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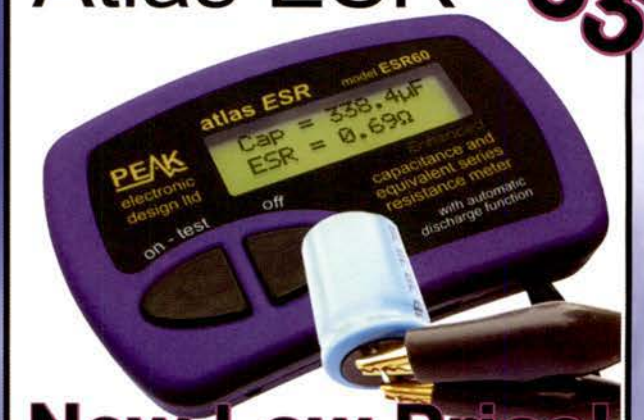

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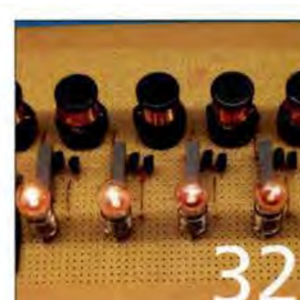

ELECTRONICS WORLD

EDITOR:
Svetlana Josifovska
Email: svetlana.josifovska@stjohnpatrick.com

PRODUCTION EDITOR/DESIGNER:
Tim Wesson

DISPLAY SALES EXECUTIVE:
Matthew Dawe
TEL: +44 (0) 20 7933 8999
Email: matthew.dawe@stjohnpatrick.com

SALES DIRECTOR:
Chris Cooke

PUBLISHER:
John Owen

SUBSCRIPTIONS:
Dovetail Services
800 Guillat Avenue,
Kent Science Park,
Sittingbourne,
Kent, ME9 8GU
TEL: +44 (0) 844 844 0230
Email: saintjohnpatrick@servicehelpline.co.uk

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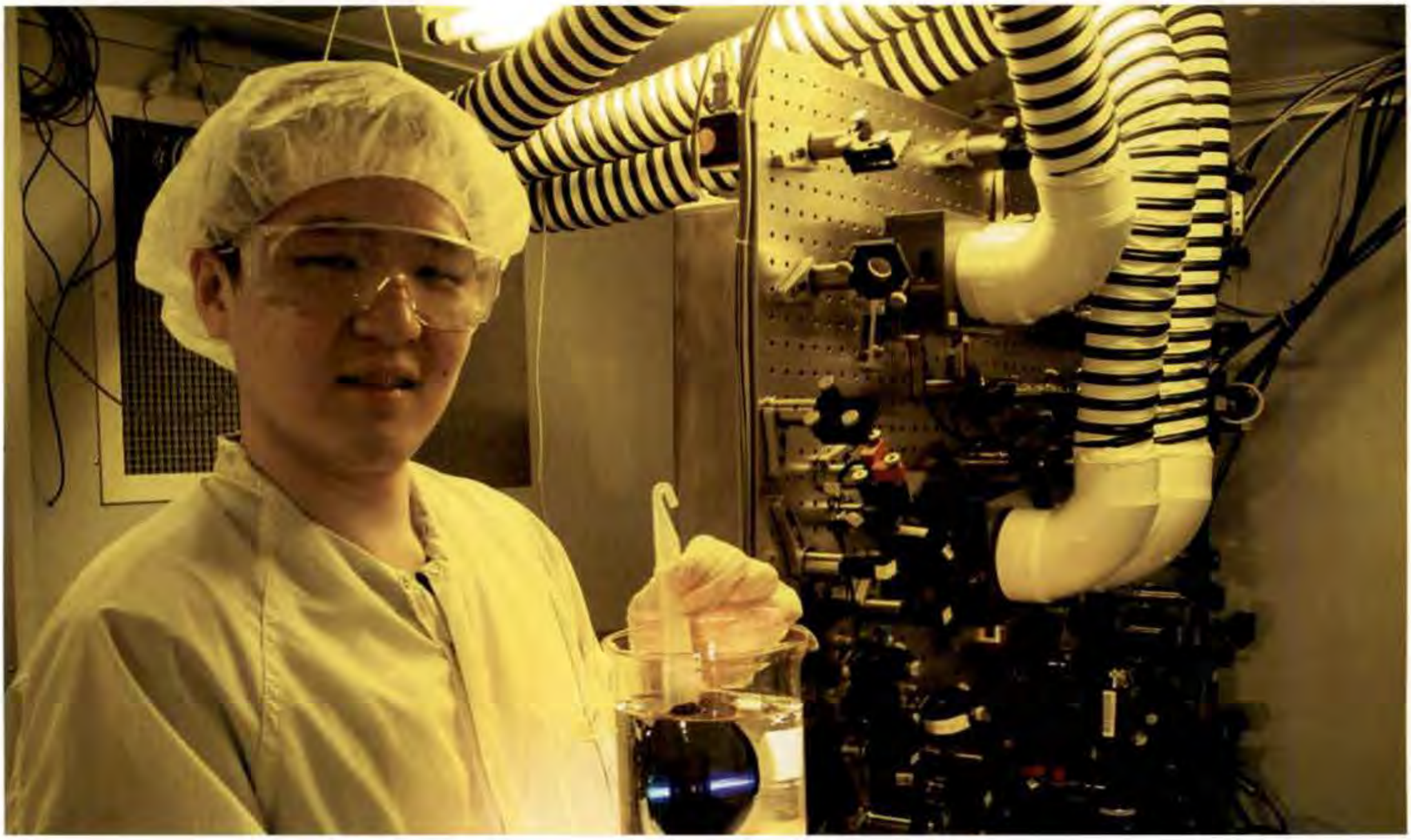
MIT shows nanoscale lithography the way forward



MIT graduate student Chih-Hao Chang holds a silicon wafer in front of the MIT nanoruler

While Intel is pressing ahead with plans to start manufacturing 32nm chips in 2009, a group of scientists from the Massachusetts Institute of Technology (MIT) has devised a novel technique that has already allowed them to create lines about 25nm wide separated by 25nm spaces.

Interference lithography (IL), an old technique that can be used to generate circuit patterns, was applied with the help of a tool called "the nanoruler". Built by MIT graduate students, the nanoruler was designed to perform a particularly high precision variant of IL called scanning-beam interference lithography (SBIL).

The technique uses 100MHz sound waves – controlled by custom high-speed electronics – to diffract and frequency-shift the laser light. According to the research team, which was led by Mark Schattenburg and Ralf Heilmann from the MIT Kavli Institute of Astrophysics and Space Research, both rapid patterning of large areas and unprecedented control over feature geometry are possible.

The unheard-of levels of precision and repeatability in pattern registration come courtesy of a clever high-precision phase detection algorithm developed by Young Zhao and a novel image reversal process developed by Chih-Hao Chang, both graduate students from the Institute's Department of Mechanical Engineering.

"What we're finding is that control of the lithographic imaging process is no longer the limiting step," said Schattenburg. "Material issues such as line sidewall roughness are now a major barrier to still-finer length scales. However, there are several new technologies on the horizon that have the potential for alleviating these problems. These results demonstrate that there's still a lot of room left for scale shrinkage in optical lithography. We don't see any insurmountable roadblocks just yet."

If commercially successful, SBIL could pave the way for next-generation computer memory and integrated-circuit chips, as well as advanced solar cells. The team is indeed confident that there are reasons which will make the technique economically attractive. Chief among these is that SBIL works without the chemically amplified resists, immersion lithography techniques and expensive lithography tools that are widely viewed as essential today to work at such small nanoscale with optical lithography.

While having key scientific and commercial applications, periodic patterns at the nanoscale are notorious for the high costs and relatively low yields associated with their production; something that the new method could help address in the future.

Sony's Wireless USB competitor earns heavyweights' support

Sony showed a prototype of the technology in Las Vegas back in January

TransferJet, a powerful new wireless, short-range data transfer technology announced by Sony earlier this year, has moved a step closer to reality following confirmation by some of the consumer electronics industry's biggest players that they will support the standard.

A new alliance called the TransferJet Consortium has been formed. Apart from Sony, the initial list of backers includes Canon, Kodak, Samsung, Panasonic, Toshiba, Hitachi, JVC, Kenwood, Nikon, Olympus, Pioneer, Seiko Epson, Sony Ericsson and KDDI.

TransferJet is designed to let any two types of consumer electronics devices, such as digital cameras, TVs, video cameras, mobile phones or portable music players, to easily exchange large digital files by just bringing the gadgets in close proximity – up to 3cm – with each other.

According to Sony, a transmission throughput of up to 560Mbit/s is possible. Effectively, though, sustained data rates will drop to 375Mbit/s. Operation is on the 4.48GHz radio frequency spectrum, while average transmission power is -70dBm/MHz.

Unlike the existing Wireless USB protocol, which boasts data rates of 480Mbit/s at up to 3m and 110Mbit/s at up to 10m, Sony says the advantage of its proposed technology is that it eliminates the need for complex setup and operation. Directly touching two compliant electronic products together will allow files to be transferred automatically, without the need for an access point.

Central to the development of the new protocol is an invention that Sony has patented as the "TransferJet coupler". Based on electric induction field coupling, the Japanese vendor claims it delivers superior propagation performance compared to conventional radiation field based antennas. It maintains high transmission gain and efficient coupling in near-field proximity, while providing sharp attenuation over longer distances to avoid interference with other wireless systems.

Given that the system doesn't require antenna polarisation to work, data can be transmitted without any performance loss regardless of the contact angle of the electronic devices.

The first task of the TransferJet Consortium will be to develop specifications and guidelines to ensure interoperability between products incorporating the technology. Licensing schemes and administration of the TransferJet logo will also be part of the organisation's remit.

No estimated dates have yet been announced for the first commercial products to feature the technology.

IN BRIEF

- **Andrew and Siemens have jointly designed an advanced wireless communications system for the CRH3 Harmony multiple unit trains, which were developed specifically for the Olympics in China and have maximum speeds of 350 kilometers per hour. The CRH3 trains began running on the Beijing-Tianjin high speed railway line on August 1, helping bring guests from all corners of the world to Beijing for the 2008 Summer Olympics. "Providing reliable wireless signals in high speed trains is challenging because of diverse terrain and constantly changing signal levels. We are proud to help in the rapid development of China's rail transportation," said Matt Melester, VP and general manager, Wireless Innovations, Andrew.**

- **STMicroelectronics (ST) and NXP Semiconductors announced the creation of a new wireless joint venture – ST-NXP Wireless – with ST owning 80% stake. ST-NXP Wireless will have the R&D scale and expertise to meet customer needs in 2G, 2.5G, 3G, multimedia, connectivity and all future wireless technologies. The JV will be incorporated in Switzerland and headquartered in Geneva, much the same as ST's headquarters.**
ST-NXP Wireless will have in excess of 7,500 employees with major facilities in Belgium, China, Finland, France, Germany, India, Italy, Malaysia, Morocco, the Netherlands, Philippines, Singapore, Sweden, Switzerland, UK and the US.

- **Building work at the Sedgefield (UK) Printable Electronics Technology Centre (PETEC) has now been completed, establishing a leader in innovation for the plastic electronics industry.**
This will be a development, prototyping and commercialisation facility for printed electronics. It spans 3,000 square metres, with high-tech cleanrooms, laboratory space, offices and seminar rooms.
With the aim of de-risking industrial research and development in printed electronics, PETEC aims to create a clear route between an innovative idea and a marketable product. The facility is designed to be an ideal platform for start-ups and larger manufacturing companies to get prototype and pilot-scale production up and running.

- New analysis from researchers at Frost & Sullivan finds that the solar cell market earned revenues of $260m in 2007 and estimates this to reach $1.2bn in 2014. Adverse climatic effects due to the emission of greenhouse gases have further catalysed the shift to alternate sources including solar energy, as being cleaner, more economical and easily replenished. Solar energy also remains the most feasible to develop on a remote property and flexible enough to meet changing requirements.
"There are clear cost advantages to installing solar panels compared to having transmission lines, particularly in areas that are not easily accessible," states a Frost & Sullivan analyst. "Moreover, solar cells are easier to manage and maintain than other sources such as wind or nuclear."

- June's WSTS results show that the semiconductor market is on the up, with Q2 sales rising 3% on Q1. On a year-on-year basis, total semiconductor sales were up 12%, with logic up 25%, followed by analogue components with 14.5% and microcontrollers 12%. Memories were down 5.8%. In the non-IC categories, opto was up 25%, followed by discrete components at 8%.
"These results are outstanding, way better than even we dared to expect less than two weeks ago when we raised eyebrows by suggesting a 2.3% quarterly growth," said Malcolm Penn, CEO of analyst house Future Horizons.

