co-ordinates (5-wire)*
*(a) Determining the X co-ordinate; (b) Determining the Y co-ordinate*

## Types of Touch Screen Displays

Touch screen displays are in the form of either large screen monitors, such as those used in PC systems, or small LCDs, used in microcontroller-based systems. Although the principle of operation is the same in either case, in this article the small LCD type touch screen displays are considered. Such displays usually have resolutions of 128x64 pixels and are used in battery-operated intelligent devices.

A touch screen LCD is basically a combination of a graphics LCD (GLCD) and a touch sensitive panel mounted on top of the GLCD. The two parts are independent of each other: The panel senses the co-ordinates where the user touched and the GLCD displays graphical information on the LCD display based upon user's selection.

There are several types of touch screen LCDs, such as resistive, capacitive, surface acoustic wave, optical imaging, strain gauge and so on. The most commonly used types are the resistive and capacitive ones and some information about each type is given below.

A resistive touch screen consists of several layers, where two electrically conductive resistive layers are separated by a very small gap and a flexible layer is used at the top. One of the layers is connected to a voltage source. When a point is pressed on the screen, the touched points of both conductive layers make a contact and if the voltage is read at the other layer this voltage will be proportional to the position of the point touched because of the voltage dividing effect. Further details about resistive touch screens are given later.

A capacitive touch screen panel is coated with a material that stores electrical charges. When the panel is touched, a small amount of charge is drawn to the point of contact and the charge is measured at each corner of the panel and is then processed to determine the point touched.

Resistive touch screens have the advantages that the screen responds when touched with any kind of object, e.g. finger, stylus, nail, etc. On the other hand, the capacitive screens respond only when touched by a naked finger (but they will not respond when touched with an object or if wearing gloves for example). On the other hand, capacitive touch screens are lower power devices, have higher granularities and also provide higher clarity.

In this article the resistive touch screen is used in a practical microcontroller-based application and further information about resistive touch screens is given in the next section.

## Resistive Touch Screens

Resistive touch screens are used in most low cost, medium resolution systems. A resistive touch screen consists of at least three layers. As shown in **Figure 1**, the touch screen is mounted on a graphics LCD (GLCD). The bottom layer is a glass (or acryl), coated with a resistive Indium Tin Oxide (ITO) solution. On top of this, a resistive ITO coated poly Ethylene Terephthalate (PTE) flexible film is used. The two conductive ITO layers are separated from each other with microdot spacers so that there is no contact between them when the screen is not touched.

When a pressure is applied to the top of the screen, e.g. by touching the screen, the two ITO layers will make contact at the point of the touch. Electrical circuits are then used to determine the point of the contact. Usually a 4-wire, 5-wire, or an 8-wire circuit is used to determine the co-ordinates of the point touched by the user. These circuits are described below in greater detail.

## 4-Wire Resistive Touch Screen

These are the least expensive and most commonly used types of resistive touch screens. Conductive bus bars with silver ink are implanted at the

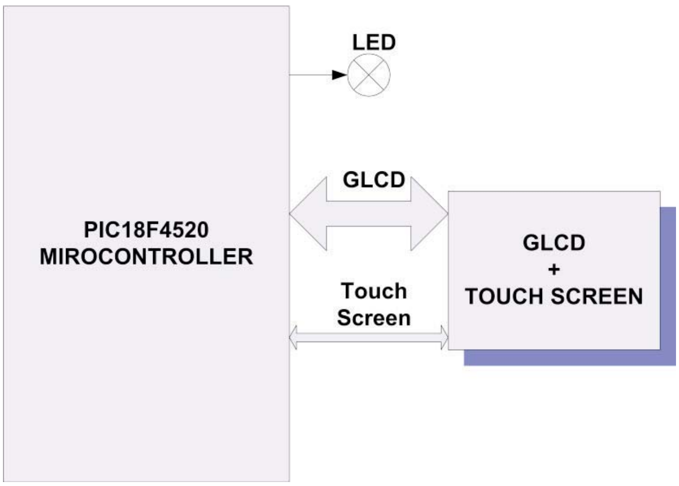



***Figure 5:** Block diagram of the project*

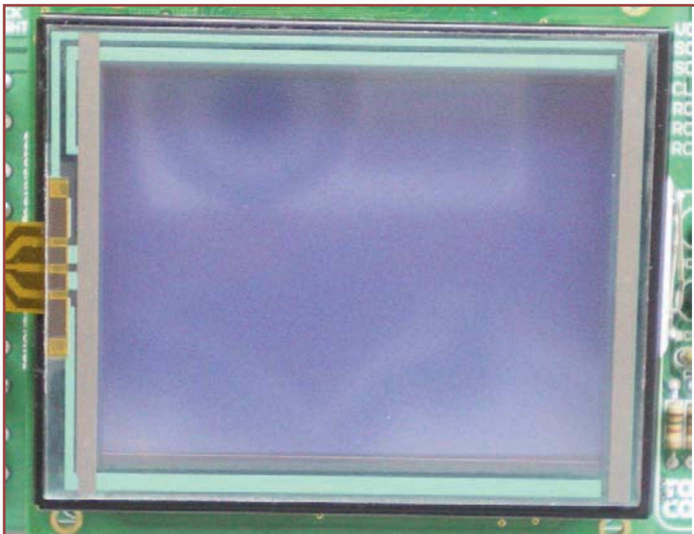


***Figure 6:** The touch screen LCD used in the project*

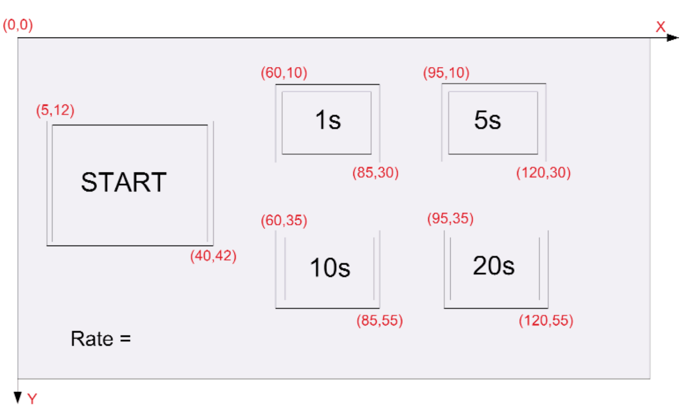



***Figure 7:** Data shown on the GLCD*

opposite edges of a screen layer. The principle of operation is such that, as shown in **Figure 2**, if one side of a layer is connected to +V and the other side to ground, a potential gradient results on the screen layer, and the voltage at any point on this layer becomes directly proportional to the distance from the +V side.

In a 4-wire touch screen two measurements are made one after the other one to determine the X and Y co-ordinates of the point touched by the user. **Figure 3a** shows how the X co-ordinate can be determined. Here, the right and left hand sides of the top layer can be connected to +V and ground respectively. The bottom layer can then be used to sense and measure the voltage at the point touched by the user. An A/D converter is used to convert this analogue voltage to digital and then determine the X co-ordinate.

Similarly, **Figure 3b** shows how the Y co-ordinate can be determined. Here, the upper and lower sides of the bottom layer can be connected to +V and ground respectively. The top layer can then be used to sense and measure the voltage at the point touched by the user. Again, an A/D is used to convert the voltage to digital and then to determine the Y co-ordinate.

## 5-Wire and 8-Wire Resistive Touch Screen

This is a modification of the basic 4-wire system where one layer (usually the top layer) is used for sensing and measuring the voltage, while the other layer is where the voltage gradient is created in X and Y directions. As shown in **Figure 4a**, to determine the X co-ordinate, the upper and lower sides of the bottom layer can be connected to +V and ground respectively. The top layer is then used to sense and measure the voltage.

To determine the Y co-ordinate we simply have to reverse polarity and sides of the bottom layer (see **Figure 4b**). The Y co-ordinate is then read from the top layer.

8-wire touch screen is used when more accurate measurements of the screen co-ordinates are required. In 4 and 5 wire implementations the resistance of the bus bars and the connection circuitry usually introduce offset errors in voltage measurements. These offset errors can drift with temperature, humidity and time. 8-wire touch screens compensate for drift by adding 4 additional reference lines, thus enabling the voltage to be measured directly at the touch screen bus bars. 8-wire touch screens are generally more expensive than others and are not covered further in this article.

## An Application Example

An example is given here to demonstrate how a 4-wire resistive touch screen LCD can be used in a real application. In this example a touch screen with a GLCD is connected to a PIC18F type microcontroller. In addition, an LED is connected to one of the microcontroller port pins. The objective of this example is to flash the LED at a rate specified by the user.

Four options (1 second, 5 seconds, 10 seconds and 20 seconds) are displayed on the touch screen and the user is expected to make a choice by touching the required option and then start the flashing.

The block diagram of the project is shown in **Figure 5**. The project is built around a PIC18F4520 type high end microcontroller (**www.microchip.com**), operating at 8MHz. A 4-wire resistive touch screen (model no: TTW4028001) with graphics LCD display (KS0108 controller compatible) is used in the project (see **Figure 6**).

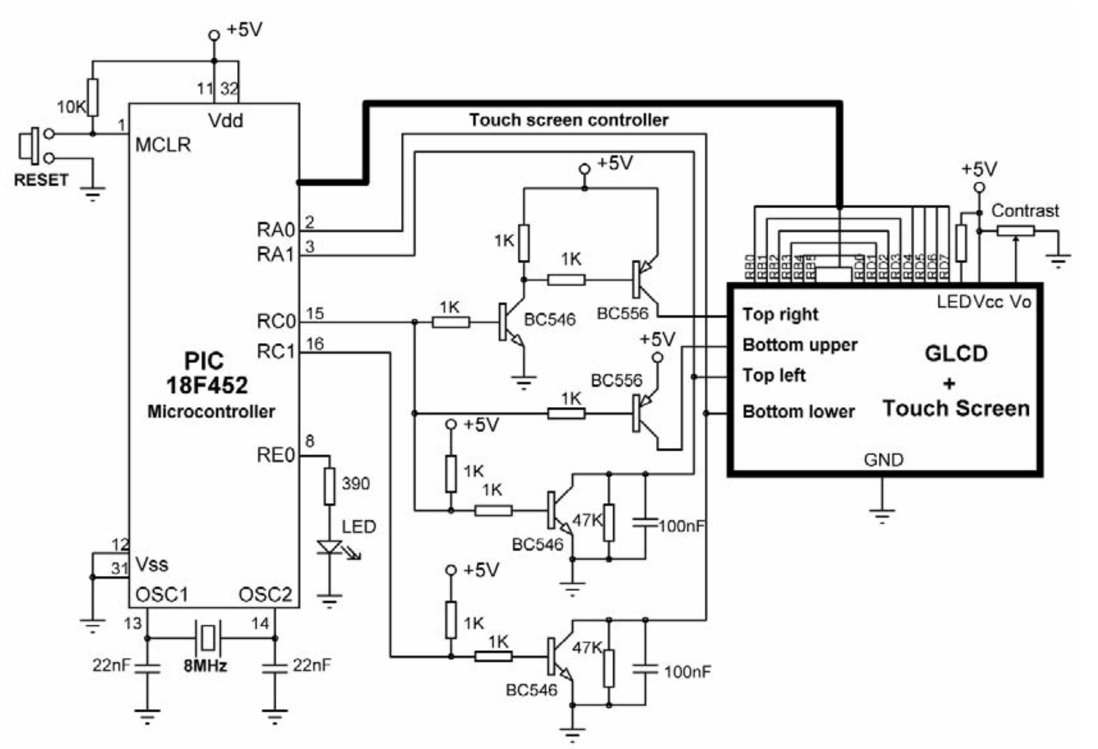



*Figure 8: Circuit diagram of the project*

The touch screen graphics display is expected to show the images as in **Figure 7**. Rectangles and boxes are drawn on the screen with text inside them. The screen is 128 pixels horizontal and 64 pixels vertical with the origin at the top left corner, the X-axis to the right and the Y-axis downwards.

The co-ordinates of the rectangles are also shown in Figure 7. The GLCD screen format can be designed using either a graph paper with a pen and pencil, or a bitmap design program can be used to draw the screen images and then convert it to hex data that can be downloaded to the GLCD controller (e.g. bmp2lcd, fastlcd, GLCDFontCreator etc).

The operation of the circuit is as follows: After power-up, the user will select the LED flashing rate by touching the required option box on the screen. The selected rate will be shown at the bottom of the GLCD screen. Flashing will then start as soon as the START box is touched. The display will show an appropriate message (e.g. "flashing…") at the bottom to indicate that flashing has started.

## The Circuit Diagram

The circuit diagram of the project is shown in **Figure 8**. Ports B and D of the microcontroller are used to drive the GLCD. The connections between the microcontroller and the GLCD are as follows:

| **Microcontroller** | **GLCD** |
|---|---|
| **RD0 – RD7** | **D0 – D7** |
| **RB0** | **CS1** |
| **RB1** | **CS2** |
| **RB2** | **RS** |
| **RB3** | **R/W** |
| **RB4** | **E** |
| **RB5** | **RST** |

The background light of the GLCD is turned ON permanently by connecting the LED input to +5V via a resistor, and the GLCD contrast is adjusted using a 10K potentiometer. A touch screen controller circuit is used to interface the microcontroller to the 4 touch screen pins. In a microcontroller-touch screen interface, a controller circuit is usually required to provide the correct logic levels to the touch screen pins.