- Electronics Yorkshire has launched a guide for entrepreneurs to help with the difficult process of launching a new product or redeveloping a current one. The 'Guide to Developing a New Product', available from www.electronicsyorkshire.org.uk, is interactive, taking the user, step-by-step, through everything they need to know before a product is launched, from research through to testing procedures and reviews.
Areas covered by the guide include basic research, design brief, prototype assembly, testing procedures and design review, as well as ways of approaching product specifications and materials usage.

Europe's intelligent train ready to roll

Fast and furiously adaptable: the Eurosprinter is ready to flout "border restrictions"

Eurosprinter, one of the world's most sophisticated electronically driven locomotives, is finally ready to go into operation.

The machine has been designed specifically to be able to travel across Europe's many borders, something that existing locomotives can't do because of the varying voltage systems which different countries use for their rail networks.

Designed by Siemens Mobility, the "universal train" is slated to go into service before the end of this year. The capitals of Austria (Vienna), the Czech Republic (Prague) and Germany (Berlin) will form the first rail-line to witness the technology.

The Eurosprinter's core component is a basic locomotive equipped with special system packages that enable it to adapt to the specific rail and voltage networks in the areas it operates. This eliminates the need for time-consuming changes of locomotives at national borders.

Across Europe, five different voltage systems, numerous train control systems and even different track gauges coexist. This patchwork of standards forces trains to stop at borders to change locomotives, a procedure that is not only cumbersome for passengers and rail operators but also puts the rail freight industry at a competitive disadvantage compared to lorry haulage.

The Vienna-Prague-Berlin line where the Eurosprinter will make its debut, for example, currently requires three changes of locomotives, given that the Czech Republic alone has two different voltage systems. The new locomotive will reduce the route's total travel time by between 40 and 50 minutes.

In order to adapt to the operational conditions of each country, the only component of the Eurosprinter that remains constant is the basic locomotive, which consists of the locomotive body, bogies and motors. All other components, including the voltage feed and train control systems, can be selected by the train manufacturer on the basis of the countries that its customer (the train operator) plans to visit.

According to Siemens, this modular approach allows for lower development costs of the resulting locomotives. The German company has so far developed special country packages for Germany, Austria, Italy, Slovenia, Croatia, Hungary and the Czech Republic.

The Eurosprinter is also the world record holder for the fastest electronically-driven locomotive. In September 2006 it reached a speed of 357 kilometres per hour.

WIMAX AND LTE PREPARE TO DO 4G BATTLE

BY JUAN PABLO CONTI

Talk about the arrival of fourth-generation (4G) mobile wireless technology has been going on for more than a decade – way before even the first 3G cellular networks started to be rolled out. And, yet, the fact remains that the International Telecommunication Union (ITU) hasn't even officially defined 4G.

Many industry observers expect the ITU to adopt the International Mobile Telecommunications-Advanced (or IMT-Advanced) set of specifications as the basis of what will ultimately evolve as 4G – much in the same way as IMT-2000 provided the umbrella under which five different air interfaces were officially recognised as 3G-compliant.

IMT-Advanced requires, among other things, that air interfaces be based on OFDMA (Orthogonal Frequency-Division Multiple Access) digital modulation and that they support data throughputs of at least 100Mbit/s.

There are currently three different radios (each of them at different stages of development) that meet both of these requirements and are, therefore, seen as the early contenders in what could potentially be a fierce battle to become the 4G technology of choice by the world's telecom operators interested in offering next-generation mobile broadband services.

One of these technologies, known as Ultra Mobile Broadband (UMB), is actually widely believed to be already out of the race. Developed by Qualcomm as the successor to CDMA2000 (the 3G platform that was mostly deployed in the US and Korea), UMB has failed to be selected by a single operator. Even in the American and Korean markets where CDMA2000 is used today, cellular operators have indicated they won't go with it.

Instead, they are pledging their support to either LTE (Long Term Evolution) or Mobile WiMAX, the two other technologies that are getting ready to battle it out for the 4G crown.

Harmonisation of WiMAX II and LTE may end up happening at the device level

"LTE IS THE TECHNOLOGY THAT THE THIRD GENERATION PARTNERSHIP PROJECT (3GPP) IS DESIGNING AS THE SUCCESSOR TO UMTS"

Different Past, Same Ambition

Although they are both aiming for the same goal, LTE and WiMAX come from very different backgrounds: the former stems from the cellular world; the latter from the IT one.

LTE is the technology that the Third Generation Partnership Project (3GPP) is designing as the successor to UMTS (which, in turn, succeeded GSM in the transition that European and many other cellular operators made – some are still making – from 2G to 3G).

Ratification of LTE (also known as 3GPP Release 8) is scheduled for December 2008. When deployed, it will offer operators and subscribers peak download speeds of 326.4Mbit/s, with maximum upload speeds of 86.4Mbit/s for every 20MHz of spectrum. Several firm dates for equipment trials and deployments have already been announced by operators around the world, but the first commercial networks are not likely to emerge before 2010 or 2011.

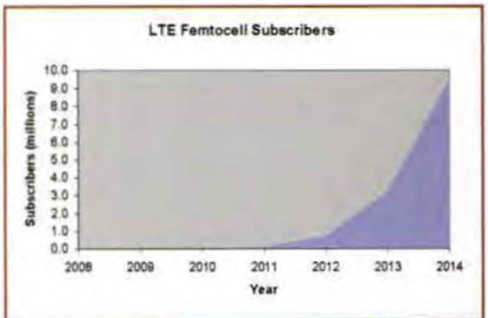
It is in this time-to-market department that Mobile WiMAX (or IEEE 802.16e) claims to have an edge over LTE. The specification was approved at the end of 2005. Earlier this year, the WiMAX Forum announced the first batch of certified products to operate in the 2.3GHz frequency band. By the end of this year, over 100 base stations, mobile phones, laptops and other access devices will have been certified as compliant with the Mobile WiMAX standard according to Ron Resnick, president and chairman of the WiMAX Forum.

In terms of concrete deployments,

Sprint Nextel (the third-largest cellular operator in the US) has recently joined forces with Clearwire, Intel, Google, Comcast and Time Warner in an ambitious plan that will see them spend $15bn to build a nationwide Mobile WiMAX network. Of the top 100 US markets that the network will reach, there will be two or three that will start enjoying the new mobile broadband Internet access before 2008 runs out.

How Fast Can You Go?

Look a bit closely, though, and this time-to-market advantage that the WiMAX camp supposedly has is not as clear-cut. IEEE 802.16e networks (such as the one Sprint Nextel is building) offer an ideal data throughput of 40Mbit/s on the downlink and 5Mbit/s on the uplink. More realistically, the WiMAX Forum expects these networks to provide up to 15Mbit/s within a typical cell radius of up to 3km. Even more realistically – given bandwidth will be subject to contention ratios and interference – users will be lucky to get anything beyond 5Mbit/s.



Projected LTE femtocell subscribers from 2008 to 2014 (Research and Markets, April 2008)

Nokia Siemens Networks' Flexi base stations will be able to support LTE via a software upgrade

That's a far cry from the 100Mbit/s entry barrier that the radio interface would need to be considered a proper 4G technology. In fact, the cellular guys argue that, in HSPA+ (or 3GPP Release 7, which supports up to 42Mbit/s down and 11.5Mbit/s up) they already have a stronger 3.5G interface than Mobile WiMAX.

"True," argues back the WiMAX camp; "but we've got WiMAX II coming." Promising a staggering 1Gbit/s data throughput, 802.16m will dispel any lingering worries about 4G-compliance. This next iteration of WiMAX is expected to enter the draft stage in 2009.

LTE is not standing still, though. By the time operators including Vodafone, NTT DoCoMo, AT&T and Verizon begin to test and roll out their first LTE networks with equipment supplied by Ericsson, Nokia Siemens Networks, Motorola, Nortel, NEC and other vendors, 3GPP will already be busy working on LTE-Advanced, which will also boast 1Gbit/s speeds.

Some industry analysts predict that, when the day finally arrives that both WiMAX II and LTE (or LTE-Advanced) are a commercial reality, with users happily sending and receiving high-definition video along these wireless superhighways, the now competing air interfaces may have merged into a single standard.

One of the arguments they put forward to back this forecast is the many technical features that both interfaces already share, such as the use of OFDMA schemes and MIMO (multiple-input, multiple-output) antenna configurations.

Others believe it may be a little too late now for universal 4G radio harmonisation to happen. Which means it will be up to the electronics engineers – once again – to come up with the single chips and multiple chips handling the rival radios to marry them at the device level. ■

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

LIGHTING – ENVIRONMENTAL AND LEGISLATIVE ISSUES (PART 2)

Following on from last month, in the second part of our look at lighting and legislation, we will consider how specific pieces of legislation such as RoHS, WEEE and EuP impact the lighting sector.

The lighting industry has made significant advances over the last decade with huge improvements in efficiency being achieved as a result of the development and implementation of new technology. Over the same time period, legislation has been introduced that forces manufacturers and users to utilise the most energy efficient technologies.

Incandescent Lamp Restrictions

There are a growing number of countries that have decided to ban incandescent lamps to help meet carbon emission reduction targets. There are plans for an EU-wide ban based on the EuP Directive, but some EU States including Italy and Ireland have announced that they will introduce bans earlier.

In the US, California is planning a ban from 2012 and several other States are introducing legislation. Australia is planning a ban from 2009 and New Zealand, Brazil, Argentina and the Philippines have all announced that they will introduce legislation.

Substance Restrictions – RoHS Directive

In the EU, lighting equipment including lamps, ballasts and luminaires are covered by the RoHS Directive. This restricts the use of six hazardous substances except where specific exemptions apply. There are many exemptions that relate to lamps with items 1-4 of the RoHS Annex permitting mercury in various types of lamp, although with upper limits on the amounts in some types.

RoHS is currently being reviewed and it is likely that these upper limits will be reviewed and could be reduced. Lead is currently allowed in the glass of straight fluorescent tubes but is no longer used; although it does occur in recycled lamp glass. There are also several specific exemptions for lead in various types of lamps.

Recycling Requirements – WEEE Directive

In the EU, lighting equipment is covered by the WEEE directive and so should be collected and recycled at end-of-life. Several countries outside of Europe have legislation requiring the recycling of certain types of waste electrical equipment, but few include lighting. Some US States however, such as Maine and Minnesota, have implemented restrictions on the disposal of lamps containing mercury.

Design of Lighting Equipment – EuP Directive

The most important legislation placing requirements on design is the EU Ecodesign of Energy using Products (EuP) Directive. This is now in force but implementing measures have not yet been introduced.

Measures will be introduced after studies on specific products have been carried out and various options considered. There have been three studies on lighting so far:

- Lot study No. 8 Office lighting (study complete and measures proposed);
- Lot study No. 9 Public street lighting (proposals include lamps, ballasts and luminaires);
- Lot study No. 19 Domestic lighting products (study complete and measures proposed).

The results of these studies and implications for equipment designers are as follows:

No. 8 Office Lighting

Lamps without integral ballasts will have mandatory limits for light output efficiency and variation over time (limiting acceptable degradation of brightness). Currently there are 7 efficiency bands from A to G with lamps marked accordingly. It is proposed that band A will be split into new grades and lamps that are currently in the most inefficient bands would not be permitted.

Ballasts are already regulated by Directive 2000/55/EC, which defines their energy efficiency. This will be repealed and replaced by a new measure that provides more stringent efficiency. Power consumption when the lamps are 'off' will be initially limited to 1 watt dropping to 0.5 watts after three years.

Luminaires – the minimum light output efficiency will be regulated and there will be several other requirements, although some applications will be exempt (medical IP65, vandal proof, adjustable, portable, emergency and hazardous area lighting). Documentation will be required to give details of lighting efficiency (up and down), ballast efficiency and instructions on cleaning, maintenance and installation.

Mercury content in some fluorescent lamps on the market is substantially below the maximum levels permitted by RoHS exemptions 1 and 2 and the EC's consultants have recommended that the limit is reduced to 2mg for lamps without integral ballasts.

Waste arising may be regulated although how is not yet clear. All items will, however, be required to be manufactured in a way that minimises waste and emissions.

THERE ARE A GROWING NUMBER OF COUNTRIES THAT HAVE DECIDED TO BAN INCANDESCENT LAMPS TO HELP MEET CARBON EMISSION REDUCTION TARGETS

No. 9 Public Street Lighting

This study included lamps, ballasts and luminaries.
The energy efficiency of street lighting has improved significantly during the last decades, but energy reductions are limited because street lighting lasts for at least 30 years after installation, therefore technology benefits are not easily realised.

Proposals for legislation will include minimum energy requirements for lamps which will permit the use of only the most efficient HID lamps – mercury lamps, metal halide and sodium lamps. Efficient luminaries and ballasts will also be required and there may also be requirements relating to maintenance.

This is more complex than the other two lots as automated control is also used for switching street lighting on and off.

No. 19 Domestic Lighting

The results of this study have identified three options of which option 2 is the most likely to be adopted.

Only lamps in the current class 'A' will be acceptable. This means that 'A' could be split into four: A, A+, A++ and A+++. These would include linear fluorescent lamps and the more efficient CFLs only. Lower efficiency lamps could not be used and so this effectively bans incandescent lamps.

Straight fluorescent lamps, most CFLs and some halogen lamps would remain on the market. The rest would be effectively banned. The main disadvantage of option 1 is that all bright point source lamps would be banned whereas the most efficient bright point source lamps are permitted by option 2.

Only incandescent lamps and the lowest efficiency halogen lamps would be banned.

Option 3 is estimated to be 1.9 times more energy efficient than the current range of lamps on the EU market, whereas option 1 would be an estimated 4.6 times more efficient. The compromise option 2 is 3.5 times more efficient.

Fixed Installations

Lighting is often installed in fixed installations in buildings and there are reasons why these would be treated differently to portable lighting equipment. The EU-WEEE and RoHS directives do not mention whether fixed installations are in scope or not, but guidance from the European Commission implies that they might be outside the remit of these directives. Variations in interpretation by EU Member States have created a situation in status that is not acceptable for the 'single market' RoHS directive which should have the same scope in all EU Member States. For this reason, the issue is being reviewed by the European Commission.

The most likely outcome is that fixed installations will be regarded as being in scope as this is the preference of the majority of Member States.

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

BIG GROWTH IN MEDICAL MICRO-MINIATURE

MEDICAL INSTRUMENTATION AND THE ADOPTION OF MICRO-MINIATURE ELECTRONIC DESIGN IS THE MOST EXCITING OPPORTUNITY IN THE ELECTRONICS INDUSTRY, ACCORDING TO **GARRY MYATT**, DIRECTOR OF SALES AND MARKETING AT EXCEPTION, THE UK'S ELECTRONICS OUTSOURCING SPECIALIST

There are huge changes taking place in hospitals and surgeries; as the ways of medical diagnoses are made changes so does the impact on the European electronics industry too.

Similar to the shift in technology that saw mainframes and dumb terminals being replaced by powerful, personal computers, doctors and nurses are swapping industrial scale scanners for nimble handheld units and even monitors that can be swallowed by patients. This seismic change in the way the medical profession assesses, diagnoses and treats patients is presenting [electronics] manufacturers and their suppliers with their own headaches, created by the need to balance performance and processing power with miniaturisation. Such a technological feat would be difficult enough, but when you then consider the serious health and safety issues concerning the use of devices that are placed on the skin or even ingested, you get some idea of the added complexities.

Clearly, when designing and manufacturing such specialised equipment – first at low volume during the test stage and then moving onto mass production – adopting the most effective cost model is a major challenge facing OEMs such as GE, Fujitsu, Siemens and Philips to name a few.

While these global brands have the know-how and expertise in more traditional types of medical equipment manufacture, this new breed of miniature medical tools is pushing many organisations to the far reaches of their abilities.

While most industry sectors see the meeting of standards as a key quality deliverable, the IPC3 standard, which was originally developed for the military/automotive sector is also being adopted by the energy and medical industries. Put simply, the IPC rate electrical components in three categories, with the highest standard, IPC.A. 600G, which is relevant to PCBs, setting out stringent quality levels for a component's reliability and safety in a range of conditions.

There are two IPC standards concerning the design of printed circuit boards; IPC 6012 for rigid PCBs and IPC 6013 for flexible PCBs. Turning to flex-rigids, which are fast gaining popularity in the field of medical diagnosis, there is a myriad of different and very specific standards, associated with the exact use of the PCB. As an example, one standard related specifically to how often a product is opened and closed (often needing to be tested to withstand thousands of movements), where in the body it will be used and to which temperatures it will be subjected. This is why the development of both rigid and flex-rigid PCBs in the medical arena is so potentially complex and challenging.

While most traditional PCB designs have had to adhere to one of four IPC standards – covering installation, flexibility (number of cycles), temperature and the US-based UL standard – the latest generation of flex-rigid PCBs often need to adhere to several standards at the same time.

Flex printed circuits (FPCs) come in flex, multi-flex and flex-rigid variations in the FPC world in static or dynamic use, in low or high T° environment (which is still rare in the medical world) and with or without UL (which is seen more often in the sector).

This new challenge presents OEMs, designers, fabricators and suppliers with a new set of rules that are still not being followed by many manufacturers. As if the burgeoning demands of the industry to develop smaller, more powerful diagnosis tools that are reliable and safe were not enough, the electronics industry also needs to address the issue of lead-free.

One of the real issues facing designers is the long term reliability of new boards that use lead-free soldering. As this needs to be manufactured at a temperature of approximately 30°C higher than previously required, long-term tests on the new generation of boards has simply not been possible, so designers need to build in additional margins for safety.

Similarly, where flex-rigids are concerned, designers traditionally needed to specify heavier copper weights to ensure that reliability is ensured, even after thousands of hours of use. Today, the use of thinner and higher-speed rated materials, microvias and HDI components is also becoming much more common, setting new challenges for the industry.

Certainly, when it comes to new product introduction, quality in terms of both manufacturing capability and design are the two key factors. Design is far more complex than simply using a bespoke CAD system to develop boards and peripherals that will meet the demands stipulated by the initial test brief. Truly effective NPI programmes look at design for manufacturing, test, assembly and volume as a continuum that ensures profit targets are met at every stage of the product life cycle. ■

This seismic change in the way the medical profession assesses, diagnoses and treats patients is presenting [electronics] manufacturers and their suppliers with their own headaches

NARROWBAND VS WIDEBAND – THE BEST RADIO MODULE FOR YOU

by Myk Dormer

Any user with reasonable familiarity of the low power radio marketplace, or with the dominant specifications that regulate it, will be aware that radio modules seem to fall into one of two definite "camps".

On one hand there are low cost, short-ranged modules with very high data rates. These have been in the spotlight recently as the suppliers and promoters of the various defined-network architectures (Zigbee, Bluetooth) buy increasing amounts of advertising column space. With the advent of these architectures, the associated radio modules are also providing much more sophisticated, software-heavy interfaces.

On the other side, there is a class of apparently more "old fashioned" narrowband radios. While these units claim longer operating range, they also have lower data rates (usually less than 10kbit/s, occasionally only an audio baseband connection) and higher comparative costs.

Before we follow the advertising hype and assume that higher data rate is always better, we should examine what the actual difference between a "narrowband" and a "wideband" radio is.

Unusually for an industry buzzword, the definition is based in basic communication theory:

The modulation index of an FM carrier
$b = Dw/wm$ (Dw = max deviation)
(wm = max mod freq)

Narrowband FM is defined as the condition where b is small enough to make all the terms (sidebands) after the first two in the series expansion of the FM equation negligible.

Narrowband Approximation:
$b = Dw/wm < 0.2$ (but can be as high as 0.5, though), so the occupied bandwidth BW is approximately 2wm.

Wideband FM is defined as when a significant number of sidebands have significant amplitudes (occurring when $b > 1$). In this case the occupied bandwidth BW approximates to 2Dw.

To relate this to practical telemetry data radio practice, we see narrowband radios with channel spacing of 25kHz or less, and maximum data rates around 10kbit/s ($b \sim 0.5$). Wideband radios typically operate with channel spacing of over 200kHz and data rates exceeding 64kbit/s ($b > 5$, although most of the higher frequency 2.4GHz band units have proportionately wider channels – several MHz occupied bandwidth – with corresponding megabit-per-second data rates).

The less obvious trade-off here is in sensitivity and hence range for a given transmitter power, as each doubling of signal bandwidth degrades S/N by 3dB. Thus, while a narrowband 25kHz unit will show a typical sensitivity of -118dBm at 2.5kbit/s, a comparable wideband unit will achieve only -107dBm at 40kbit/s and will require a 300kHz wide channel. For the same transmitter power, this will result in about half the range compared to the 25kHz radio.

In terms of actual circuit design, the choice of wide or narrow channel has some important implications. Unfortunately, some of these are also issues that drive narrowband radio prices up.

1. Required frequency accuracy is proportional to the width of the occupied channel. A 25kHz channel needs a centre frequency accuracy of around 1.5-2kHz. In the 433MHz UHF band this corresponds to approximately 3ppm reference stability.

A wideband radio in the same band with 300kHz channel width can tolerate over 50ppm of drift before the wanted carrier is outside the receive filter's optimum passband.

So the wideband unit can use an inexpensive crystal, or even a good SAW resonator, while the narrowband unit needs a TCXO, or hard-to-source high stability crystal.

2. Receive filters require narrower bandwidth and far better shape factors.

The narrowband radio requires crystal and/or high performance ceramic filters. The wideband receiver can use low cost "broadcast" 10.7MHz elements, or can even use low or zero IF techniques and integrate the receive filters onto a chip.

There have been attempts to combine narrowband operation with on-chip filtering in some recent products, but the

IN TERMS OF ACTUAL CIRCUIT DESIGN, THE CHOICE OF WIDE OR NARROW CHANNEL HAS SOME IMPORTANT IMPLICATIONS. UNFORTUNATELY, SOME OF THESE ARE ALSO ISSUES THAT DRIVE NARROWBAND RADIO PRICES UP

actual RF performance is so far woefully inadequate compared with "traditional" crystal filters, resulting in adjacent channel rejection figures below 30dB, where 60-70dB are needed.

3. Local oscillator noise (purity) is far more critical in the narrowband design, simply because the adjacent channel is closer to the wanted frequency, so low noise oscillator design techniques are required. The resulting circuitry is more complex, requires more careful screening and uses more costly, large, high-Q parts.

4. Transmitter switching is slower (10-50mS typically) and transmitter circuitry is more complicated in narrowband radios compared to wideband, since the acceptable frequency aberration (or 'pull' when turning on or off) is also proportional to channel width, and phase stability (recirculation) is more critical with the lower modulation index.

On the other hand, some factors decidedly favour the narrowband module:

5. Regulatory authorities often permit higher transmit power on narrowband only frequency allocations (in the UK for instance, 10mW is the maximum power in the 'all modes' 433MHz band, but 500mW is allowed on the 458MHz narrowband only allocation).

6. Obviously, the smaller channel widths allow more channels per allocated MHz, permitting practical use to be made of very simple frequency division multiple access band plans and making it easier to avoid fixed interferers (by changing channels).

7. Most, if not all, VHF allocations are narrowband only, including most of the new 169MHz band and all of the older UK allocation at 173MHz.

The upshot of this comparison is clear:

If data rate and cost are crucial, and multiple users are accommodated by limited duty cycle or time division duplexing, then choose a wideband module. But if range, resistance to interferers, better power efficiency, or multiple channel operation are required, then a narrowband radio module is still the best choice.

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

ELECTRONICA IS THE LARGEST ELECTRONICS INDUSTRY EVENT, TAKING PLACE EVERY TWO YEARS IN MUNICH, GERMANY.
THIS YEAR IT RUNS FROM 11TH TO 14TH OF NOVEMBER, AT MESSE MUNCHEN

Turner, Constable and a Lascar Data Logger

As well as exhibiting works by great British artists such as J.M.W. Turner and John Constable, the Bury Art Gallery, Museum and Archive also contains a number of Lascar's EL-USB-2 temperature and humidity data loggers.

Alison Green, Museum Assistant said: "It's very important we monitor the environment in which the collections are housed. Exposure to extremes of heat, cold, aridity or humidity can cause textiles, canvas, wood and other materials to quickly deteriorate."

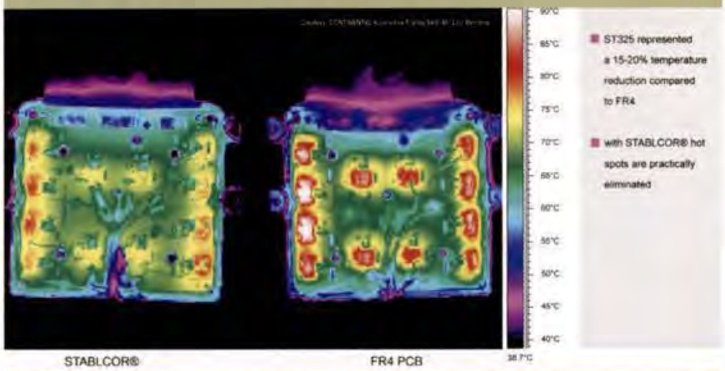
A search on the Internet turned up a product by Lascar Electronics – a data logger – designed to measure and record both temperature and humidity over a specified period of time. "This is a great product", says Alison. "I can simply plug it into my computer's USB port, give it a name, set some alarms and choose a sampling rate. When it's programmed, it's small enough that I can pop it back into a case without it taking over the display and away it goes measuring temperature and humidity levels. When the logger is full of data or I see an alarm level has been reached because its red alarm light is flashing, I take it back to the computer and download all the recordings to see what environment our exhibits have been exposed to. It's not just in the best interest of the exhibits; we're a publicly funded organisation and we have to actually prove we're looking after everything in the museum."