Normally, logic 0, logic 1 and OFF state are required. The OFF state can be provided using an open-drain microcontroller pin in input mode. Alternatively, touch screen controller chips such as AD785 or AD7846 can be used to provide the necessary interface voltage levels. In Figure 8, switching transistors are used as the touch screen controller. For example, when RC0 is set to logic 1, Top Right pin becomes 1, Top Left pin becomes 0 and Bottom Upper pin becomes OFF.

## Measuring the X Co-ordinate

In reference to **Figure 9** and assuming the top layer has contacts Top Right and Top Left and the bottom layer has contacts Bottom Upper and Bottom Lower, the following setup is required to determine the X co-ordinate:

| | |
|---|---|
| **Top Left:** | **GND** |
| **Top Right:** | **+5V** |
| **Bottom Lower:** | **To A/D converter (X co-ordinate)** |
| **Bottom Upper:** | **OFF** |

Similarly, to determine the Y co-ordinate, the following setup should be made:

| | |
|---|---|
| **Top Left:** | **To A/D converter (Y co-ordinate)** |
| **Top Right:** | **OFF** |
| **Bottom Lower:** | **GND** |
| **Bottom Upper:** | **+5V** |

In Figure 9 for example, the X co-ordinate can be read into analogue port RA0 when:

| | |
|---|---|
| **RC0 = 1** | **(Top Left= 0, Top Right = 1, Bottom Upper = OFF)** |
| **RC1 = 0** | **(Bottom Lower = OFF)** |
| **Read RA0** | **(Read Bottom Lower)** |

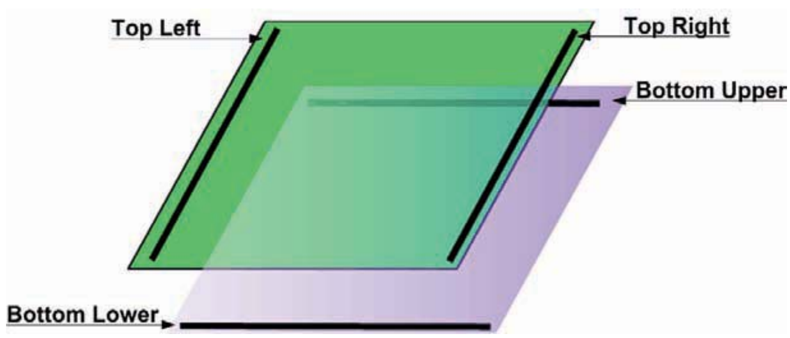



***Figure 9:*** *Connection of the touch screen*

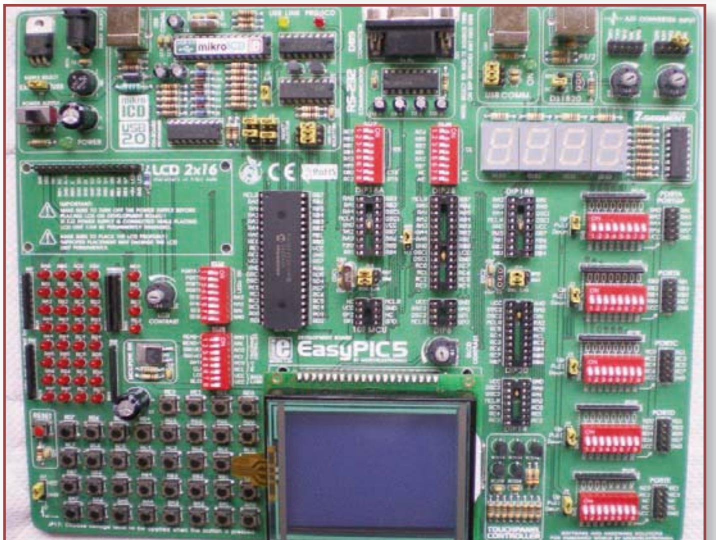


***Figure 10:*** *EasyPIC 5 microcontroller development board*

```
BEGIN
Configure the GLCD
Configure I/O ports
Display selection boxes on GLCD

DO FOREVER
    Get X and Y co-ordinates of touched point
    IF box "1s" touched Rate = 1
    ELSE IF box "5s" touched Rate = 5
    ELSE IF box "10s" touched Rate = 10
    ELSE IF box "20s" touched Rate = 20
    ENDIF
    Display "Rate = <Rate>"

    IF box "START" touched
        DO FOREVER
            Turn LED ON
            Wait Rate seconds
            Turn LED OFF
            Wait Rate seconds
        ENDDO
    ENDIF

ENDDO
END
```

***Figure 11:*** *PDL of the project*

Similarly, to read the Y co-ordinate:

| | |
|---|---|
| **RC0 = 0** | **(Top Left = OFF, Top Right = OFF, Bottom Upper = 1)** |
| **RC1 = 1** | **(Bottom lower = GND)** |
| **Read RA1** | **(Read Top Left)** |

## The Construction

The project was constructed easily using an EasyPIC 5 microcontroller development board (see **Figure 10**). Using this board one can develop and test touch screen software in a relatively short time. This board (**www.micro.com**) offers the following features:

- Socket for 12/16/18/20 and 40 pin PIC microcontrollers
- On board crystal, reset circuit and power supply
- LCD and touch screen GLCD interface with controller
- 7 segment 4-digit display
- 4 LEDs and 40 push-button switches
- RS232 and USB interfaces
- In-circuit debugger
- Programmer
- Access to microcontroller port pins

The board includes a touch screen controller circuit built using transistors as in Figure 8. A programmer is available on the board so that compiled programs can very easily be downloaded to the program memory of the microcontroller.

## The Software

The software was developed using the mikroC Pro language. This is a high-level C programming language for PIC microcontrollers, developed by mikroElektronika (**www.mikroe.com**) and it offers a large number of built-in libraries to interface various devices to PIC microcontrollers. Some of the libraries are for SD cards, Compact Flash cards, RS232, RS485, CAN bus, USB, LCD, GLCD, I2C bus and many more.

The compiler also includes a software simulator in the form of an in-circuit debugger that can be very useful during program development. **Figure 11** shows operation of the software as a PDL. The complete program listing is shown in **Figure 12**.

At the beginning of the program the GLCD-microcontroller interface is defined and Glcd_Init command is used to initialise the GLCD. Then the microcontroller I/O ports are configured. The images shown in Figure 7 are then created and displayed on the GLCD. Command Glcd_Rectangle draws a rectangle with the specified top-left and bottom-right co-ordinates. Similarly, command Glcd_Box draws a box with the specified co-ordinates. Texts are then written inside the boxes using the Glcd_Write_Text commands by specifying the starting co-ordinates of the texts. Inside the main loop of the program the X and Y co-ordinates of the option boxes are read by functions ReadX and ReadY respectively, to see if the user touched any of the boxes and, if so, the appropriate flashing rate is selected. mikroC built-in functions ADC_Read(0) and ADC_Read(1) are used to read the analogue data from inputs RA0 and RA1 respectively. The physical X co-ordinate is calculated by multiplying the read X value by 128 and then dividing by the 1024 (maximum value for 10-bit A/D). Similarly, the physical Y co-ordinate is calculated by multiplying the read Y value first by 64 and dividing by 1024 and then taking away from 64 (since the +5V is applied to Bottom Upper layer during Y measurements). Finally, touching the START box starts flashing the LED connected to port RE0 at the selected rate.

**Figure 13** shows a typical run of the program where the flashing rate

```
/**********************************************************************************************
                              TOUCH SCREEN EXAMPLE
                              =====================

In this example, an LED is flashed at a rate determined by the user by selecting
the rate from a touch screen GLCD. The project is based on a PIC18F452 type
microcontroller, operating at 8MHz. The software is based on the mikroC Pro.

**********************************************************************************************/
char GLCD_DataPort at PORTD;
sbit GLCD_CS1 at RB0_bit;
sbit GLCD_CS2 at RB1_bit;
sbit GLCD_RS at RB2_bit;
sbit GLCD_RW at RB3_bit;
sbit GLCD_EN at RB4_bit;
sbit GLCD_RST at RB5_bit;

sbit GLCD_CS1_Direction at TRISB0_bit;
sbit GLCD_CS2_Direction at TRISB1_bit;
sbit GLCD_RS_Direction at TRISB2_bit;
sbit GLCD_RW_Direction at TRISB3_bit;
sbit GLCD_EN_Direction at TRISB4_bit;
sbit GLCD_RST_Direction at TRISB5_bit;

char msg_Start[] = "START";
char msg_1s[] = "1s";
char msg_5s[] = "5s";
char msg_10s[] = "10s";
char msg_20s[] = "20s";
char msg_Rate[] = "Rate=               ";
char msg_Flashing[] = "flashing...";

long x_real,y_real;
char rate;

long ReadX(void)
{
  long x;
  PORTC.F0 = 1;
  PORTC.F1 = 0;
  Delay_Ms(5);
  x = ADC_Read(0);
  x = x*128/1024;
  return(x);
}

long ReadY(void)
{
  long y;
  PORTC.F0 = 0;
  PORTC.F1 = 1;
  Delay_Ms(5);
  y = ADC_Read(1);
  y = 64 - ((y*64)/1024);
  return (y);
}

void Delay_Seconds(char d)
{
  char i;



 for(i=0; i<d; i++)Delay_Ms(1000);
}


void main()
{
char i;
  TRISA = 0x03;
  TRISC = 0;
  TRISE0_bit = 0;
  ADCON1 = 0x0F;
  PORTA = 0;
  PORTC = 0;
Glcd_Init();
Glcd_Set_Font(Font_Glcd_5x7,5,7,32);
Glcd_Fill(0);

Glcd_Rectangle(5,12,40,42,1);               // START rectangle
Glcd_Box(7,14,38,40,1);                     // START box
Glcd_Rectangle(60,10,85,30,1);              // 1s rectangle
Glcd_Box(62,12,83,28,1);                    // 1s box
Glcd_Rectangle(95,10,120,30,1);             // 5s rectangle
Glcd_Box(97,12,118,28,1);                   // 5s box
Glcd_Rectangle(60,35,85,55,1);              // 10s rectangle
Glcd_Box(62,37,83,53,1);                    // 10s box
Glcd_Rectangle(95,35,120,55,1);             // 20s rectangle
Glcd_Box(97,37,118,53,1);                   // 20s box

Glcd_Write_Text(msg_Start,8,3,0);           // START text
Glcd_Write_Text(msg_1s,67,2,0);             // 1s text
Glcd_Write_Text(msg_5s,102,2,0);            // 5s text
Glcd_Write_Text(msg_10s,65,5,0);            // 10s text
Glcd_Write_Text(msg_20s,100,5,0);           // 20s text
Glcd_Write_Text(msg_Rate,10,7,1);           // RATE= text

for(;;)
{
 x_real = ReadX();
 y_real = ReadY();

 if((x_real >= 62 && x_real <= 83) && (y_real >= 12 && y_real <= 28))
 {
       rate = 1; msg_Rate[5]='1'; msg_Rate[6]='s'; msg_Rate[7]=' ';
 }
 else if((x_real >= 97 && x_real <= 118) && (y_real >= 12 && y_real <= 28))
 {
       rate = 5; msg_Rate[5] = '5'; msg_Rate[6] = 's'; msg_Rate[7]=' ';
 }
 else if((x_real >= 62 && x_real <= 83) && (y_real >= 37 && y_real <= 53))
 {
       rate = 10; msg_Rate[5]='1'; msg_Rate[6]='0'; msg_Rate[7]='s';
 }
 else if ((x_real >= 97 && x_real <= 118) && (y_real >= 37 && y_real <= 53))
 {
       rate = 20; msg_Rate[5]='2'; msg_Rate[6]='0'; msg_Rate[7]='s';
 }
 Glcd_Write_Text(msg_Rate,1,7,1);

 if ((x_real >= 7 && x_real <= 38) && (y_real >= 14 && y_real <= 40))


  {
        for(i=0; i<11; i++)msg_Rate[i+9]=msg_Flashing[i];
        Glcd_Write_Text(msg_Rate,1,7,1);
        for(;;)
        {
               PORTE.F0 = 1;
               Delay_Seconds(rate);
               PORTE.F0 = 0;
               Delay_Seconds(rate);
        }
  }
 }
```

***Figure 12:*** *Program listing*


**Figure 13:** *A typical run of the program (selecting a Rate)*

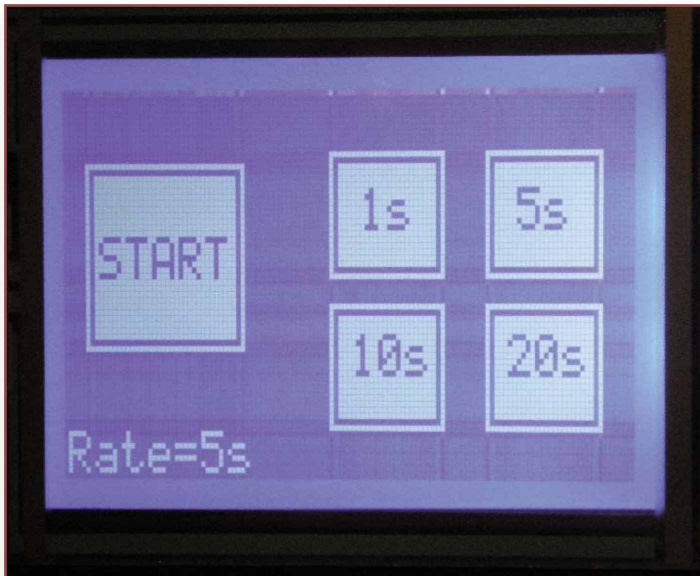



**Figure 14:** *A typical run of the program (starting the flashing)*

was selected as five seconds. Touching the START box starts to flash the LED and the GLCD display changes to indicate that flashing has started, as in **Figure 14**.

The touch screen GLCD example given here is very simple, but using these principles very complex touch screen GLCD based projects can easily be designed. ■

# The Solution to FM DISTORTION due to Multipath Transmission Part 2

**Archie Pettigrew** from Ampsys Electronics Ltd revisits the issues behind receiving the perfect broadcast radio signals

**WHEN EDWIN** Armstrong transmitted the first FM signals in 1935, a limiter circuit was used to saturate the carrier to a constant voltage. It has reigned supreme in the art of FM demodulation. By removing all amplitude variation, the signal can be recovered with much higher fidelity than any amplitude-modulated signal. Without a limiter, the signal would be as poor as an AM signal if not worse.

The downside of a limiter is that as the carrier envelope approaches zero, noise alone is amplified by the near infinite gain. This causes problems in the following stages.

Many researchers in the past have attempted to use the information contained in the envelope of the carrier as it arrives at the antenna. The carrier was transmitted at constant amplitude so that changes imposed on it should be a clue to the type of conditioning it has experienced in the transmission path. Unfortunately, all these attempts failed.

## The Arc Sine Law

When a pure noise-free sine wave is applied to a limiter, the absolute time when the limiter switches is at the origin or FM reference point. If noise is introduced, this absolute time is shifted by the elementary equation:

$$A \sin \omega_{carr} t_{jitter} = v_{noise}(t)$$

Rearranging gives:

$$\sin \omega_{carr} t_{jitter} = \frac{v_{noise}(t)}{A}$$

$$\omega_{carr} t_{jitter} = \arcsin \frac{v_{noise}(t)}{A}$$

$$t_{jitter} = \frac{1}{\omega_{carr}} \arcsin \frac{v_{noise}(t)}{A}$$

This analysis shows that as the size of the incoming carrier reduces, the jitter increases until complete failure occurs when the carrier amplitude becomes smaller than the noise and demodulation ceases. This is equivalent to division by zero where the jitter can be said to approach infinity.

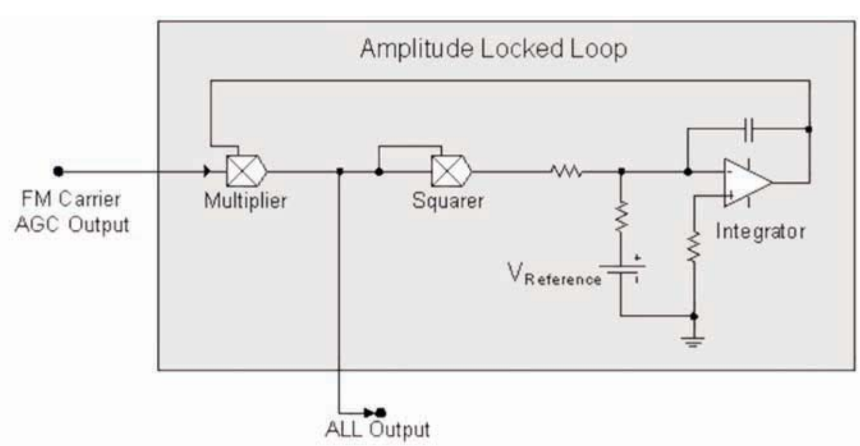



***Figure 1:*** *The Amplitude Locked Loop (ALL)*

This is not a problem under good reception conditions, but what happens in weak signal areas? The mixing of two nearly equal sine waves (signal and band limited noise) produces a spike. A second less obvious phenomenon occurs. The arc sine law and Gaussian white noise determine the precise timing of the spike. This happens at an undetermined time and due to this jitter, there is no possibility of using the amplitude envelope of the carrier to improve demodulation.

A circuit must be conceived, which will exhibit all the good properties of the limiter but not suffer from its disadvantages. It must provide a constant carrier envelope under all input conditions but not be subject to the arcsine jitter law.

The Amplitude Locked Loop (ALL) circuit was designed to meet these requirements.

## The Amplitude Locked Loop

The ALL was conceived as the dual of the phase locked loop where the amplitude is the controlled variable instead of the phase. The servo circuit consists of three main blocks, a linear gain multiplier, a pure squaring multiplier and an integrator. The carrier is applied to the variable gain block at the input. The output of this stage is rectified and compared to a set point. The error is integrated and this signal is presented to the second input of the variable gain stage to close the loop. This is shown in **Figure 1**.

The output is taken from the variable gain stage, which is the stabilised version of the original carrier, free of all amplitude variation so long as the loop is in lock. Due to servo feedback, this is equivalent to the limiter but without any saturation.

The situation changes when the carrier amplitude falls below a specified level as shown in **Figure 2**. The integrator saturates and the output cannot increase further. The stabilised carrier is a simple copy of the input amplified by approximately four times.

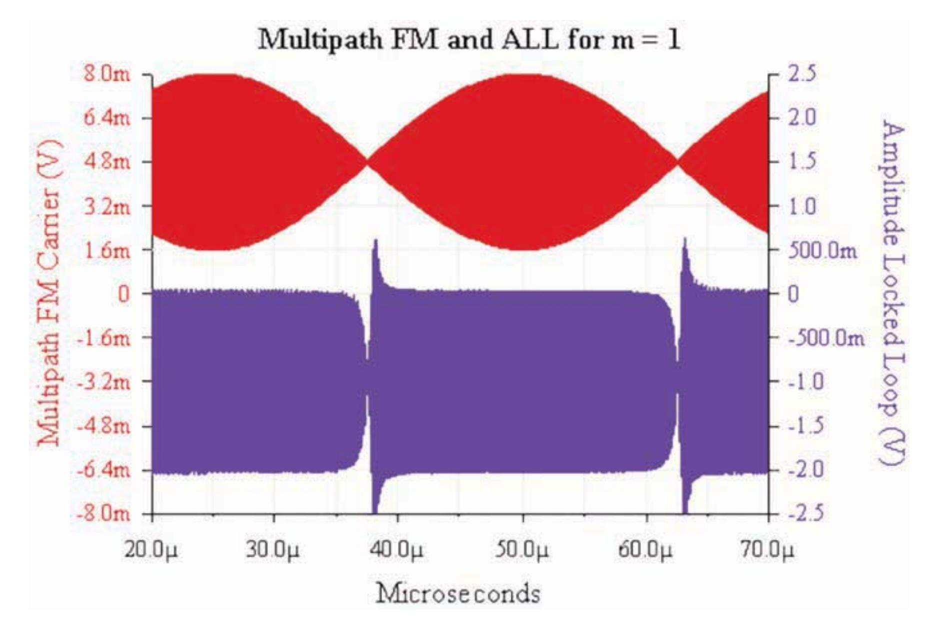



***Figure 2:** The ALL output (blue trace) drops out of lock as the carrier amplitude (red trace) decreases to zero. When the signal returns, the ALL circuit re-locks with a small overshoot and constant amplitude is restored*

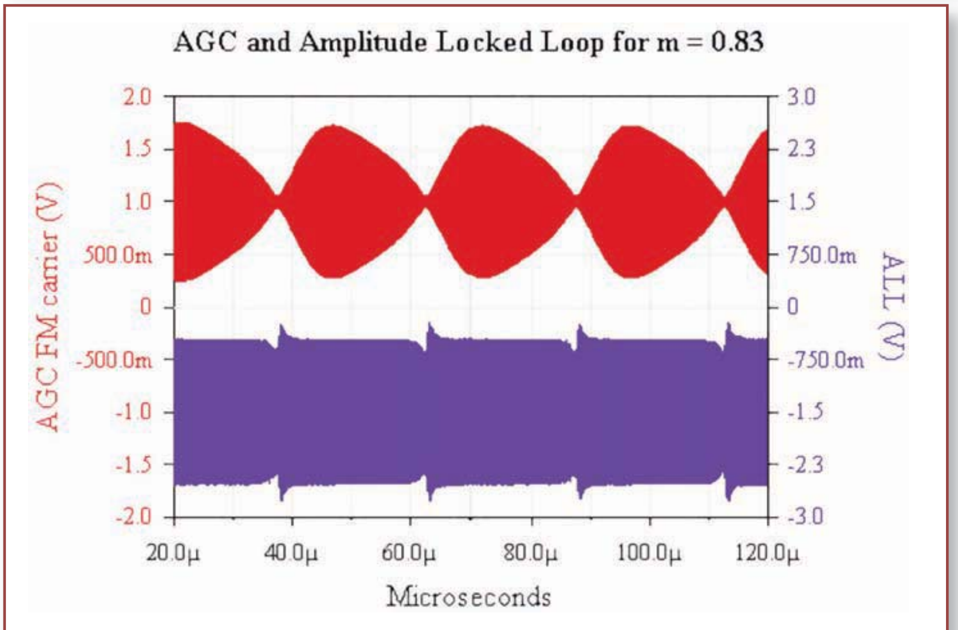



***Figure 3:** The red upper trace represents the FM Carrier output from the AGC. The blue lower trace represents the output of the ALL*

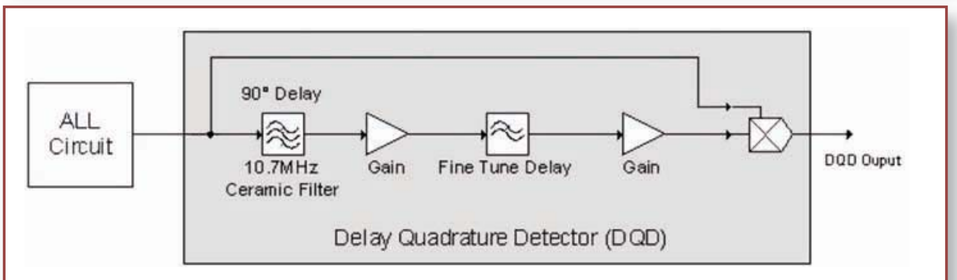



***Figure 4:** The delay quadrature detector consists of a ceramic filter delay line and a fine tune circuit for quadrature phase matching*

Since there is no infinite gain as in the limiter, the output follows the input down to zero and the ALL circuit does nothing while waiting for the carrier to recover in amplitude.

With no arc sine law, there is no jitter in the carrier as its amplitude reduces towards zero. Consequently, there is no jitter in the demodulated spikes at the FM output. The envelope of the carrier can now be used to assist in the demodulation process.

## The AGC

By using the ALL in place of the limiter, the bandwidth of the ALL must be as large as possible to cope with the in-lock out-of-lock transients of the incoming signal. It is not feasible to have wide bandwidth with a very large track range so a slower AGC circuit must precede the ALL circuit.

The bandwidth of this standard AGC proved to be quite critical. Since the intention is to use the amplitude of the received carrier to assist the demodulation, any artificial variation must be kept to an absolute minimum. In the IF stage of a receiver, the ceramic filters (or any other type of channel filters) impose AM on the carrier at twice the modulation frequency due to filter roll off at the peaks of FM modulation. This would cause premature saturation in the audio and the servo AGC bandwidth must be high enough to keep this at an acceptable level.

However, the servo action must not attenuate the sub carrier at 38kHz, which is the major cause of the spikes and subsequent audio crackles. This defines the unity gain to be in the region of 50-60kHz.

The bandwidth of the ALL must be made as high as possible to minimise the out-of-lock transient and is set at 2.0MHz for a 10.7MHz IF carrier.

## The Delay Quadrature Detector (DQD)

A problem arises with any standard FM demodulator in that it relies on the presence of a limiter circuit, especially for example the quadrature detector, which requires two limiters for normal operation. The solution is to use a ceramic filter as a pure delay line in combination with a fine trim circuit as shown in **Figure 4**.