The EL-USB-2 is available immediately directly from Lascar Electronics at a price of £49.95 GBP at 1-off. Discounts for quantity are available upon request.

www.lascarelectronics.com

Electronica Location A3.118

Design Flex-Rigid PCBs With Confidence



Flex-rigid multilayer PCB structures offer a unique solution for numerous electronic interconnection and packaging requirements. Much has been written about their potential, with applications from military electronics to consumer digital cameras.

However, the adoption of flex-rigid technology still has a tendency for concern and consternation. Stevenage Circuits has had many years experience with all forms of PCB interconnect and flex-rigid designs are a particular speciality. A highly experienced engineering team can advise from the earliest stages of design and demonstrate a vast array of previously successful applications. Flex-rigid design often require a combination of all that may be incorporated into rigid multilayer PCBs and flexible circuits, including sequential HDI structures with blind and buried microvias, with controlled impedance and thermal management solutions.

At Electronica 2008, Stevenage Circuits will have on display a wide range of flex-rigid PCBs and experienced technical staff will be on hand to discuss how to adopt the technology with a high degree of confidence.

www.stevenagecircuits.co.uk

Electronica Location B1.645

New Vandal-Proof Keypad For Secure Switching

Lorlin Electronics, one of the UK's longest established switch manufacturers, announces the introduction of the KP range of vandal-proof metal keypads. Responding to increasing demand for secure and rugged security switching these attractive metal keypads may be used in public and industrial environments for access control, vending machines and kiosks, environmental control and service access.

Keypads may be specified with 1, 2, 3, 4, 12, or 16, buttons and are for front or rear mounting on to a flat surface. The keys are available back-lit by LEDs with a choice of blue, red, green, white and yellow colour, have a large clear type style on the button faces and there is a choice of casing and button colours.

Low profile mounting bezels are available that can be fixed from the rear of the control panel ensuring mounting-screws cannot be accessed by vandals.

The Lorlin KP keypads are manufactured from strong, powder-coated, die-cast zinc, with an anti-pull key design. IP rated for weather water and dust resistance. The switch contacts are rated at 24VDC @ 20mA and are reliability tested to 4,000,000 cycles per key. Electrical connection is to 2.5mm pitch PCB terminals and a suitable cable connector and the keypad is RoHS and CE compliant. Operating temperature range of the keypad is –40°C to +80°C and it is impact resistant to 20 joules via a 50mm Ø steel impactor.

www.lorlin.co.uk

Electronica Location B4.643

Grand About Cyclops

The Cyclops Group will be showcasing its services to the electronic component industry at the Electronica 2006 Trade Show from 11th – 14th November at the New Munich Trade Fair Centre in Hall A5, Stand 175/A.

With four specialist Electronic Component Divisions, 20 key services, nine global offices and 106,536 line items in stock, Cyclops Group offers a complete purchasing solution for all your component requirements.

The groups four divisions are: Cyclops Electronics, Trading Specialists, Global Supply Services and Apache Electronics.

Cyclops Electronics is one of the UK's largest independent distributors, dedicated to procuring shortage, obsolete, emergency and day-to-day, active, passive and electro-mechanical components.

Trading Specialists is the excess stock division, which has expanded rapidly, purchasing over 310 million parts.

Global Supply Services are an innovative provider of global procurement, logistics and supply chain management, supplying inventory directly to your manufacturing process. With their multi-lingual procurement teams they are able to break down the language barriers and develop a direct relationship with suppliers.

Apache Electronics specialises in asset recovery, recycling, test, refurbishment and terminal finish conversion services, focused on printed circuit boards and electronic components. Apache can reclaim and professionally prepare valuable components for re-use at a fraction of the cost of buying the components new.

www.cyclops-group.com

Electronica Location A5.175

Prism Brings Audio Testing To Meridian's F80

In 2005, Meridian Audio began a unique collaboration with car manufacturer Ferrari to develop a range of products that reflected the unique qualities of both companies. Ferrari's reputation for producing high-performance and desirable GT cars, as well as running a record-breaking Formula One racing team, is well established.

The result of this partnership is the Meridian F80, a transportable home entertainment system that is small and stylish, yet incredibly powerful and versatile.

Meridian Audio also used Prism Media Ltd's dScope Series III for the F80, because it offered the ability to customise scripting for the production line."I thought the dScope was an ideal solution," said Paul Holmes, Meridian's Test Manager. "It was already being used by our R&D engineers, who have three in their department, so I knew what it was capable of. The importance of the F80 gave us the impetus we needed to make the change."

Prism Sound's dScope Series III is a comprehensive and powerful measurement system for analogue and digital audio generation and analysis, including digital audio carrier analysis.

www.prismsound.com

Electronica Location A1.446

The UK group presentation at Electronica is managed by Tradefair on behalf of Intellect, the UK trade association for the IT, telecoms and electronics industries; and supported by UK Trade & Investment, the government body responsible for promoting exports from and inward investment into the UK.

Tradefair assists more than 700 firms every year at over 40 trade shows across the world. The company believes it offers "more than just exhibition space and logistics – helping clients not only plan their globalisation but also integrate real-world and virtual strategies and get the best out of limited budgets".

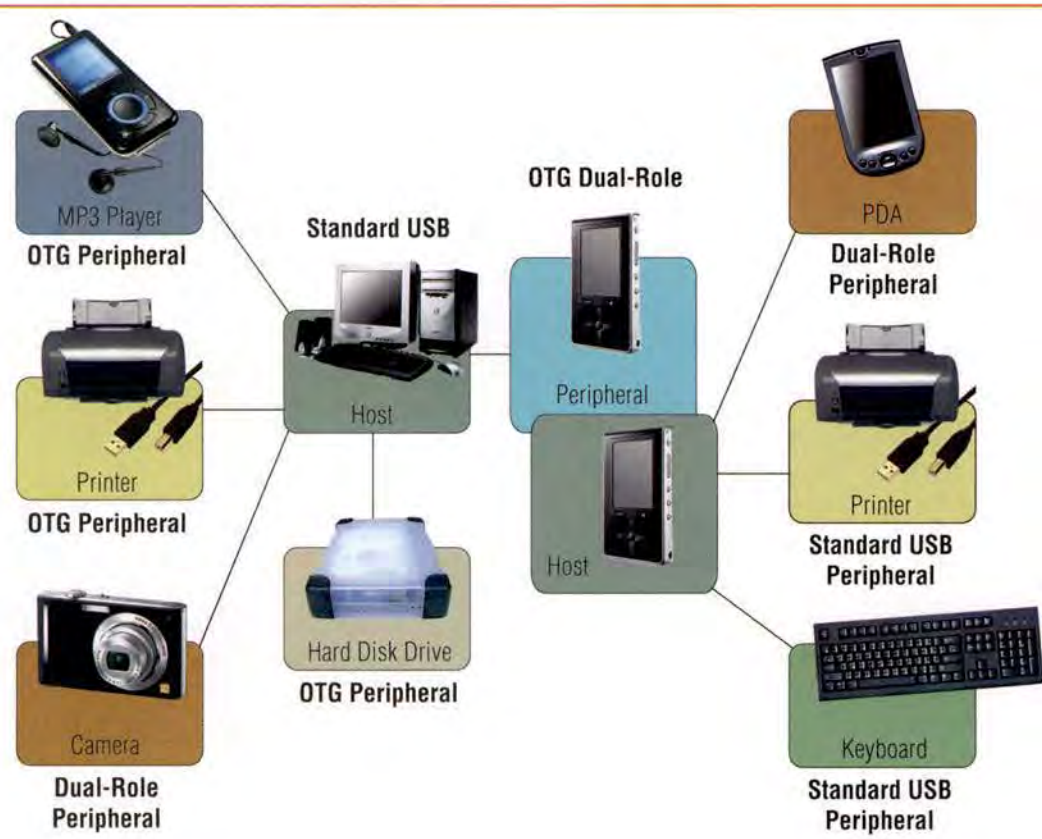
USB ON-THE-GO FUNCTIONALITY, SIMPLY AND EFFICIENTLY

STEVE KNOTH, PRODUCT MARKETING ENGINEER AT LINEAR TECHNOLOGY CORPORATION DISCUSSES THE IMPORTANCE OF THE UNIVERSAL SERIAL BUS ON-THE-GO (USB OTG) TECHNOLOGY FOR MOBILE-CENTRIC APPLICATIONS

Our portable world is ever-changing. With the advent of Universal Serial Bus On-the-Go (USB OTG) technology, the PC, once a centre hub, has now become merely an accessory in our connected life.

USB OTG allows a peripheral to act as both a host to provide power – enabling a direct point-to-point connection between itself and peripherals – and to allow itself to be powered by a USB power source. The USB OTG feature allows, for example, a user to conveniently connect a camera or smart phone directly to a printer, thereby providing pictures without the need of a PC as an intermediary device. However, integrating USB OTG technology into power management ICs has its own set of design difficulties.

At the same time, designers of today's battery-powered portable electronic products have their share of design challenges. Among these are the demands for high performance power management systems to accommodate growing system complexity, higher power budgets and thermal constraints. These systems strive for an optimum balance between long battery



Dual Role Nature of USB OTG Devices

runtime, compatibility with multiple power sources, high power density, small size and effective thermal management.

Battery-Powered

Lithium-Ion and Lithium Polymer batteries are preferred in portable consumer products because of their relatively high energy density – they provide more capacity than other available chemistries within given size and weight constraints. As portable products become more complex, they consume more power, so the need for higher capacity batteries increases, with a corresponding need for more advanced battery chargers. Larger batteries require either higher charging current or additional time to charge to their full capacity.

Further, USB-capable battery charging in many cases means more convenience to the user; however USB compatibility poses the constraints of USB current (500mA max) and power (2.5W max) limits. A USB-based battery charger must extract as much power from the USB port as efficiently as possible, to meet the stringent thermal constraints of today's power-intensive applications.

A new power management integrated circuit (PMIC) is available to efficiently power these systems and also provide USB OTG functionality in a much smaller footprint and with much higher performance than other "traditional" PMICs.

Efficiently Providing an USB OTG Rail

Typically, OTG solutions – especially for 100mA USB supplies – have used switched-capacitor voltage converters, or charge pumps. Charge pumps are simple, small, low in cost and have inherent output disconnect so nothing blows up if the VBUS gets shorted to ground.

More and more, however, users want the ability to supply the full 500mA on the VBUS, so an inductor-based switching regulator is more desirable than a charge pump from an efficiency point of view (in OTG mode, power usually comes from the battery), thus saving battery run time. The difficulty with a switching regulator in these OTG boost applications is that it needs to have output disconnect and would ideally also have short-circuit fault capability and accurate output current limit.

Reducing Heat

Many industry-standard PMICs come with a variety of linear regulators on board. However, linear regulators, if not managed properly with sufficient copper trace routing, heat sinks, or well-designed input/output voltage and output current levels, can generate localised thermal "hot spots" on the PC board itself.

Alternatively, a switching regulator provides a more efficient way to step down voltages when the difference between input and output voltage is high and/or if the output current is large. Their usage is commonplace in today's feature-rich devices with low-voltage microprocessors on board. As a result, implementing switch mode-based power supplies for the majority of voltage rails is increasingly necessary.

Additionally, linear battery chargers can be another source of heat, depending on the input voltage to battery voltage differential and charging current. In principle, linear chargers act like a linear regulator in terms of power dissipation, therefore LDOs combined with linear chargers on the same chip can present a real thermal problem.