The carrier is delayed by 90 degrees or 270 degrees or a (2n-1) multiple thereof. The original signal and the delayed signal are multiplied together to produce the required FM output. The

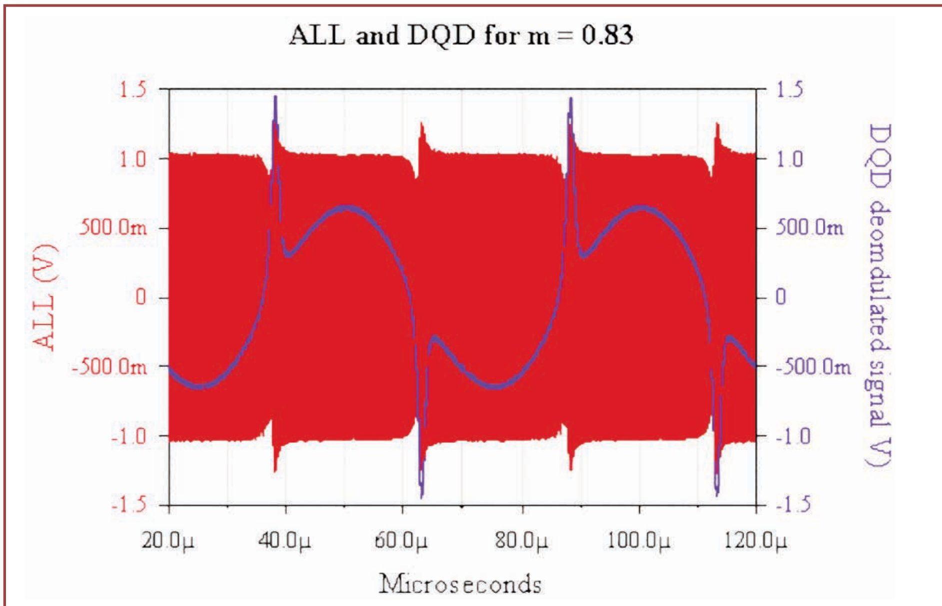



***Figure 5:*** *The DQD output in blue, with 19kHz signal showing large distortion spikes at every zero crossing due to the 180-degree phase change. The DQD is obtained from the ALL shown in red*

(2n-1) factor acts like a 'phase' amplifier just as in the MPD equation and improves the efficiency of the process. This circuit is called the delay quadrature detector (DQD).

The combination of the AGC, the ALL and the DQD working together generate the first high quality FM demodulator without using a limiter.

The performance of this circuit is as good as a standard quadrature circuit, but with one key difference. When a distortion spike occurs at each zero point of the carrier envelope, no excess jitter is present, unlike a standard limiter circuit. The timing correlation factor is practically unity between the demodulated signal and the carrier envelope.

The demodulated signal is the required sine wave but with a destructive spike at every zero crossing. A low-pass filter will turn the sine wave into a stepped sine wave, which will sound equally distorted. See **Figure 5**.

What can be done to reduce this distortion? Would it be possible to generate a waveform which can be multiplied into the spike and reduce it to negligible proportions? To be seen in the next part presented in next month's issue of Electronics World. ■

*This article continues in the next issue of Electronics World magazine. If you missed Part 1, you can now order it online at* ***www.electronicsworld.co.uk***

# The Cascode Gain Stage CAS

**Burkhard Vogel** presents a series of short features with general remarks on triodes in audio applications

**AS I EXPLAINED** in the previous article, Part 3 (*Electronics World*, August 2010), the CAS consists of a sequence of a CCS (V1) plus a CGS (V2) as the V1 anode load. This type of gain stage is rarely used in audio applications, however, it can be found as high gain microphone amp or moving coil phono-amp (for example Vacuum State Electronics FVP5 with a common source configured SK170 FET as input stage together with ½ E88CC/6922 CGS output stage).

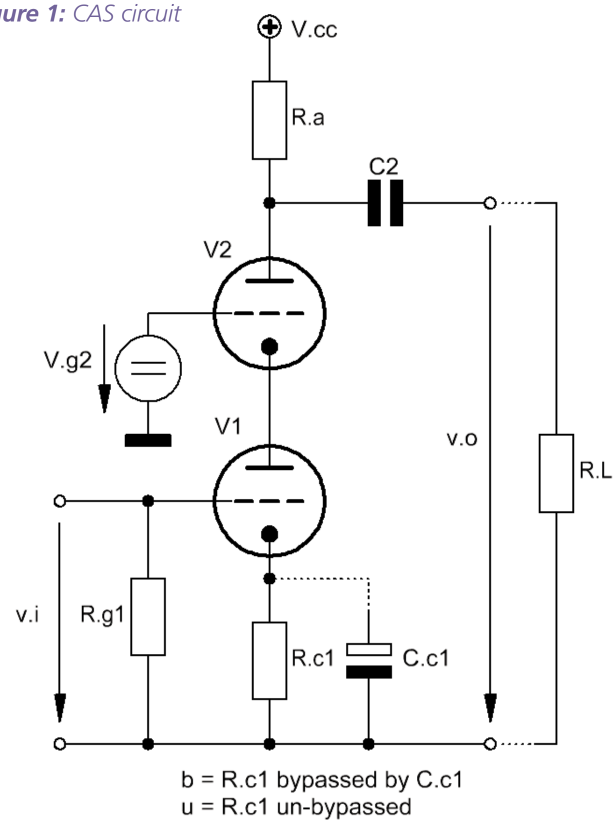
One of the major advantages, besides the rather high achievable gain and the high input impedance, is the fact that the Miller capacitance doesn't play a significant role because of the very low gain of V1. However, to calculate the input capacitance $C_i$ we need to have an equation for the V1 gain as well.

As function of the output load $R_L$ and with $r_{g1}$ = infinite the general gain equations for the $R_{c1}$ un-bypassed and bypassed CAS can be derived as:

$$G_u(R_L) = \frac{v_o}{v_i} = -\mu_1 \frac{(1+\mu_2)R_a}{\frac{r_{a2}\left(1+R_aR_L^{-1}\right)+R_a}{r_{a1}\left(1+R_aR_L^{-1}\right)+R_a}\left[R_a+\left[(2+\mu_1)r_{a1}+(1+\mu_1)^2R_{c1}\right]\left(1+R_aR_L^{-1}\right)\right]} \quad (1)$$

$$G_b(R_L) = \frac{v_o}{v_i} = -\mu_1 \frac{(1+\mu_2)R_a}{\frac{r_{a2}\left(1+R_aR_L^{-1}\right)+R_a}{r_{a1}\left(1+R_aR_L^{-1}\right)+R_a}\left[R_a+(2+\mu_1)r_{a1}\left(1+R_aR_L^{-1}\right)\right]} \quad (2)$$

*Figure 1: CAS circuit*




It is not specifically recommended to use a double-triode for V1 and V2. An additional resistor between V1 anode and Vcc could increase the V1 anode current to a bigger current level than the V2 anode current, thus, in general, increasing the V1 gain.

The special case of a double-triode for V1 and V2 simplifies **Equations 1** and **2**. With $\mu = \mu_1 = \mu_2$, $r_a = r_{a1} = r_{a2}$, $R_c = R_{c1}$ and a $C_{c1}$ of a value that does not hurt a flat frequency and phase response in $B_{20k}$, the gains $G_u(R_L)$ and $G_b(R_L)$ become:

$$G_u(R_L) = -\mu \frac{(1+\mu)R_a}{R_a+\left(1+R_aR_L^{-1}\right)\left[(2+\mu)r_a+(1+\mu)^2R_c\right]} \quad (3)$$

$$G_b(R_L) = -\mu \frac{(1+\mu)R_a}{R_a+\left(1+R_aR_L^{-1}\right)\left[(2+\mu)r_a\right]} \quad (4)$$

For the V1 gains $G1_u$ and $G1_b$ of a CAS with two different triodes we obtain:

$$G1_u(R_L) = \frac{v_{a1}}{v_i} = -\mu_1 \frac{r_{a2}+R_a}{\frac{r_{a2}\left(1+R_aR_L^{-1}\right)+R_a}{r_{a1}\left(1+R_aR_L^{-1}\right)+R_a}\left[R_a+\left[(2+\mu_1)r_{a1}+(1+\mu_1)^2R_{c1}\right]\left(1+R_aR_L^{-1}\right)\right]} \quad (5)$$

$$G1_b(R_L) = \frac{v_{a1}}{v_i} = -\mu_1 \frac{r_{a2}+R_a}{\frac{r_{a2}\left(1+R_aR_L^{-1}\right)+R_a}{r_{a1}\left(1+R_aR_L^{-1}\right)+R_a}\left[R_a+(2+\mu_1)r_{a1}\left(1+R_aR_L^{-1}\right)\right]} \quad (6)$$

and in the case of a double-triode we get:

$$G1_u(R_L) = -\mu \frac{r_a+R_a}{R_a+\left[(2+\mu)r_a+(1+\mu)^2R_c\right]\left(1+R_aR_L^{-1}\right)} \quad (7)$$

$$G1_b(R_L) = -\mu \frac{r_a+R_a}{R_a+(2+\mu)r_a\left(1+R_aR_L^{-1}\right)} \quad (8)$$

The equations to calculate the output resistances $R_{o.u}$ and $R_{o.b}$ look as follows:

$$R_{o.u} = \left(R_a^{-1}+\left[r_{a2}+(1+\mu_2)\left(r_{a1}+(1+\mu_1)R_{c1}\right)\right]^{-1}\right)^{-1} \quad (9)$$

$$R_{o.b} = \left(R_a^{-1}+\left[r_{a2}+(1+\mu_2)r_{a1}\right]^{-1}\right)^{-1} \quad (10)$$

The equations to calculate the input impedance Zi and the output capacitance $C_o$ are the same like the ones of the CCS (see Part 2 and replace G by G1 from above).

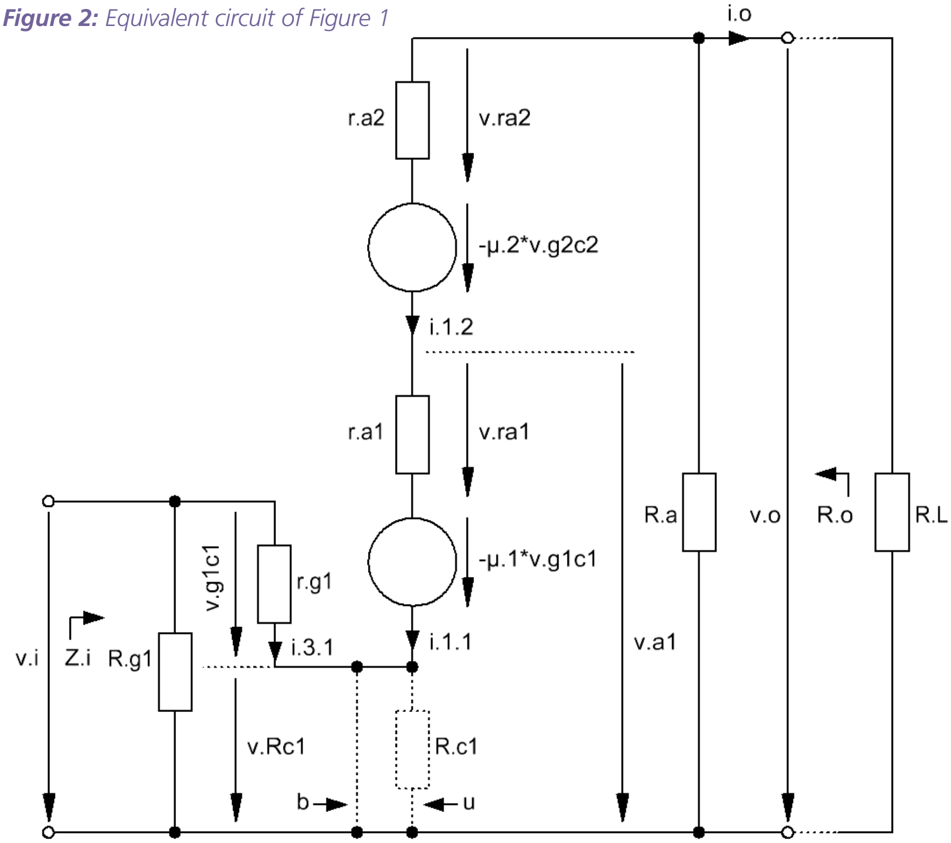
The calculation of the $R_{c1}$ bypass capacitance $C_{c1}$ depends on the cathode output resistance $R_{o.c1}$ of V1. To guarantee a flat frequency and phase response in $B_{20k}$ the corner frequency $f_c$ should be chosen << 20Hz, hence, Cc1 becomes:

$$C_{c1} = \left[2\pi f_c R_{o.c1}(R_L)\right]^{-1} \quad (11)$$

$$R_{o.c1}(R_L) = \left[\frac{(1+\mu_1)(1+\mu_2)}{r_{a2}+\left(R_a^{-1}+R_L^{-1}\right)^{-1}+(1+\mu_2)r_{a1}}+R_{c1}{}^{-1}\right]^{-1} \quad (12)$$

With a constant $V_{a1} = V_{a2}$ = 90V for the circuit of **Figure 1** we can plot graphs as in **Figures 3-6** for the example double-triode E88CC/6922 (note: with constant $V_{a1}$ and $V_{a2}$, a constant $R_a$ means automatically a changing $V_{cc}$ for a changing $I_a$; "$_k$" indicates the number of the ten $I_a$ values from 1mA to 20mA).

*Figure 2:* Equivalent circuit of Figure 1




**Coming in the next issue is**
***Part 5: 'The SRPP Gain Stage'***

**If you missed any of the previous parts, you can order them online by going to Electronics World's website at**
**www.electronicsworld.co.uk**

*Figure 3:* CAS gains $G_u$ and $G_b$ vs. anode current $I_a$ ($R_L$ = 1MΩ, $R_a$ = 10kΩ)

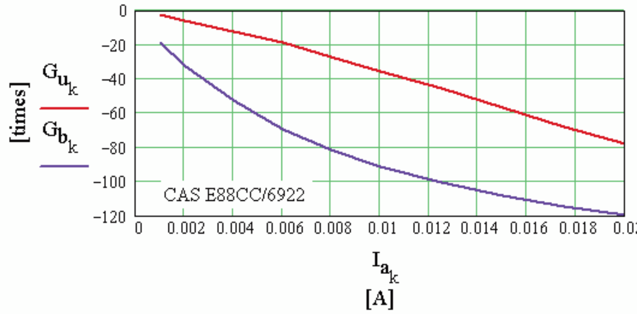



*Figure 5:* CAS output resistances $R_{o.u}$ and $R_{o.b}$ vs. anode current $I_a$ ($R_a$ = 10kΩ)

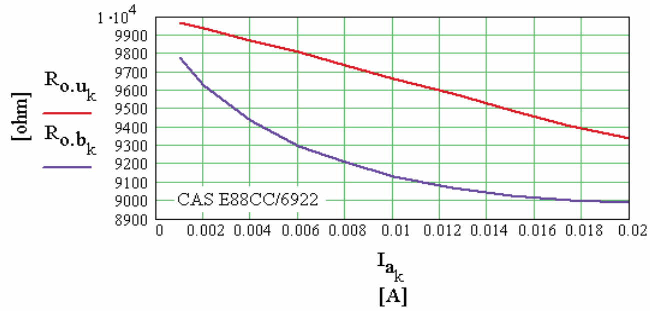



*Figure 4:* CAS gains $G_u$ and $G_b$ vs. output load $R_L$ ($I_a$ = 15mA, $R_a$ = 10kΩ, $R_c$ = 80Ω)

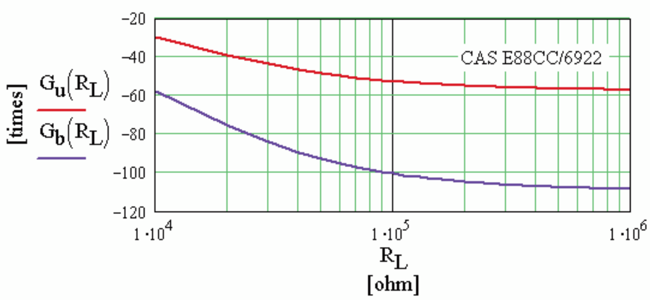
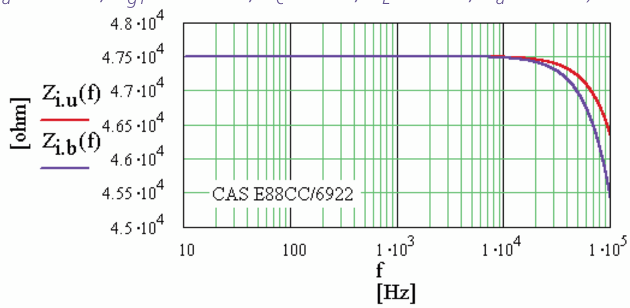



*Figure 6:* CAS input impedance $Z_i(f)$ vs. frequency ($I_a$ = 15mA, $R_{g1}$ = 47.5kΩ, $R_c$ = 80Ω, $R_L$ = 1MΩ, $R_a$ = 10kΩ)



# BIT FOR BIT

**DAVE MATHEW FROM AUDIO PRECISION (AP) LOOKS AT THE IMPORTANCE OF BIT TESTING IN AUDIO SYSTEMS AND HOW TO BEST GO ABOUT IT**

**BACK IN THE DAYS** when audio was only ever analogue, the best performance an audio device could offer was that the device added no imperfections or colourations of its own. This was the origin of the phrase 'high fidelity', where 'fidelity' meant 'faithfulness'. How true was the output to the input?

Of course, it could be very faithful, and distortion, noise and response tests existed to measure just how tiny the difference was.

With digital computing came binary transmission and storage, with parity bits, error correction and, finally, a guarantee that every iota of information was correct and accounted for. The digitization of audio brought this rigour to hi-fi, at least while it remained in the digital domain. Every audio sample, in theory, could be checked.

But digital transmission and storage and, especially, error correction are not always perfectly designed or implemented, or are not always robust enough to endure environmental insults.

Enter Digital Error Rate testing, which quantifies the 'bit accuracy' of a digital audio system. If even one bit is different from the stimulus data stream, it will be reported.

### How Does Bit Testing Work?

Any digital audio signal where the value of every sample is determinate can be used for measuring the digital error rate. 'Digital DC', for example, is a constant sample value that never changes, and if a DUT (device under test) passes it correctly, it can be said to be 'bit transparent' – at least at that value.

For most purposes, a determinate pseudo-random signal is the best choice for digital error rate testing. A pseudo-

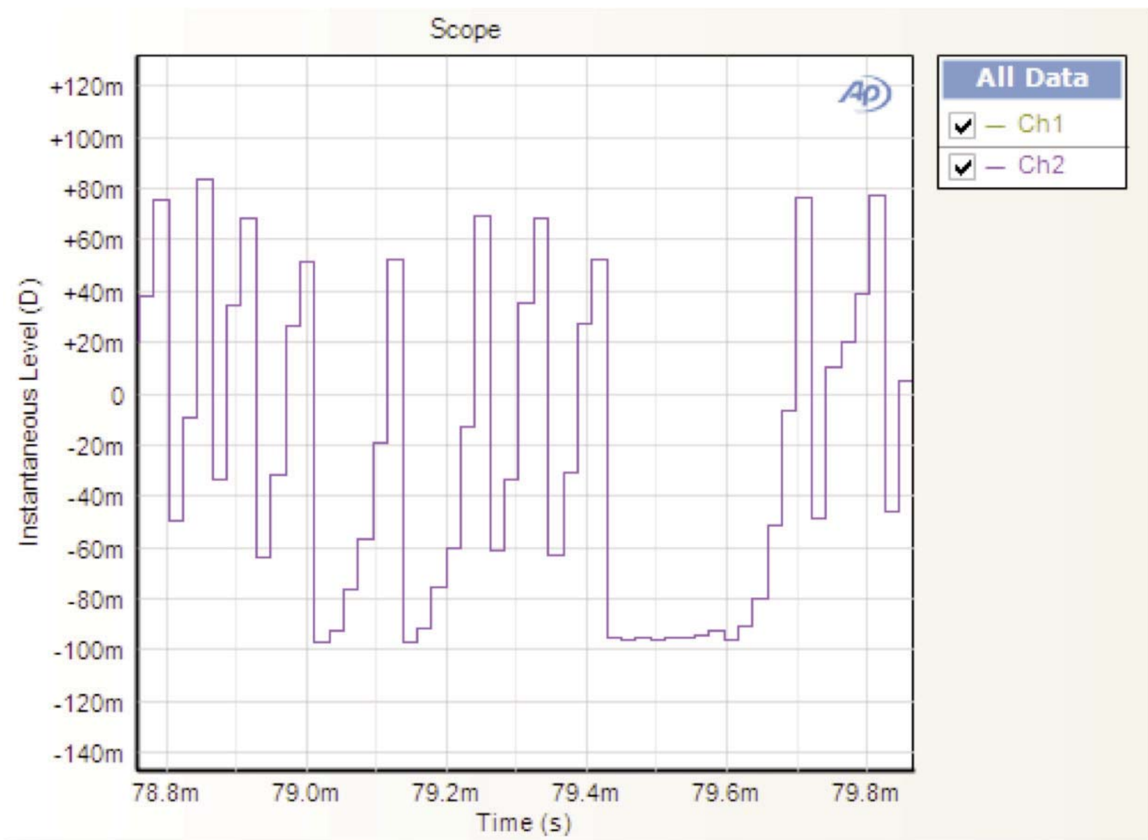



***Figure 1:*** *Short snippet of a 48kHz 24-bit Bit Test signal, sample display*

## BIT TEST AND LOSSY CODECS

**Audio analyzer maker Audio Precision (AP) has come up with a way to test the bit-accuracy of a transport stream that would nominally carry audio encoded with a lossy codec.**
**Using a proprietary file editing technique, AP's designers open up the encoded, lossy formats and package a single-channel bit test signal as the payload. Care is taken to ensure that the format envelope is valid so that the coded file or bitstream will be accepted by the device under test and other components in the stream.**

**AP calls audio files or streams produced by this method 'bitstream' bit test signals. When played into an Audio Precision APx500 analyzer, these 'bitstream' files can be evaluated for Digital Error Rate and will be bit-accurate if not degraded in the device under test (for best results with Blu-ray players, the decoder in the player should be switched off, and the HDMI 'bitstream' audio output option selected, so that the player's output decoder does not compromise the test).**
**However, bitstream files do not contain valid coded audio and will not decode in a surround decoder.**
**Lossless codecs (for example mlp, Dolby TrueHD, dts-HD Master Audio, FLAC and AAC) can be tested using properly prepared 'bitstream' bit test files, in addition to losslessly encoded bit test files.**

random signal is a mathematically-generated noise-like signal that exercises every digital value across a wide range of frequencies. An algorithm can be written that generates such a pseudo-random signal with the property that for any sample value, the next sample value is known. This has the advantage that a very short snippet of signal (two samples) is all that is necessary to begin qualifying the accuracy of the DUT. There is no beginning or end to the signal; you can 'drop in' at any point in a test track and the algorithm will track the signal immediately.

Pseudo-random 'bit test' signals can then be made in a number of 'flavours' to identify the various linear and coded formats.

### Bit-Accurate Processes

Here are a few devices or processes that should always be bit-accurate:

- Linear digital transport, including transmission and reception of digital audio over the IEC60958 family, for example AES3, AES/EBU, S/PDIF, optical and so on); I2S; other linear transport systems.
- Linear transport conversion systems, for example optical to coax, HDMI to S/PDIF).
- Linear digital storage, including storage and retrieval of digital audio to and from computer files, magnetic tape and optical discs.
- Lossless codecs, when passed through a properly configured encode/decode cycle. These include mlp, Dolby TrueHD, dts-HD Master Audio, FLAC and AAC. Note that any processing within the codec, such as filtering, downmixing or volume normalization will negate bit accuracy.

In a bit-accurate process, the sample values remain unchanged when received or read at a rate different from the rate at which the samples were transmitted or written. This means that variances in audio sample rate, including jitter, will not affect bit accuracy, as long as the receiver can lock on the signal.

### Bit-Inaccurate Processes

If the data is changed as a result of passing through the device or process, the latter cannot be said to be bit-accurate.

Certain devices or processes will never be bit-accurate, whether by accident (because there is a defect of some kind) or by design (where the audio is supposed to be changed by the process, as in DSP algorithms). Here are some examples of bit-inaccurate processes:

- Audio processing, whether level change, equalization, mixing, compression or any of the many of DSP effects available in audio devices.
- Dithering.
- Truncation, with or without dithering.
- Sample rate conversion, where the data is modified such that the pitch remains the same at a different sample rate.
- Pitch-shifting, where the data is modified so that the pitch changes while the sample rate remains the same.
- Lossy codecs, including mp3, AAC, Dolby Digital, Dolby Digital Plus, Dolby E, dts Digital Surround, dts-HD High Resolution and others.
- Spurious noise or errors that cannot be accurately corrected.
- Methods of hiding uncorrectable errors that interpolate samples or otherwise change data.

## Codecs and Bit Test

The decoder half of an audio codec, whether lossless or lossy, must receive a correctly formatted compatible datastream to function.

Lossy codecs, for example mp3 or AAC, or most of the surround sound codecs used in Dolby Digital or dts Digital Surround, cannot – by their nature – transport bit-accurate audio. As part of the encoding process, the original audio data is often level-adjusted or filtered. Channels may be combined or set out-of-phase and the signal is compressed for a reduced bit rate. Although the audio might sound pretty good, it is impossible to recover audio data from a lossy codec cycle with bit accuracy.

It is, therefore, completely pointless to use a bit test signal encoded using a lossy codec. However, a neat solution to testing lossy codec transport streams is now available (see 'Bit Test and Lossy Codecs').

By contrast, lossless codecs can successfully encode and decode multiple channels of Bit test with bit accuracy. When the encoder is properly configured such that there is no level or phase shift and no mixing, the lossless codecs can be bit-accurate.

## Checking Your Signals

Bit accuracy measurements only have meaning for signals in the digital domain.

When a signal is measured as bit-accurate (Digital Error Rate of zero), it means that every sample is received as sent. It does not mean that the sample rate is accurate, or that there is no jitter.