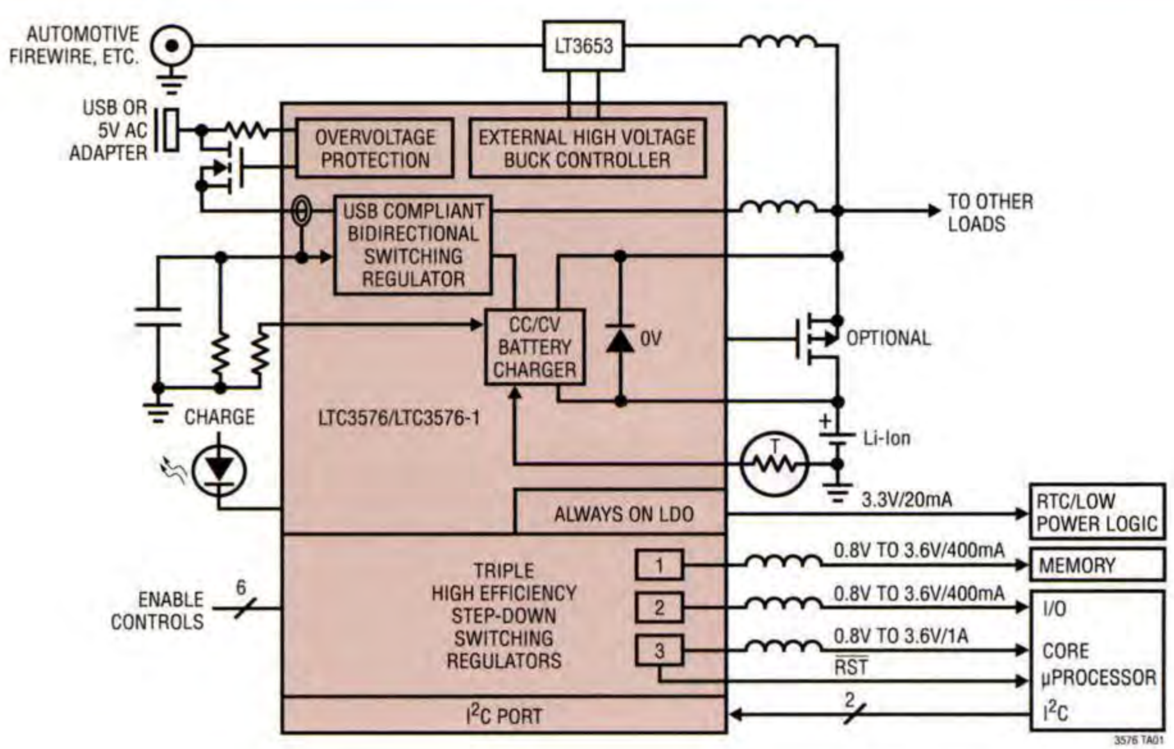


Figure 1: LTC3576 simplified block diagram

Multiple Input Power Source Management

Managing power flow, while minimising heat generation in a portable handheld product, presents a significant design challenge. Virtually all portable battery-powered products can be powered from low voltage sources such as a 5V wall adapter, a USB port or Li-Ion/Polymer battery. Also, high-voltage sources such as automotive adapters and Firewire ports are growing in popularity. Autonomous management of the power flow between these multiple input sources and the battery while efficiently providing power to the load presents a significant technical obstacle.

Traditionally, designers have performed this function using discrete components like MOSFETs and op-amps, but have faced difficult problems with hot plugging, excessive heat generation, large inrush currents and large voltage transients to the load, which can cause system reliability problems.

Efficiently Extracting Power from the USB

USB technology has increased the convenience of electronic devices. Now it is possible to charge a device from this same USB port that performs the data transfer, eliminating the need for a separate wall adapter. However, there are power limitations (2.5W maximum) when the USB is used for charging the device's battery.

USB-capable battery charging in many cases means more convenience to the user, but it poses the constraint of USB current limits (500mA maximum). Thus, a battery charger must efficiently extract power from the USB port without exceeding the thermal limitations of the end product.

In summary, the key challenges for the system designer include:

- Efficiently boosting the battery voltage to provide a 5V/500mA USB OTG supply;
- Minimising any power dissipated as heat;
- Managing the power flow between multiple input sources, to the battery and the load;
- Maximising the current delivered from the USB port (2.5W available);
- Minimising the solution footprint and profile.

A Simple Solution

Best-in-class integrated functional blocks, such as a USB OTG boost converter and efficient programmable switching regulators, and among them Linear Technology's PMICs with PowerPath control, solve these design challenges outlined here simply and easily. In fact, in many systems one PMIC is sufficient to power the entire system. In Linear's case this is possible because of its different approach to the PMIC development, utilising a more selective integration level that offers a compact solution without any performance compromises.

PowerPath Control

A key feature of LTC's PMICs is the PowerPath control. This automatic load prioritisation offers the ability to autonomously and seamlessly manage power flow between multiple input sources such as USB ports, wall adapters and the battery, all while preferentially providing power to the system load.

In a traditional battery-fed charging system, the user must wait until there is sufficient battery charge and voltage level available to obtain system power. Conversely, PowerPath control allows the end product to operate immediately when plugged in, regardless of the battery's state of charge, commonly referred to as "instant-on" operation. These PowerPath control circuits can be found in both linear and switching topologies. Benefits of the linear PowerPath topology include an adaptive output control capability with an external high-voltage buck regulator and improved thermal performance with power flowing to the system load.

Switchmode PowerPath technology eliminates the power lost in the linear battery charger element, especially critical when the battery voltage is low and/or input power is limited (i.e. USB), giving it excellent thermal properties. Another advantage is its ability to extract up to 700mA battery charge current from a standard USB port (~ 2.3W) when battery voltages are low (< 2.9V).

PMIC with USB OTG Support

Linear Technology's LTC3576 features a bidirectional switching power manager with input overvoltage protection and USB OTG functionality, a stand-alone battery charger, three high efficiency synchronous buck regulators, an ideal diode, I^2C control, plus an always-on LDO (see **Figure 1**).

The LTC3576's USB-compatible bidirectional switching regulator features programmable input current limits of 100mA and 500mA, as well as a 1A wall adapter input current limit.

The IC can also take power from the battery to generate the 500mA at 5V needed for USB OTG applications without any additional components, allowing the device to act as a host. For fast charging, the LTC3576 converts nearly all of the 2.5W available from the USB port to charging current, enabling up to 700mA from a 500mA limited USB supply. Charging current can be as high as 1.5A from a wall adapter or from a second external source.

The IC provides an overvoltage protection (OVP) control circuit that prevents damage to its input from the accidental application of voltages as high as 68V. This OVP circuit can even protect the USB port when the IC is providing power for USB OTG. The LTC3576 also provides Bat-Track control of a companion Linear Technology high voltage switching regulator for efficient charging from a high voltage input source while minimising heat dissipation and providing a seamless transition between the USB and the higher voltage power source.

Conclusion

We are gradually moving away from a PC-centric world. USB OTG is tailored for mobile applications and simplifies data exchange by allowing direct point-to-point communication and connectivity of two devices when a PC is not present. This allows portable devices and USB peripherals to act both as hosts and to provide power.

Instead of using discrete power IC components or traditional large PMICs, a system designer can use a new generation of compact PMICs that integrate key power management functions for a new level of performance with smaller and simpler solutions.

Linear's family of compact battery-fed, linear or switching PowerPath PMICs makes the product designer's job much easier. These ICs feature USB OTG boost technology, the ability to extract more power from a USB port, seamlessly manage power flow between input sources, improved thermal performance, increased charging efficiency via Bat-Track adaptive output control, provide low/intermediate/high voltage rails across the entire Lithium battery input range and simplify designs by utilising fewer and smaller external components.

Finally, these ICs enable benefits for a battery-powered portable device as well, including USB OTG convenience and charging, instantaneous system power with a dead battery, higher reliability, longer battery run times and faster charge times.

VITAL SIGN MONITORING IN **WIRELESS BODY SENSOR NETWORKS**

A. WONG, D. MCDONAGH, G. KATHIRESAN, O. OMENI, O. EL-JAMALY, T. CHAN, P. PADDAN AND **A. BURDETT** OF TOUMAZ TECHNOLOGY IN THE UK PRESENT A HIGHLY-INTEGRATED, 1V MICROPOWER SYSTEM-ON-A-CHIP FOR VITAL SIGN CAPTURE IN WIRELESS FORMAT AS THE FIRST DISPOSABLE PLATFORM SOLUTION FOR THE "LAST METRE" BODY AREA NETWORKS

Wireless body sensor networks (WBSN) consist of sensor nodes used to monitor vital signs such as temperature, heart rate and electrocardiogram (ECG/EKG). These sensor nodes gather, store and locally process vital signs data, before transmission to a central base-station node. Although prototype modules for such WBSN applications are becoming available, these devices tend to be multi-chip solutions manufactured from off-the-shelf components and suffer excessive power consumption and relatively large form-factors.

Improvements to the patient's quality of care can be achieved through miniaturisation and power consumption reduction, which dictates the development of a custom system-on-chip (SoC). Although ultra low power wireless transceiver ASICs have previously been reported, in this paper we describe the integration of a system solution with a full custom hardware MAC, digital microprocessor core and I/O peripherals, on-chip memory, micropower ADC, wireless transceiver and custom sensor interfaces. This SoC platform device is capable of achieving ubiquitous medical monitoring when interfaced to appropriate body worn sensors and represents state-of-the art in terms of functionality and ultra low power consumption.

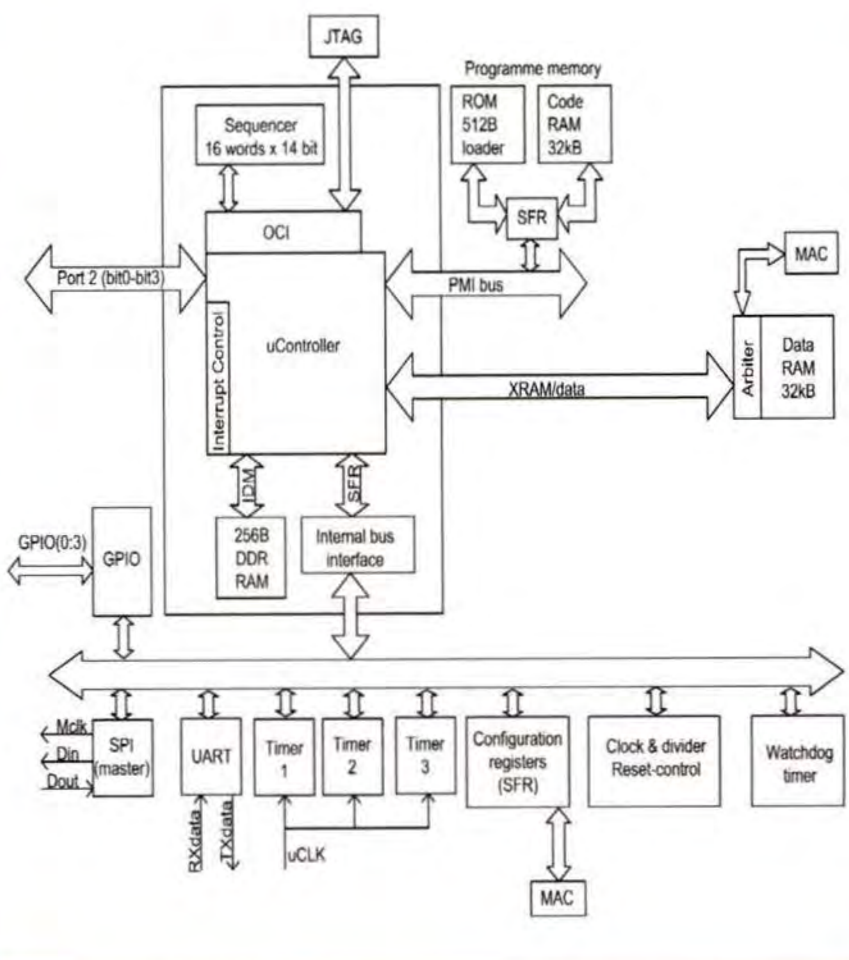


Figure 1: *Block diagram of the digital section showing the microprocessor core, peripherals, memory and I/O structures*

Novel Low-Power Design

The encapsulated wireless sensor node is in the form of a thin and flexible patch,