When a signal fails bit accuracy, it can mean a number of things:

- Improper configuration. Input bit depth (word length) must match signal bit depth, for example.
- Some processing has occurred. In the case of Blu-ray discs, for example, the player may be downmixing or filtering the signal. In the case of a computer soundcard, there is a good chance that the card is sample-rate converting all output.
- Improper design or implementation in the device. Without naming names, there are Blu-ray players on the market that are never bit-accurate.
- Unrecoverable transmission errors, whatever the cause.

*Dave Mathew is Senior Technical Writer at Audio Precision*



## BOOK REVIEW OFFER!

We would like to offer our readers a chance to review the book '*Understandable Electric Circuits*' by Meizhong Wang. There are many 'Electric Circuits' books on the market but this unique book provides an understandable and effective introduction to the fundamentals of DC/AC circuits. It covers current, voltage, power, resistors, capacitors, inductors, impedance, admittance, dependent/independent sources, the basic circuit laws/rules (Ohm's law, KVL/KCL voltage/current divider rules) series/parallel and wye/delta circuits, methods of DC/AC analysis (branch current and mesh/node analysis), the network theorems (superposition, Thevenin's/Nortons theorems, maximum power transfer, Millman's and substitutions theorems) transient analysis, RLC Circuits and resonance, mutual inductance, transformers and more.

**To get a copy of the book, please write to the Editor at Svetlana.josifovska@stjohnpatrick.com with the following details:**

- **Full name**
- **Address**
- **Company name (if applicable)**
- **Email address**

**The first successful respondent drawn at random will receive a copy of the book, which you can then keep. We'll give you a few weeks following receipt of the book to complete your review.**

**Deadline for entrants will be Tuesday 31st of August.**
**Good Luck!**

BOOK REVIEW OFFER!

# SIZE REDUCTION TECHNIQUE FOR MICROSTRIP PATCH ANTENNA

**A COMPACT MICROSTRIP** patch antenna for 5GHz is suggested here. It presents the very small size at resonance (5GHz) that represents a surface reduction of 60% compared with a conventional microstrip patch antenna. The branch line coupler is used for 900 phase shift between two vertical feed and equal power coupling. The proposed antenna exhibits a gain of 5.1dBi to 5.5dBi for E-plane in the range of its bandwidth, which is 60MHz.

Microstrip antennas have many unique and attractive properties such as low in profile, light in weight, conformable in structure, compact and easy to fabricate and to be integrated with solid-state devices. Microstrip antennas have found wide applications in radio systems with single-ended signal operation. Recently, microstrip antennas have been used in radio systems, with differential signal operation.

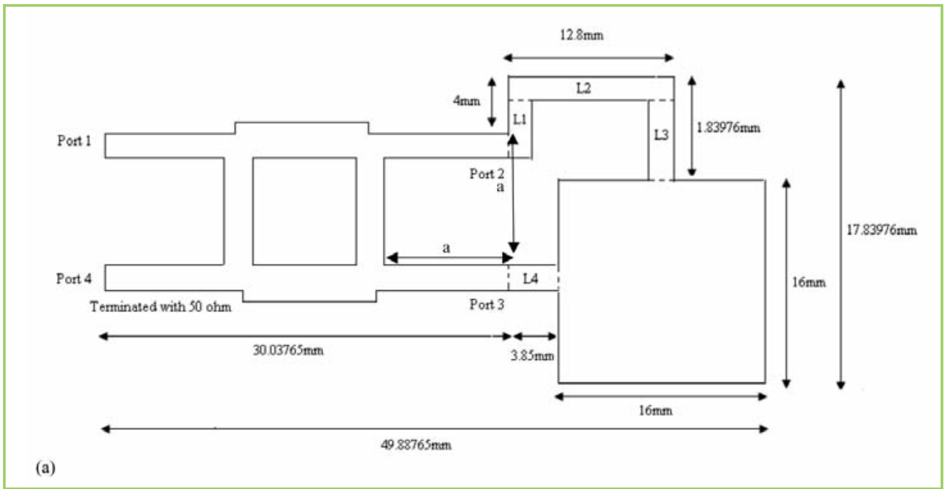



***Figure 1 (a):*** *Proposed compact circularly polarized microstrip patch antenna connected to a 3dB 90-degree coupler*

One such antenna, the circularly polarized microstrip patch antenna, is often exploited in mobile terrestrial and satellite communication terminals. To accomplish the need of high performance devices, there is a great need for compactness of circuits and antennas. This includes the use of high dielectric constant substrate, short-circuiting the patch to ground plane and modifying the geometry of the patch.

In this design idea, we introduce the design and implementation of dual-fed circular polarization rectangular microstrip patch antenna using microstrip line feeding. The proposed antenna is both theoretically and experimentally investigated. We present the performance of the antenna circularly polarized and the radiation pattern for both H-plane and E-plane.

## Proposed Antenna Design

The proposed circularly polarized microstrip patch antenna and its feeding coupler are shown in **Figure 1**. The quadrature (900) hybrid (3dB) coupler generates orthogonal modes for circular polarization. There are two microstrip feed lines in the design as shown in Figure 1. The first feed line is used to connect Port 2 of the coupler to the centre of the length of the antenna. It is comprised of three microstrip lines that are L1, L2 and L3. The second feed line was used to connect Port 3 to the centre of the width of the antenna which is L4. The feed lines were connected to the two adjacent edges of the rectangular microstrip patch antenna so that circular polarization could be obtained. The antenna is mounted on an ROGERS (RO4003C) substrate with dielectric constant of 3.38 and thickness of 31 mil.

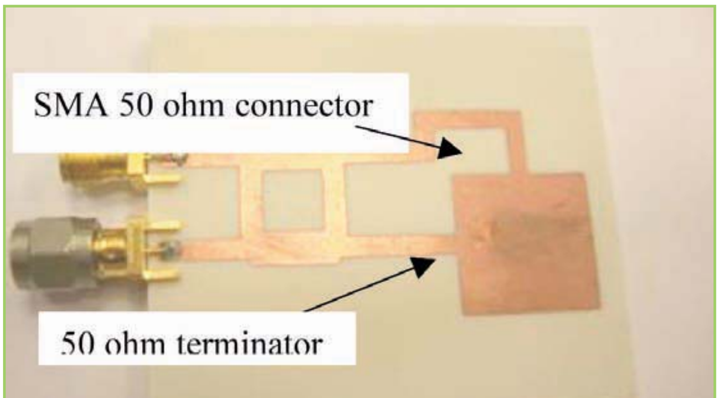



***Figure 1 (b):*** *Fabricated microstrip antenna*

## Results and Discussion

**Figure 2** shows the measured and simulated S11 that indicates how well the antenna is matched to a signal source and how wide the impedance bandwidth is. The impedance bandwidth is the difference between the upper and lower frequencies for which S11 is less than or equal to -9.5dB (or VSWR less or equal to 2).

The measured impedance bandwidth is 60MHz. In the range from 4.97GHz to 5.03GHz, the antenna exhibits return losses lower than -10dB, and at 5GHz the return loss is at -30dB which represents good matching characteristics.

An Agilent network analyzer was used to measure S11, an HP network analyzer the radiation patterns, and an Agilent signal generator and an HP spectrum analyzer the gain in an anechoic chamber. The agreement between the measured and simulated results is, in general, acceptable.

**Figures 3** and **4** show the simulated and measured radiation patterns of microstrip patch antenna at 5GHz. It is observed that a good agreement is obtained between the simulation and measurement. The front-to-back ratio is 19.2dB for the E-plane and 24.3dB for the H-plane. The cross-polarization level is lower than -25.2dB for the E plane and -26.1dB for the H-plane.

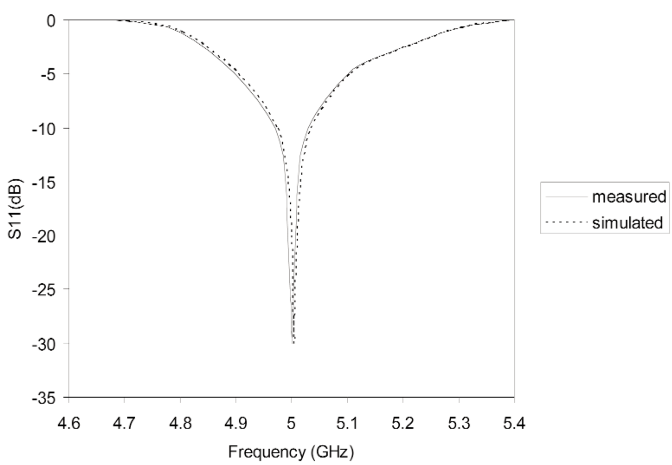



*Figure 2:* *Simulated and measured S11 versus frequency of the proposed microstrip antenna*

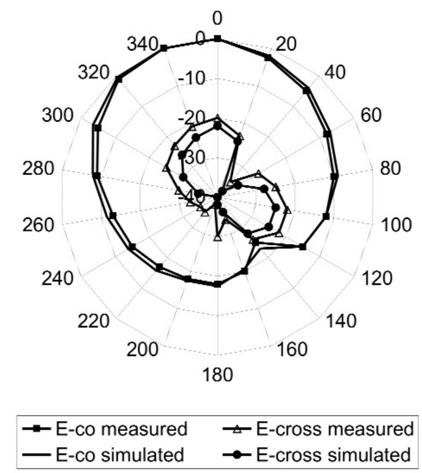



*Figure 3:* *Simulated and measured radiation patterns at 5GHz for the E-plane*

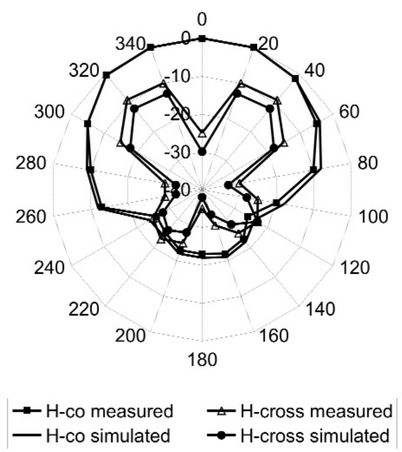



*Figure 4:* *Simulated and measured radiation patterns at 5GHz for the H-plane*

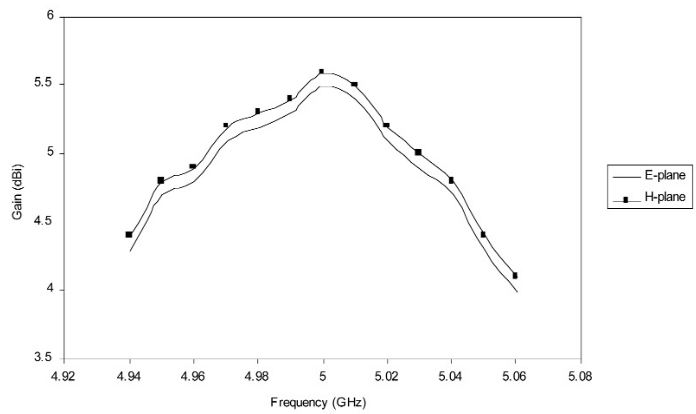



*Figure 5:* *Measured gain (the bandwidth of 60MHz corresponds to -10dB isolation frequency range shown in Figure 2)*

Figure 4 shows the measured gain of the bandwidth of 60MHz corresponds to the -10dB response curve frequency range shown in Figure 2. The peak gain was measured with the approach of two identical antennas. The measured peak gain values at 5GHz are 5.5 and 5.6dBi for the E-plane and H-plane, respectively. In the range of the frequency bandwidth, the gain of the antenna varies between 5.1dBi to 5.5dBi for the E-plane and between 5.2dBi to 5.6dBi for the H-plane.

The antenna exhibits the compact overall size of 49.8mm x 18mm, which corresponds to a surface reduction of about 60% in comparison with a conventional microstrip patch antenna.

## Applications

A compact circularly polarized microstrip patch antenna has been shown here. The antenna is characterized by a size reduction of 60% when compared to a conventional microstrip patch antenna. This structure should find applications in compact phased arrays due to its small size and integration of the feedline in the plane of the antenna. ■

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**Fakuliti Kejuruteraan dan Alam Bina**
**Universiti Kebangsaan, Malaysia**

When the LEDs are reconnected after any amount of time, the LED current quickly settles at its programmed 100mA level (50mA per channel with two channels in parallel for eight LED strings). The high output voltage allows the internal eight string ballaster to operate immediately. The ballast LED pin voltages quickly rise up to the level needed for 100mA through each LED string tied to the high output voltage. Then the output voltage and ballast voltage drop down to their expected operating points with the LEDs turned on.