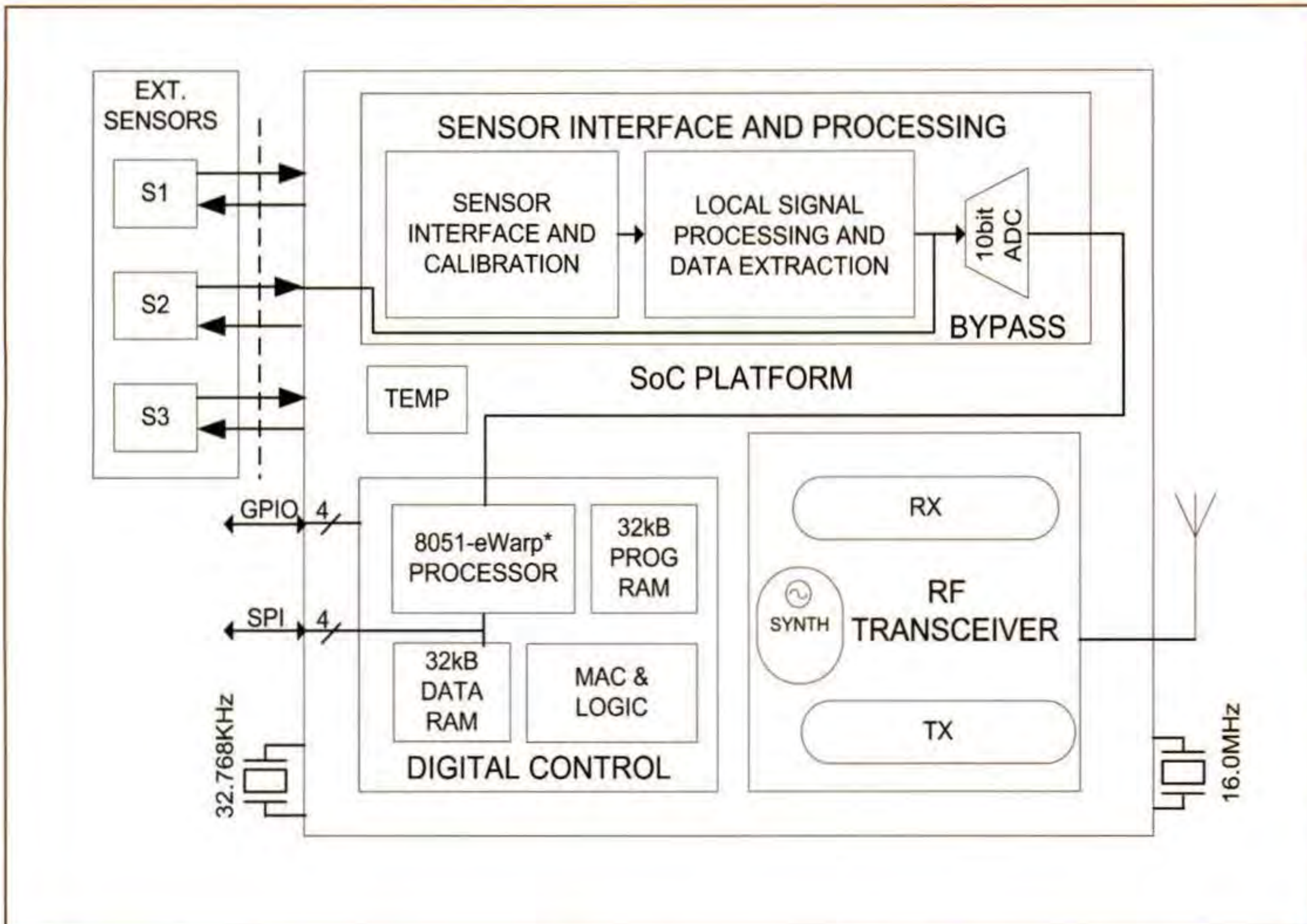


Figure 2: *Block diagram of the Sensium SoC*

comprising sensors, SoC, battery and antenna. The patch is attached to the patient for a period of typically 4-7 days, after which it is thrown away and a new patch attached if necessary. The battery is manufactured from environmentally-friendly materials such that it can be recycled or safely disposed of, and provides typically 3mAh/cm^2 at 1.4V, dropping to 0.9V at end of battery life. The limited energy capacity means that the average current drain must be of the order of uA to achieve the target operating lifetime. In addition the battery peak currents must be limited to be no higher than a few mA to avoid battery collapse.

These energy constraints require a novel low-power design methodology to be applied at all levels – network protocol, system architecture, circuit topology and implementation – in order to guarantee reliable and robust operation within the battery's maximum peak current discharge capacity . Figure 1 shows the SoC block diagram which comprises three major sections; sensor interface, digital baseband and wireless transceiver.

The sensor interface is designed to support a number of different types for monitoring applications including: glucose/pH using amperometric sensors; motion using a 3-axis accelerometer; heart rate/ECG (EKG) using a single lead electrode; temperature using thermistors; pressure using a Wheatstone bridge. A block diagram of the sensor interface circuitry is shown in **Figure 2**. Mixed signal circuitry provides gain, filtering, biasing and buffering of the sensor inputs. The embedded digital processor may be used for sensor calibration to ensure excellent offset and gain accuracy.

A 10bit delta-sigma analogue-to-digital converter (ADC) samples sensor input signals within a dc to 250Hz bandwidth. The ADC is a third order switched op-amp (SO) implementation with a 64 times oversampling ratio. Due to the low frequency nature of the input physiological signals, minimisation of dc offsets and 1/f noise is crucial. Optimal switch sizing was key to minimising 1/f noise while achieving low current consumption.

The transceiver's block diagrams is shown in **Figure 3**. The receiver uses a two stage zero IF architecture based on a sliding IF approach which provides advantages in filtering and noise profiling

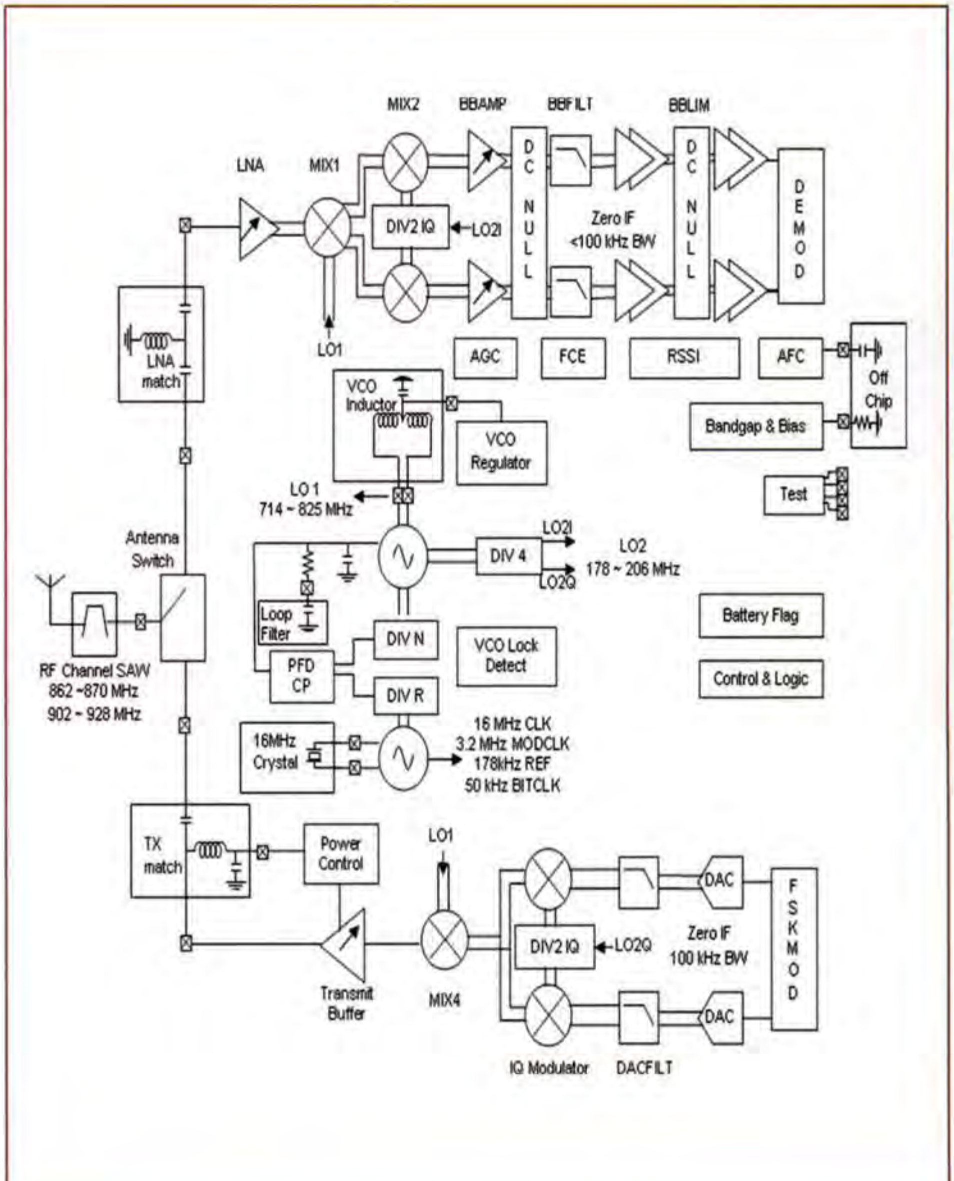


Figure 3: *The transceiver block diagram featuring sliding IF architecture and integer-N synthesiser*

and, thus, allows a lower current consumption than a single-stage, direct-conversion architecture. The PA stage is designed to deliver -10dBm into a matched antenna load, giving a range of typically 10m indoors.

The digital section contains the 8051 advanced architecture processor, peripherals, memories, timers and MAC, shown in block diagram in **Figure 1**. The MAC protocol block is a custom design to ensure ultra-low power operation while guaranteeing robust performance, and controls the RF channel selection, LBT compliance, link establishment, data transfer and sleep management.

Joining the Network

The network adopts a master-slave architecture. Unlike traditional peer-to-peer wireless sensor networks, the nodes in this biomedical WBSN are not deployed in an ad-hoc fashion. Joining a network is centrally managed and all communications are single-hop.

To reduce energy consumption, all the sensor nodes are in standby or sleep mode until the centrally assigned time slot. Once a node has joined a network, there is no possibility of collision within a cluster as all communication is initiated by the central node and is addressed uniquely to a slave node. To avoid collisions with nearby transmitters, a clear channel assessment algorithm based on standard listen-before-transmit (LBT) is used.

To handle time slot overlaps, the novel concept of a wakeup fallback time is introduced. Using single-hop communication and centrally-controlled sleep/wakeup times leads to significant energy reductions for this application compared to more 'flexible' network MAC protocols such as Zigbee.

A direct memory access (DMA) controller ensures that data samples from the ADC can be continually written to the data memory while at the same time allowing previous data samples to be passed to the uP for processing, or to the MAC for encoding prior to transmission. Up to three independent sensors can be connected to a single SoC, and the sample interval and number of samples per sample time can be independently set for each sensor – this allows sensors with different speed and accuracy requirements (e.g. temperature vs ECG) to be optimally sampled. These control functions are implemented in hardware, thus in operation the microprocessor core is essentially 'free' to run any user-defined application code; for example, fusing data from multiple sensors to allow intelligent decision making.

The Sensium Chip

The Sensium SoC is implemented in a 0.13μm CMOS technology. The chip occupies an area of $16mm^2$. Full functionality for centre-processed samples has been verified down to 0.85V; initial yield across corner lots is greater than 95% at a test time of < 3s on a Terradyne J750.

This device is the first SoC designed specifically for wireless vital signs monitoring and represents state of the art in terms of functionality and ultra low power operation. In WBSN applications this SoC is able to provide typically one to two orders of magnitude lower power consumption than competing solutions, and as such offers the possibility for truly unobtrusive and disposable vital sign monitoring.■

THREE LEVELS OF WIRELESS FOR **MACHINE-TO-MACHINE** NETWORKING

JOHN MOORE, SALES AND MARKETING DIRECTOR FOR ALPHA MICRO COMPONENTS, DESCRIBES THE GROWTH OF MACHINE-TO-MACHINE TECHNOLOGY AND HOW IT FITS WITHIN THE THREE MAIN LEVELS OF WIRELESS NETWORKING

Machine-to-machine (M2M) networking has become a buzzword in the electronics industry in recent years – and rightly so. Increasingly, a variety of industry sectors are enhancing productivity by connecting assets to a network to allow them to be controlled and managed remotely. Such remote management can now be performed by a specially designed device, which results in savings in man-hours and management costs.

Following the '80s PC revolution, the Internet explosion in the '90s and the current rise of convergence technologies, experts believe that autonomous machine-to-machine communication will herald the next era of technological progression.

Wireless networking offers a number of obvious benefits to users, which are enhanced by wireless M2M networking. It is crucial to select the right connectivity module for a given environment and functionality. These requirements must then be successfully incorporated into the new device or added to legacy equipment.

Telemetry Advantages

As the implementation of independent wireless networking grows, the advantages of telemetry and asset tracking have expanded. Practical examples are evident in environments ranging from fleet management through to stock control, point of sale and power-saving applications in industrial settings. At the same time, the ongoing price race in the electronics industry is acting as a catalyst for the implementation of M2M technology in a growing number of environments.

Industrial manufacturing has been a rapidly expanding market for M2M technologies as the benefits are quickly recognised in terms of productivity and fault recognition. Recent M2M implementations allow both the remote registration of the fault and execution of the remedy itself, giving managers the ability to oversee the situation at the facility remotely and ensure minimal downtime for critical equipment.

It is certain that M2M networking will continue to grow in the coming years. Machines will increasingly "talk" to one another and act autonomously. Experts, such as the leading networking manufacturer Lantronix, see M2M technology expanding to a new class of applications in the consumer market such as entertainment, home automation and residential equipment, where cost has traditionally been a major barrier to adoption.

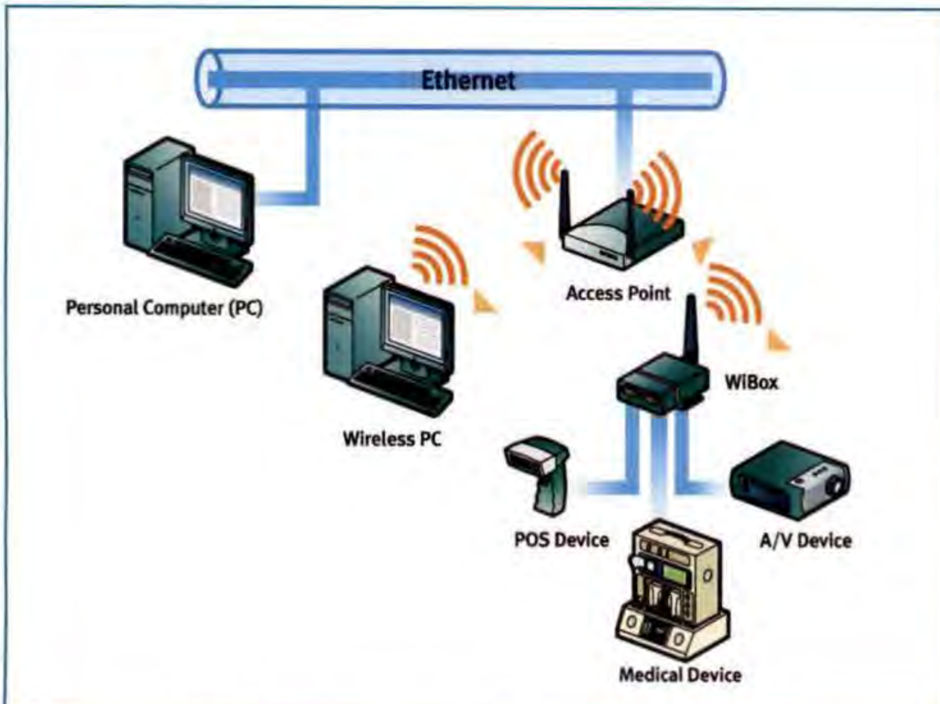
Sagem's HiLo, one of the smallest GPRS modules around

Practical Application Through Wireless Connectivity

A number of different networks are available when connecting devices to a wireless network and the three standard levels of networking offer different advantages.

For the shortest distances but requiring very low power consumption, ZigBit from MeshNetics running on ZigBee technology, provides excellent value for money and installed devices are able to function on one battery pack for up to five years.

ZigBee technology allows small, low-cost embedded devices to transmit small amounts of data over a low-power wireless



Wireless device networking

network. Typical applications include temperature readings for thermostats, control of light switches in managed buildings or checking of stock levels in vending machines.

The ZigBee protocol is a lower-cost alternative to Bluetooth for wireless sensing and control applications. Based on the approved international packet radio standard 802.15.4, ZigBee uses the unlicensed 868MHz and 2.4GHz frequencies with a range of about twenty metres indoors and up to one hundred metres outdoors. The ZigBee protocol allows multiple units to form a network or 'micro-net', which extends the operating range of a device by using other enabled devices to relay data forward. Together with extremely low power consumption, this network ability makes a battery powered, multi-sensor system achievable with no installed infrastructure. If one wireless spot goes down, the rest of the network is able to continue transmitting information.

Second Level Wireless Networking

The second level of wireless networking, ideal for larger span solutions, is the well-known Wi-Fi technology. The IEEE 802.11 standard, which has emerged as the primary standard for wireless networking, offers variable data rates and standard technology with data rates from 11 to 54Mbit/s.

The 802.11b is the most widely used of the IEEE standard wireless protocols followed by the IEEE 802.11g. It is widely used for secure industrial applications and LAN solutions. As a second level, the technology offers faster data rates and Wi-Fi Ethernet and IP providing global remote access. In comparison to the next level, it does not represent extra cost compared to adopting GSM.

This technology functions on a flexible media-independent 802.11 b/g standard working on 2.4GHz with a range of up to 328 feet (approximately 100 metres) indoors. As a complete solution, it takes the complexity out of RF (Radio Frequency) and embedded Ethernet networking design, by delivering out-of-the-box components compliant with all standards and legal requirements. This significantly reduces development time and time-to-market – two crucial factors in today's highly competitive landscape.

In some devices, using this technology as a user-controlled, intelligent power-management option saves power by turning the radio off during periods of inactivity. As a solution more often used in industrial wireless networking, this option offers proven security standards, which ensures that no intruders are allowed access without permission.

Ratified in 1999, the 802.11b improved standard gained increased acceptance as 'the' wireless LAN technology. This technology is used for remote telemetry, industrial sensors, point-of-sale terminals, building management systems, fire panels and security systems.

The 802.standard 11b is usually used in a point-to-multipoint setup, wherein an access point communicates via an omni-directional antenna with one or more clients that are located in a coverage area around the access point. With high-gain external antennas, the protocol can also be used in fixed point-to-point arrangements with ranges up to five miles (8.1km), which can be further increased if a line of sight can be established. Its successor, the 802.11g standard ratified in June 2003 works in the 2.4GHz band like 802.11b, but operates at a maximum raw data rate of 54Mbit/s or about 19Mbit/s net throughput. The 802.11g hardware is backwards-compatible with the 802.11b hardware.

Third Level of Wireless Networking

The third level of wireless networking covers most of the Earth's surface through available satellites and GSM networks. This brings extra functionally by not only transmitting data, but also locating the source of the signal geographically. This helps companies to know exactly where their device is, how fast it is moving and in what direction.

In many cases, systems offer tracking dependent on time, i.e. a signal is sent via a GSM network to the monitoring centre at set intervals. This means that vehicles stuck in traffic send unnecessary and costly positioning signals, while having moved only a few metres in distance. At Alpha Micro, we have solved this problem by offering a solution that sends signals at given time intervals, but also depending on the mileage covered. This results in a significant reduction of signals sent, when the vehicle is moving slowly or not at all, making it a very cost-effective solution for tracking in heavy traffic conditions such as those common in cities and on jammed motorways. We believe this additional improvement is the future of asset tracking and telemetry for the years to come, as automotive electronics continues to evolve and become increasingly adopted.

Wireless Packet Data networks, such as GPRS, also hold great promise for applications that rely on M2M communication. Widespread availability and low price per kilobyte are two key benefits of GPRS networks that make it an attractive technology to replace existing equipment or to deploy new wireless solutions.

The new level of intelligence through M2M technology and networking delivers a wide range of tangible benefits. Equipment can connect to a network and monitor itself to ensure it is functioning properly by re-booting, switch adjustment or re-setting without human interference. When human assistance is needed, the technical personnel can diagnose the problem over the network and solve it quickly. Systems can even recognise an approaching failure themselves and send an alert in advance. This gives service technicians the ability to determine the status and operating conditions of the remote equipment and organisations can increase customer satisfaction by keeping the quality of their services constant.

This was demonstrated by our recently completed project for Irish Broadband, whereby distantly located transmitters in mountainous areas can now be monitored, diagnosed and serviced remotely using a GSM wireless network. The new facility helps to deliver reliable service to end-user customers with fewer signal disruptions and reduces the cost of technical personnel servicing the equipment in person.

The Growth of M2M Networking

As the world of device networking evolves and technology advances, users and manufacturers alike are calling for more complete systems that offer ubiquitous reach. There are several trends shaping the future of machine-to-machine technology, including the shift towards true autonomous control of networked equipment and a greater level of intelligence built into the machine infrastructure. But, what may have the greatest impact – actively propelling the M2M market toward substantial growth – is the convergence of technologies that enable an end-to-end system for device control.

For the past few years, analysts have touted M2M as a rapidly-growing market full of promise. Technologies such as web services, XML data schemas and RFID were expected to impact the market's growth, as well as remote device server technology that effectively enables M2M communications and is the foundation for distributed device intelligence. The market for M2M is ripe with possibility due to the convergence of four major trends:

1. The omnipotence of the Internet now connects everyone and everything quickly and easily;

2. Users now expect continuous access to information;

3. Users now recognise the need for and value of real-time information sharing;

4. Technological advancements have lead to a reduction in both the size and cost of networking hardware and software.

There is no doubt that the technologies required to make M2M a reality are readily available, from hardware to software, user interface to server-side applications; what has been missing is a single source to unify implementation. By putting all the pieces together, suppliers will inevitably create more advanced systems that make it easier to share information.

For suppliers, this would mean finally demonstrating the significance of M2M; for users, it would mean having an 'all-access pass' to enjoy all the benefits of M2M through connectivity.

The first step toward total information convergence is the adoption of device networking technology within the market. While this has been achieved, the next step is for suppliers to provide the final pieces of the puzzle. Once this has been achieved, vendors will be more likely to stick with the same supplier, creating long-term partnerships that will drive the creation of complete systems and increase confidence in M2M. Beyond that, suppliers can work together to create complete systems that will gain wider acceptance. ■

TRANSMISSION LINE MODEL: AN INTRODUCTION TO THE WORLD OF RF

The transmission of signals along wires is one of the most important ways in which communications have been realised. Wires exhibit capacitance and inductance; and these affect the propagation of signals being transmitted. Such properties have been known since Maxwell first articulated the behaviour of electromagnetism.

This paper describes a "real" model of a transmission line using the lumped element equivalent circuit. It was built to illustrate the phenomena of reflection and standing waves in a transmission line, and may be used to demonstrate the effect of load matching, and even introduce S-parameters.

It is intended for engineers with little prior knowledge of the subject. Those of you who are already familiar with high frequency signals can skip the rest of the paper.

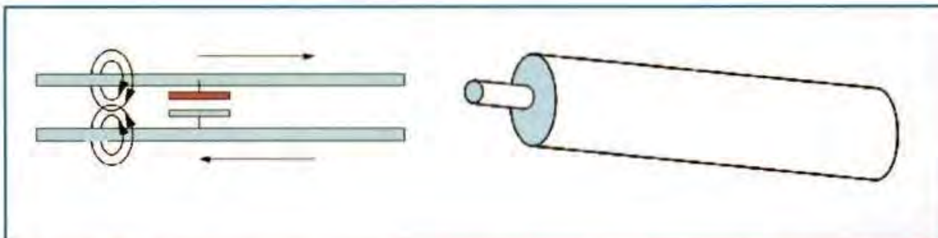


Figure 1: (a) A parallel wire pair, showing capacitive and inductive elements; and (b) A coaxial cable comprising an outer conductor, usually made from a braid or plain wires and having an inner wire separated by a plastic insulator

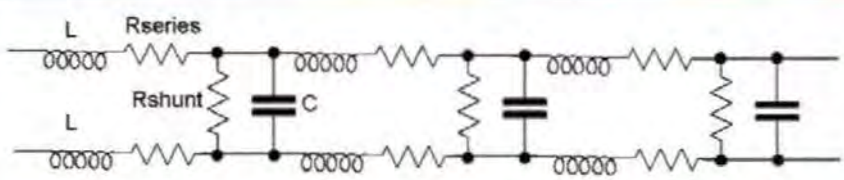


Figure 2: Generic equivalent circuit of a transmission line comprising inductance along the length; capacitance between the wires and resistances in series and in parallel representing the wire resistance and leakage paths between the wires

TRANSMISSION LINES

Any pair of wires can be used to convey electrical signals. Familiar examples include a flat pair such as used in FM aerial connection wires and coaxial cables such as those used for TV aerial connections. What is common between all pairs of wires like these is that two conductors held apart with a dielectric between them have the property of capacitance: the plates can charge and, in so doing, offer an impedance to the signal which reduces with frequency.

Two conductors, where one might be thought of as carrying a current to a destination and the other returning the signal, form a loop. A single wire carrying a current exhibits a magnetic field surrounding the wire and the effect of a loop is to enhance the magnetic effect by providing an additional magnetic field on the return.

Coils of wires having multiple turns of course have high magnetic fields, because each coil contributes its own field, but this induces an electromotive force in all of the other turns. Since each turn thus increases the magnetic effect in all the others, coils exhibit a magnetically-induced inductance with value that increases with the square of the number of turns.

The two key properties of a transmission line, are, therefore, the capacitance and inductance of the wires. In addition, wires also have resistance which is in direct proportion to the length, diameter of the wire and its resistivity; but also a resistivity between the wires. This is sometimes referred to as a leakage impedance, but is frequently so high because modern insulating materials have almost no conduction, that it can be ignored.

Transmission lines can be represented typically by a flat pair as shown in **Figure 1** (a) and a coaxial pair (b). There are capacitive elements between the conductors, and inductive elements along the wires. The equivalent circuit for a transmission line is shown in **Figure 2**. Figure 2(a) shows the general conceptual equivalent, while Figure 2(b) shows the circuit network. The inductance and capacitance are distributed: the values, in other words, are proportional to the length of the line.