**Figure 2a** shows the LED current with 100us turn on using the discrete LED disconnect shown in Figure 1. **Figure 2b** shows the 1.35ms LED current turn on in comparison with 2a when the conventional LED connection is made and PWM is used to turn the LEDs on and off. In both cases, the LEDs were held off for five seconds before being turned on. ■

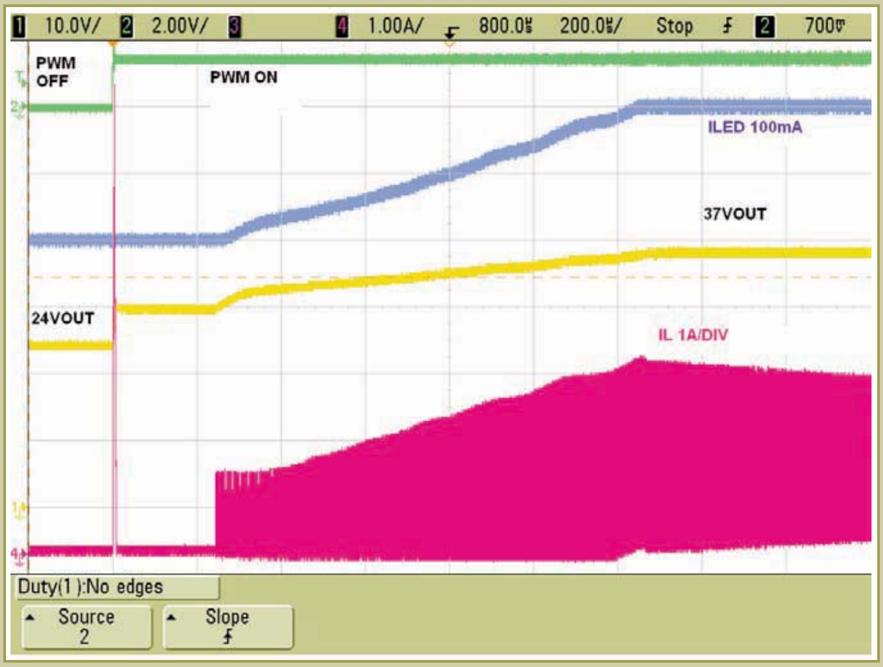



***Figure 2b:*** *LED turn on using conventional option 2 PWM dimming after 5s PWM off*

## DUAL FULL-BRIDGE MOTOR DRIVER ICS WITH OVERCURRENT PROTECTION

Two new full-bridge stepper-motor driver ICs, the A4986 and A4987, have been added to the family of motor driver devices available from Allegro MicroSystems Europe.

The new devices are dual DMOS full-bridge stepper-motor drivers with parallel input communication and overcurrent protection, and offer improved microstepping accuracy along with high reliability.

Each device includes a fixed off-time pulse-width-modulation (PWM) current regulator, along with a 2-bit nonlinear digital-analogue converter that allows stepper motors to be controlled in full, half and quarter-step modes. Each full-bridge output of the A4986 and A4987 is rated at up to 35V and ±2A (A4986) or ±1A (A4987).

Internal synchronous rectification control circuitry is provided to improve power dissipation during PWM operation. Industry standard phase, I0 and I1 logic inputs are used to control each full-bridge, making it easy for the A4986 and A4987 to be used as replacements for most existing drivers.

**www.allegromicro.com**

## INTELLIGENT EMBEDDED RADIO TRANSCEIVERS

MK Consultants has introduced a new range of embedded intelligent radio transceivers that operate in the UHF bands of 434, 457, 868 and 915MHz with a VHF 169MHz version also available.

The iGenesis series operates in narrow band 25kHz channels producing adjustable RF power up to 15mW, coupled with a receiver sensitivity in excess of -120dBm and best-in-class blocking immunity against interference.


Housed in a fully shielded SIL package with compact overall dimensions of just 44mm x 15mm x 5mm, the iGenesis series is ideal for the growing number of portable electronics products that require reliable, long range and repeatable wireless interconnectivity. Applications include M2M, Bluetooth and Zigbee replacement for enhanced performance, automatic meter reading, home automation and wireless sensors.

The new modules have a wide operating voltage range of 2.8VDC to 6VDC and can achieve a wireless range in excess of one kilometre.

**www.mkconsultants.eu**

## ACCURATELY DETERMINING INSULATION MOISTURE CONTENT WITH DIRANA

DIRANA, the DIelectric Response ANAlyzer from Omicron, determines in a simple and efficient way the moisture content of liquid filled transformers. Accurate knowledge of the moisture content is a crucial factor in the condition assessment of power transformers.

High moisture levels accelerate insulation decomposition, decrease dielectric strength and may cause bubbles to form at elevated temperatures. Additionally, the condition (water content) of the oil is determined. The DIRANA is also applicable to the condition assessment of bushings, instrument transformers, cables and rotating machines. Other applications include verification of proper drying for a new transformer at the factory or confirmation that the transformer is properly dried out after field assembly, repairs or oil processing.

The DIRANA determines the moisture content on the basis of Dielectric Frequency Response (DFR). Unique to DIRANA is the combination of the two measurement techniques: Polarization Current Measurement (PDC) and the Frequency Domain Spectroscopy (FDS).

**www.omicron.at**

## SHORT-TRAVEL PROBE FOR BATTERY CONTACT APPLICATIONS

The new P909 Series from Peak Test Services is a short-travel probe for battery contact applications.

Depending on the application, it can be pressed or soldered to a printed-circuit board or used with a separate receptacle. For soldered use, a high-temperature solder-tight version is available.

The new probe has an overall length of only 5.3mm and is designed for mounting at centres of 1.7mm.

The P909 Series is available in the UK and Ireland from Peak Test Services and via a range of appointed distributors worldwide.

**www.thepeakgroup.com**

## SENSIRION'S NEW HUMIDITY SENSOR QUALIFIED TO AUTOMOTIVE STANDARD

Sensirion's new SHT21 humidity and temperature sensor has now been qualified in accordance with the AEC-Q100 automotive standard. This confirms the outstanding reliability, stability and robustness of the sensor, which has been in regular production since April 2010.

During the qualification process, the SHT21 was put through the relevant series of tests. Its aging resistance was confirmed by the High Temperature Operating Lifetime (HTOL) test, and its stress resistance was demonstrated by the Unbiased Highly Accelerated Stress Test (UHST). Furthermore, a Temperature Cycling (TC) test confirmed the compatibility of the packaging material with the chip and substrate, and the Electrostatic Discharge (ESD) and Electromagnetic Compatibility (EMC) tests proved the robustness of the sensor with regard to these parameters.

The SHT21 humidity sensor passed all the tests without any permanent changes to its characteristics and therefore fulfilled the quality requirements of the AEC-Q100 automotive standard.

**www.sensirion.com**

## MOST FLEXIBLE INTELLIGENT POWER MANAGEMENT IC

Integrated Device Technology (IDT) announced a highly integrated microcontroller-based Intelligent System Power Management Solution targeted for portable consumer products, such as smartphones, portable navigation devices, mobile Internet devices and eBooks.

The unique architecture of the IDT P95020 features a best-in-class high-fidelity audio subsystem, clock generation, resistive touch controller, backlight LED driver, Li+/Polymer battery charger, multi-channel DC-to-DC converters and a high resolution analogue-to-digital converter (ADC).

By embedding a microcontroller, the IDT P95020 offers full programmability and flexibility into designs using leading multimedia application processors. All of the functional blocks can be accessed via I2C. The programmable regulators satisfy the dynamic voltage adjustment required by application processors.


The IDT P95020 is the latest generation of cost-effective, customizable Power Management Integrated Circuits (PMICs) that provide optimum performance, functionality, programmability and flexibility to the system designer of portable consumer applications.

**www.IDT.com**

## NEW LOW PROFILE KEYPAD SWITCHES FROM FOREMOST ELECTRONICS

Foremost Electronics from Essex has been appointed as the UK distributor for the Marquardt 6425 range of keypad switches. With worldwide sales of more than 3,000,000 pieces per year the 6425 switch range has proven to be highly reliable and very successful in a wide range of applications including telecoms, control and alarm panels, weighing scales and similar instrumentation and point of sale equipment. The 6425 switch range has low operating noise making them suitable for pro-audio, broadcast and medical applications.

The low profile Marquardt 6425 series has comfortable actuation characteristic with long travel, soft tactile "feel" and secure switching functionality, ideal for assembling into keypads or keyboards. Caps are available for the switches in a wide range of shapes and colours for panel spacings of 16mm or 19mm to ensure simple integration into control panels. The 6425 switch caps feature ergonomic surfaces and may be over-printed in different colours with a variety of legends.

**www.4most.co.uk**

## NEW LAYER 3 SOFTWARE FOR HIRSCHMANN MACH1040 GIGABIT ETHERNET SWITCHES

Belden has introduced a new Layer 3 software that makes it possible to use all Gigabit Ethernet switches Hirschmann MACH1040 family as routers. Using wire-speed technology makes for extremely fast functions, which include not only static and dynamic routing, but also multicast routing (DVMRP, IGMPv1/v2/v3, PIM-DM) and router redundancy (VRRP, OSPFv2, RIPv1/v2).

Hirschmann MACH 1040 switches are designed specifically for use in the power industry. They can be connected to form sub-networks, which in turn can be linked up to each other. Thanks to their fanless design, their ability to withstand temperatures from -40°C to +70°C and their Fast HIPER Ring redundancy mechanism, these switches guarantee the highest degree of availability for production facilities. Moreover, they also support Profinet and EtherNet/IP.

MACH1040 switches meet a wide variety of standards and have a range of approvals and they offer both high vibration-resistance and extensive resilience to magnetic fields and electrostatic discharges.

**www.beldensolutions.com**

## SMALLEST 6A SMT SINGLE IDC DISCRETE WIRE-TO-BOARD CONTACT

AVX Corporation has expanded its 917x series of reliable discrete wire-to-board connectors with the launch of the 9176-400 series contact and cap – the smallest discrete surface mount IDC wire-to-board connector with a 6A rating.

The 917x series connectors fit almost every application where there is a requirement to connect a single wire to a PCB; this new connector offers a smaller profile and lower cost alternative by providing a simple, low cost reliable, SMT termination point for 22-24AWG wires, especially for SSL and industrial applications. More, individual contacts can be located anywhere on the PCB enabling great design freedom.

Originally developed to meet harsh environment automotive and industrial market applications, the industry-proven IDC contact system has been tested to automotive levels of shock, vibration and temperature cycling to prove their reliability and robustness. This new, single, standalone component enables a wide range of devices to be connected to the PCB without soldering.

**www.avx.com**

## KONTRON PC CB 752 NOW AVAILABLE FOR EXTENDED AMBIENT TEMPERATURES

The Kontron Embedded Box PC CB 752, introduced by Kontron in November 2009, is now available for ambient temperatures from -15°C to +60°C. The electronics are equipped with particularly robust specified components and the whole system was fully tested in the climate chamber. Customers benefit from improved reliability in a wider range of harsh environments thanks to the expanded capabilities of the Kontron CB 752.

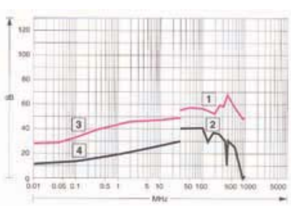
The improved temperature tolerance makes the compact Kontron Embedded Box PC CB 752 suitable for particularly demanding applications in transportation, automation, medical, POS and digital signage, as well as in many other unheated and non air-conditioned work environments that do not necessarily require the industrial temperature range (E2) -40°C to +85°C. Applications where the temperature range -15°C to +60°C is sufficient benefit from the extensively tested, cost effective and validated long-term available system design with high security.

**www.kontron.com**

## MORE PROTECTION FROM EMC

Have you ever designed a piece of kit which let you down, by being susceptible to EMC, when you didn't think it ought to be?

Rittal says it has the answer with the Ripac Vario subrack for mounting multiple board electronic solutions in 19" (482.6mm) racks, as the range is easily upgraded from standard to EMC after it has been completed. This will provide over 40dB of shielding effectiveness at 1GHz, both for incoming and outgoing protection.



For a simple upgrade top and bottom covers can be added, a rear panel and a few gaskets, to ensure good electrical and mechanical contact between adjacent surfaces. These components are readily available from stock and Rittal have a 20 strong sales team who can assist customers with the selection.

For full protection from the beginning, the Ripac Vario EMC subracks are also available on short lead times, along with EMC front and rear panels and a wide range of useful accessories.

**www.rittal.co.uk**

## SYSTEM CONNECTIVITY SOLUTIONS FOR IN-VEHICLE NETWORKS

Harting now offers a complete range of interconnectivity solutions for in-vehicle Ethernet communications networks in road and rail vehicles.

A combination of the company's Ha-VIS 4000 range of Ethernet switches and Ha-VIS EtherRail data cables forms the basis for reliable Ethernet networks both within and in between vehicles.

In addition, the implementation of redundant networks that are specially designed to meet the connectivity requirements encountered in buses, trams and trains can be optimised with a combination of supplementary, interactive products, such as Ethernet switches with PoE (Power over Ethernet), highly flexible data cables compliant with LSZH (low-smoke/zero-halogen) requirements and Harting's wide range of industrial connectors.

Harting's Ha-VIS eCon 4080-BPoE1 8-port PoE switch can be used to implement video networks as an aid to enhancing passenger safety in the driver's cab or at bus/train stops. Highly flexible data cables with four-star construction can be used both as connecting cable at the carriage transition and for installations in the vehicles.

**www.HARTING.com**

## TT ELECTRONICS OPTEK TECHNOLOGY'S LAB DELIVERS CUSTOM LED TEST CAPABILITIES

Providing design engineers of LED light engines with the ability to perform the precision testing required for uniform colour temperature and intensity, TT electronics OPTEK Technology's LED lab offers a comprehensive range of services and customized testing capabilities for the design and development of solid-state lighting applications.

Built specifically for the testing and analysis of LED light engines, OPTEK's lab capabilities include 100% colour temperature and/or intensity screening for the tightest binning specifications (CIE colour coordinate testing with a repeatability of 0.002 with respect to X and Y; intensity testing with an accuracy of ±2%; and wavelength testing with accuracy of ±0.75nm).


"This level of precision screening and testing is vital for customers who require a specific colour light associated with their brand or corporate image, and it's a capability that typical contract manufacturers are unable to provide," said Roland Chapa, OPTEK's vice-president of Integrated Solutions.

**www.optekinc.com/contactus.aspx**

## TRAC GAINS FULL ACCREDITATION FOR IEC/EN60601 MEDICAL DEVICE TESTING


TRaC, a provider of testing, certification and approvals services, is now able to offer testing of medical equipment in accordance with the IEC/EN60601 standard. TRaC is fully accredited by UKAS (United Kingdom Accreditation Service) to test equipment in accordance with the international standard.

IEC/EN60601 is a family of standards that govern safety of electrical medical equipment and is identical with the International IEC standard 60601; approval under the standard is a fundamental requirement before a manufacturer can market any electrical device for patient diagnostics, monitoring or care, in any market worldwide. The standard sets minimum requirements not only for basic electrical safety, but also for EMC (electromagnetic compatibility) and mechanical safety, as well as a range of other parameters, according to the particular technology employed in any particular item of medical equipment.

Developers of medical electrical systems now have a single point of contact for all their safety and EMC testing needs.

**www.tracglobal.com**

## FREESCALE MMA8450Q ACCELERATION SENSOR AVAILABLE FROM MOUSER

Mouser Electronics announced it is now stocking the Freescale Semiconductor MMA8450Q 3-axis digital accelerometer. The accelerometer is a next generation motion sensing device that provides 12-bit data with FIFO to accomplish complex gesture recognition and positive detection required for next-generation mobile applications that go beyond basic algorithms.


The Freescale MMA8450Q 12-bit, 3-axis low g I²C digital capacitive acceleration sensor with extremely low power provides increased embedded intelligence such as orientation, tap, double tap, jolt, freefall and shake detection. It allows the development of more robust applications such as position detection, 3D gesture detection, pedometry and many other next generation motion detection functions. It appeals to design engineers seeking advanced sensing for future portable applications.

Mouser Electronics's website, with interactive online catalogue, is updated daily and searches over 6.7 million products to locate over a 1.6 million part numbers available for easy online purchase. Plus, it houses downloadable data sheets, supplier-specific reference designs, application notes, technical design information and engineering tools..

**www.mouser.com**
**www.freescale.com**

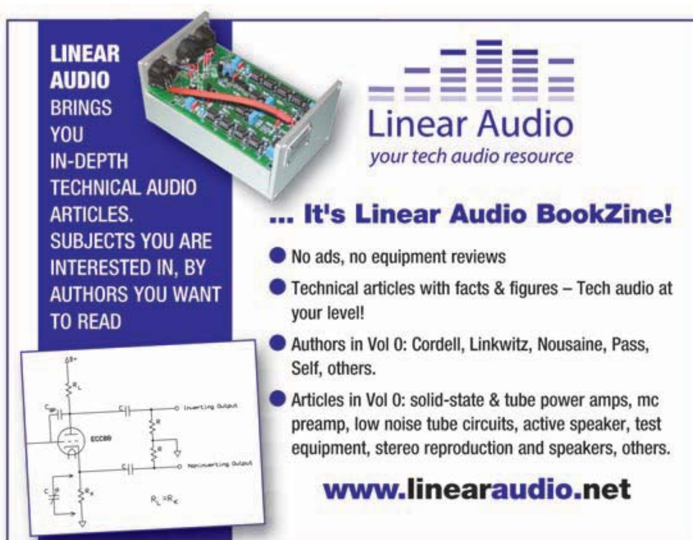

## CABLE HARNESS COMPANY EXPANDS AND LAUNCHES NEW WEBSITE

Fast growing specialist cable harness manufacturer Inconnect has recently doubled its capacity by investing in new overmoulding and production machinery at its plant in Lincoln.

In line with the company's rapid expansion, Inconnect has just launched a brand new website www.inconnectcables.co.uk giving much more information to the electrical and electronics industry looking for quality custom cable assemblies and connectors.

**www.inconnectcables.co.uk**





# UNLICENSED WHITESPACE FREQUENCIES TO **REVOLUTIONIZE WIRELESS NETWORKS,** SAY EXPERTS

A new report released by Cambridge Consultants, called '*Whitespace: a revolution in wireless communications?*', looks at how the highly desirable TV band whitespace could fundamentally change today's wireless provider model while spotlighting technology hurdles that will limit immediate disruption. The new whitespace frequencies, recently authorized in the US by the Federal Communications Commission (FCC), greatly increase the global wireless bandwidth available to computers, set-top boxes, laptops, WiFi hot spots and other radio devices that currently use the unlicensed bands at 2.4 and 5GHz.

Firms such as Intel, Dell, Philips, Nokia, Microsoft and Google contributed to the report to discuss the potential $100bn US market for wireless technologies enabled by whitespace frequencies. The consensus is that new wireless devices will soon emerge taking advantage of the increased range and wall-penetrating ability of the newly allotted band. This could be in the form of supplementing traditional cellular networks or by creating low cost wireless broadband capabilities in some urban environments.

## Our panel of commentators says the following on this development:

**BURKHARD VOGEL, MANAGING DIRECTOR, GERMANY:**

Isn't it a shame? Europe slept well and the US (FCC) acts! Now, US's respective industry got a huge advantage over the competition of the rest of the world. And again, they will dictate which way to go. It was not unknown to the European wireless industry that a broad range of new business adventures could be passed in the whitespace frequency range. Why didn't they act? Why do we (the Europeans) always miss an opportunity instead of simply being faster?

Nevertheless, the use of the whitespace by data transmitting activities à la Internet should not be organized nor should it be pushed through at the expense of the wireless microphone manufacturers. On the other hand, if it's true that 80% of the spectrum capacity below 3G is unused and the demand for free spectrum space for long-range wireless data exchange will become the growing market challenge in the near future, the following question should be answered by the respective international organizations as soon as possible: Isn't it high time reorganizing the spectrum < 3G according to this growing demand? The 600MHz whitespace can only be a first step.

**BARRY MCKEOWN, RF AND MICROWAVE ENGINEER IN THE DEFENCE INDUSTRY, AND DIRECTOR OF DATOD LTD, UK:**

I note that CCL recognize that LTE is a short term proposition and that there is much misinformation placed in the public domain by incumbent vested interests over the past six years in the US where this technology initiative originates; which their report should hopefully sanities. I would disagree with CCL about the unlicensed whitespace technology rivalling licensed cellular networks though. This is to misunderstand the current regulatory framework and how it is evolving such that developments in future healthcare Body Area Networks shall be required to interface with both broadband fibre and cellular network operators on basic economic grounds.

**PROFESSOR DR DOGAN IBRAHIM FROM THE NEAR EAST UNIVERSITY IN NICOSIA, CYPRUS:**

One of the major problems with the existing wireless devices is the seriously limited range and the fact that the signals do not penetrate through walls. Many people find it difficult to connect to their access points even within their homes, when for example the access point is located upstairs and there may be no signal downstairs or in the garden. This is mainly as a result of the limitations of the existing 2.4 and 5GHz wireless frequency bands. In general, lower frequency bands, such as the whitespace radio bands offer several times longer range than the existing wireless bands.

Television whitespace bands will enable an access point to serve a much greater area, e.g. a single low-cost access point would be sufficient to service a public place such as a library, train station or an airport. Without a doubt, the use of whitespace radio frequencies will revolutionarise the wireless connectivity.

**MAURIZIO DI PAOLO EMILIO, TELECOMMUNICATIONS ENGINEER, INFN – LABORATORI NAZIONALI DEL GRAN SASSO, ITALY:**

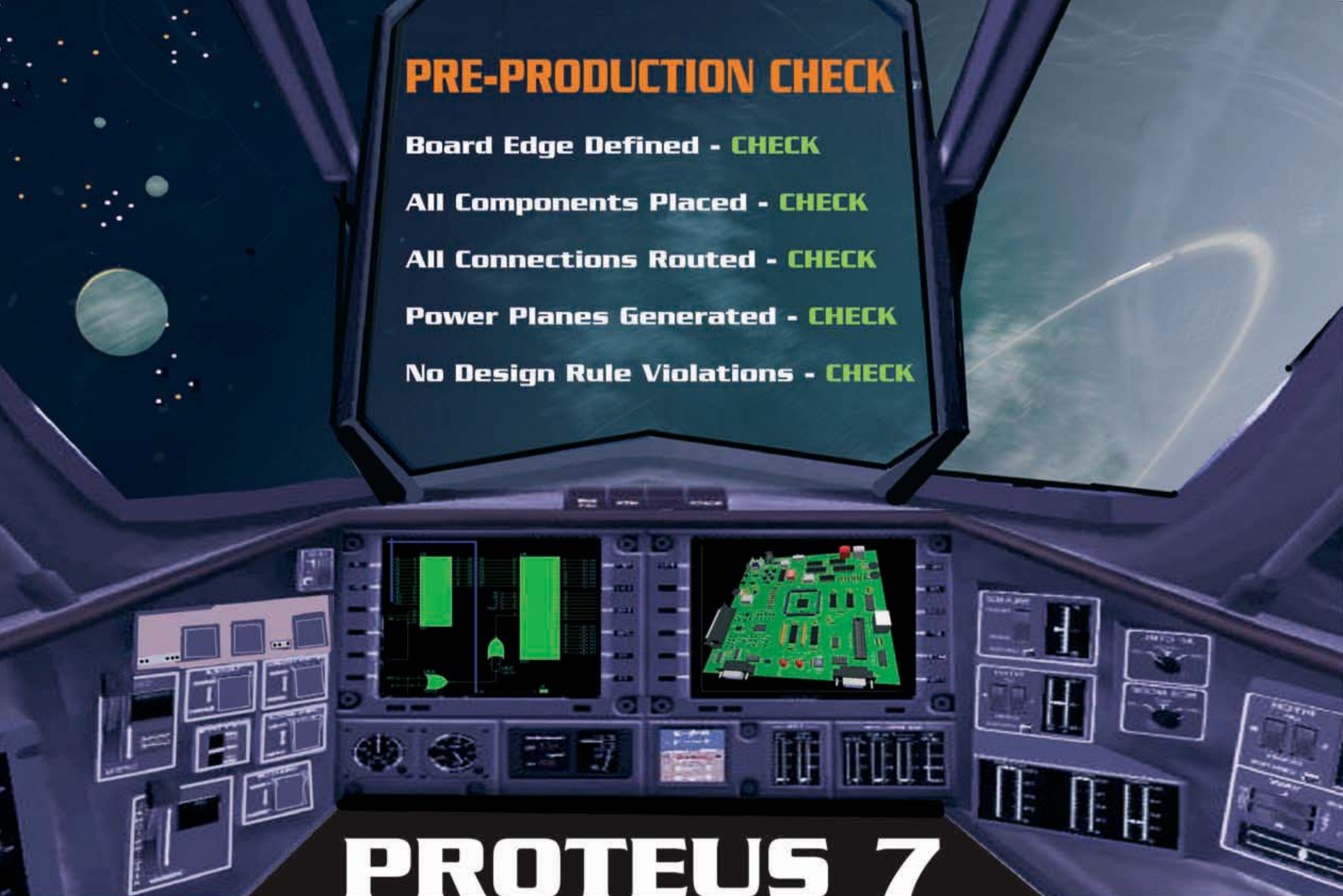
Whitespace devices take advantage of wireless innovations and advances in computer processing power and automatically detect unoccupied TV frequencies. For consumers, they're very similar to the wireless devices we use today.

Whitespace devices will have a greater positive impact than wi-fi and spur far more innovation than mobile phones.

**HAFIDH MECHERGUI, ASSOCIATE PROFESSOR IN ELECTRICAL ENGINEERING AT THE UNIVERSITY OF TUNISIA:**

The spectacular innovations in the field of telecommunications represent a true scientific revolution. It is noted that with the numerical world, allotted to telecommunications, the transmission of the television programs is ensured by distributive firms and operators. Indeed, the transmission of the video signals and the data are digitized in a numerical flow. This operation made it possible to have whitespace frequencies. It is a new era in telecommunications. It constitutes a revolution of the wireless network. Thus whitespace frequencies will be used by titular companies and allotted to radio broadcast diffusion.

*If you'd like to comment on this subject or want to become a member of our panel, please write to the Editor at Svetlana.josifovska@stjohnpatrick.com*


PRE-PRODUCTION CHECK
Board Edge Defined - CHECK
All Components Placed - CHECK
All Connections Routed - CHECK
Power Planes Generated - CHECK
No Design Rule Violations - CHECK
PROTEUS 7

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