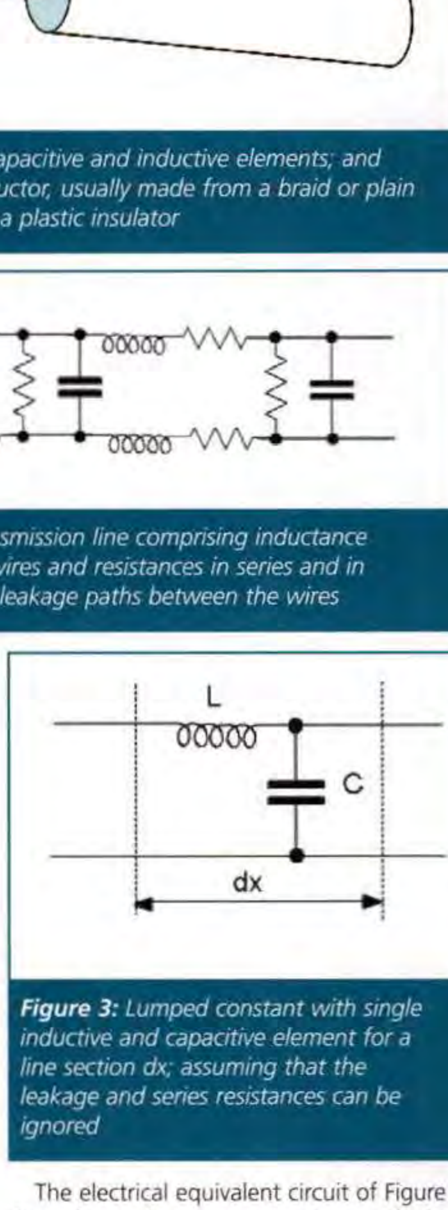


Figure 3: Lumped constant with single inductive and capacitive element for a line section dx; assuming that the leakage and series resistances can be ignored

The electrical equivalent circuit of Figure 2 can be made to approximate a particular length of line dx using an inductor and a capacitor, ignoring series resistances and leakage paths as shown in **Figure 3**. This is the so-called "lumped equivalent" circuit of a transmission line. For greater accuracy (for example, if long lines were to be simulated) the resistances and leakages should be included.

To illustrate a lumped element model for a typical coaxial cable which may have a capacitance of 100pF/m and an inductance of 0.4μH/m, the element could be simulated by a 100pF capacitor and 0.4μH inductor to represent 1 meter of cable. While this is strictly true, and may under some conditions measure the same as a 1 meter length of a cable having these values, the actual performance of a lumped element equivalent circuit is not quite the same as a real distributed line: the attenuation of 100pF and 0.4μH representing 1 meter is not identical to ten smaller elements made up from 10pF and 0.04μH, representing 100mm each. At frequencies below the cut-off point of the cable, the behaviour is approximately the same, the difference becoming apparent only at high frequencies near or above cut-off. With this warning, we will use the lumped model at frequencies below cut-off to avoid undue attenuation.

THE CAPACITANCE OF A TRANSMISSION LINE

A parallel pair of wires was often used to convey FM radio signals from an FM aerial to the receiver. These days, many FM radios are sensitive enough not to require a classical balanced dipole aerial, but there may be some areas in the UK which have weaker signals where an FM aerial is still be needed.

The capacitance of any conducting surface is obtained from the integration of the electric field over that surface. The integration of the field gives the charge

$$Q = \varepsilon \int EdA$$

For a uniform field is:

$$C = \frac{Q}{V} = \frac{A\varepsilon E}{V} = \frac{A\varepsilon}{d}$$

which is the well-known expression for a parallel plate capacitor.

By way of a diversion, it is worth recalling that the capacitance of a sphere

$$C = 4\pi\varepsilon r$$

where r is the radius of the sphere. There is no "other plate": the capacitance here arises simply due to the surface area of the metal – in effect this may absorb a charge of electrons. A plastic football 250mm diameter covered in aluminium foil will make a 14pF capacitor. It may not be particularly relevant for miniaturised electronic circuits, but may serve as a capacitor to tune a Tesla coil!

The capacitance of two parallel conductors held apart by a thin plastic coating is more difficult to calculate. A formula for an air gapped pair is

$$C = \frac{\pi\varepsilon}{\log\left(\frac{d-r}{r}\right)}$$

where d is the distance separating the wires and r their radius. For example, consider a pair of wires 0.5mm in diameter, giving $r=2.5\times10^{-4}$m and held 1 cm apart, giving $d=1\times10^{-2}$m. The expression above gives a Figure of 7.5pF/m for the pair. But, most practical parallel-pair wires are supported by a thin plastic film which also wraps around the wires to insulate them. The relative dielectric constant of many plastics is around 2.5, and if we treat the wire pair as a parallel-plate capacitor, with the area set by half the circumference of the wire (this assumes that the separation is much greater than the diameter of the wire) and that the plastic film between is also about 0.5mm thick, a figure of about 15pF/m is obtained.

Coaxial lines can be shown to have a capacitance (per metre)

$$C = \frac{2\pi\varepsilon}{\log\left(\frac{r_o}{r_i}\right)}$$

where r_i and r_o are the radii of the inner and outer conductors. For a typical coaxial line with diameters of perhaps 0.6mm and 4mm respectively, and a low dielectric supporting insulator, often made with plastic fins supporting air gaps to minimise the dielectric constant, the capacitance would be about 60pF/m: filled dielectrics with solid plastic might be around 120pF/m or more.

THE INDUCTANCE OF A TRANSMISSION LINE

F.W. Grover's book "Inductance Calculations" was first published in 1947. Grover both calculated the inductance and collated other authors' calculations, to cover virtually every possible type of wire, shape and combination. The book was once out of print, but such a tome is still invaluable for electrical engineers and has been re-printed at least twice. It is available currently from Dover publications.

Taking another short detour, it is worth stating the inductance for some basic elements which are common yet seldom derived in basic texts because of the involved calculations needed. For example a straight wire has an inductance

$$L = \frac{\mu_0}{2\pi} l \left[\log\left(\frac{2l}{r}\right) - 0.75\right]$$

where l is the length of the wire and r is its diameter.

A single turn has an inductance

$$L = \mu_0 R \left[\log\left(\frac{8R}{r}\right) - 1.75\right]$$

where R is the radius of the loop and r is the radius of the wire section.

While many formulas were devised to approximate the inductance of coils based on circular forms, Grover's equations can be used to calculate the performance of virtually any coil with a high accuracy. The procedure is, as for all inductors, to calculate the inductance of each turn, and sum these with the mutual inductances of each turn from every other turn.

In terms of mutual inductance, the summation is written

$$L = \sum_{\substack{i=1..N \\ j=1..N \\ i<>j}} M_{ij}$$

where M_{ij} represents the mutual inductance components for each turn on every other: that is to say the effect of all turns i=1...N on all others j=1...N, excepting the condition i=j when the self-inductance is used. The mutual inductances are obtained from

$$M = \mu\sqrt{r_1 r_2}\left[\left(\frac{2}{k} - k\right)K(k) - \frac{2}{k}E(k)\right]$$

where r_1 and r_2 are the radii of any two turns, k is obtained from

$$k^2 = \frac{4r_1 r_2}{d^2 + (r_1 + r_2)^2}$$

with d being the distance between the centres of the two turns, and K and E are elliptic integrals of k:

$$K(k)=\int_0^{\frac{\pi}{2}}\frac{d\phi}{\sqrt{1-k^2\sin^2\phi}}$$

$$E(k)=\int_0^{\frac{\pi}{2}}\sqrt{1-k^2\sin^2\phi}\,d\phi$$

Computers can calculate the inductance of a 2000 turn coil in under a few seconds these days that it is no longer necessary to use approximation formulas.

Returning to the transmission line model, the inductance of a parallel pair of wires can be shown to be

$$L=\frac{\mu}{\pi}\log\left(\frac{d}{r}\right)$$

where d is the distance between the wires and r the radius of the wire. The inductance would be roughly 1.5μH (per metre).

The inductance of a coaxial line can be shown to be

$$L=\frac{\mu}{2\pi}\log\left(\frac{r_o}{r_i}\right)$$

where r_o and r_i are the outer and inner radii.

UNITS

The units of capacitance and inductance above were not stated. They are of course farads for the capacitance, and henries for the inductance. These well known units are not the most basic, which may be a surprise for anyone who has not thought this through before.

From circuit theory, it is known that the impedance of a capacitor varies inversely with frequency. The impedance is usually given the symbol Z, which is typically indicative of a component having a phase difference between the voltage and current flow, which can be elegantly described using complex arithmetic:

$$Z=\frac{1}{2\pi fC}$$

where C is in farads. This impedance is measured in ohms, but can be re-written to give the capacitance in terms of ohms and seconds:

$$C=\frac{t}{2\pi Z}$$

This is a less common definition of capacitance, but it illustrates the point that a more fundamental unit of capacitance than farad is seconds/ohm.

The impedance of an inductor is given by the well-known expression

$$Z=2\pi fL$$

where L is measured in henries, and again, the impedance Z is measured in ohms. This too can be re-written in terms of time to give

$$L=\frac{Zt}{2\pi}$$

showing that a more basic unit than henry is ohm.seconds. The relevance of these more basic units will become clear later.

TRANSMISSION LINES

Consider an equivalent lumped equivalent circuit for an element representing a length of a transmission line dx comprising an inductance and capacitance as shown in **Figure 4**. The impedance of the line is calculated here by the "method of induction". Assuming that a transmission line has a characteristic impedance, the lumped elements are used to determine what it might be, and in so doing it is shown that a line can be represented by such an impedance, given the symbol Z_0.

With the foregoing assumption, the impedance Z_0 represents the rest of the line outside of the lumped-constant element. The equivalent circuit is shown in Figure 4.

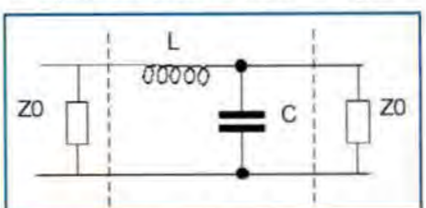


***Figure 4:** Equivalent circuit*

In the transmission line segment of Figure 4 the impedance of the inductive element is Z_L.dx. This is because the inductance is proportional to the length of the line element, and Z_L represents the inductance per unit length. The capacitive impedance element, however, is inversely proportional to the length of the line. This is because the capacitance increases with length, but the capacitive impedance is lower for a higher capacitance. The equivalent impedances for the line segment is as shown in Figure 5:

From the right, the impedance of the capacitor and the characteristic impedance Z_0 is the well-known "inverse of the sum of the inverses"

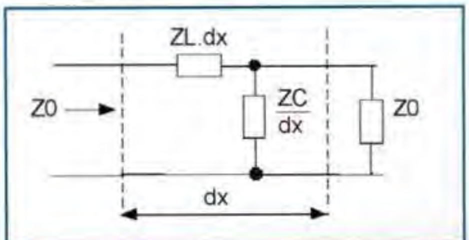


***Figure 5:** Lumped element model of line showing impedances for the line section dx*

$$Z=\frac{1}{\frac{1}{Z_0}+\frac{1}{\left(\frac{Z_c}{dx}\right)}}$$

Adding this to the inductor impedance gives

$$Z=Z_L.dx+\frac{1}{\frac{1}{Z_0}+\frac{1}{\left(\frac{Z_c}{dx}\right)}}$$

which, if the line has a characteristic impedance, must also equal the characteristic impedance. Performing the cross multiplication for the inverse sum

$$Z=Z_L.dx+\frac{Z_0\frac{Z_c}{dx}}{Z_0+\frac{Z_c}{dx}}$$

giving

$$Z_0=\frac{Z_L.dx\left(Z_0+\frac{Z_c}{dx}\right)+Z_0\frac{Z_c}{dx}}{Z_0+\frac{Z_c}{dx}}$$

Multiplying out gives the expression

$$Z_0\left(Z_0+\frac{Z_c}{dx}\right)=Z_L.dx\left(Z_0+\frac{Z_c}{dx}\right)+Z_0\frac{Z_c}{dx}$$

Subtracting the term $Z_0.\frac{Z_c}{dx}$ from each side

$$Z_0^2=Z_L.dx.Z_0+Z_L.Z_c$$

In the limit, as dx tends to zero, the inductive element term will also tend to zero, giving

$$Z_0 = \sqrt{\frac{L}{C}}$$

This result is one of those equations which should be an electronics engineer's equivalent of the mathematician's $e^{i\pi} = -1$.

If we apply the method of dimensions to the characteristic equation, the inductance is written as Ωs; while the capacitance is written as $s\Omega^{-1}$. Dividing the inductance by the capacitance cancels the seconds terms, and gives a product of ohms squared. Hence, taking the square root gives the characteristic impedance of the transmission line, in ohms, with no time constant at all included.

PROPAGATION DELAY

This can be derived as follows:

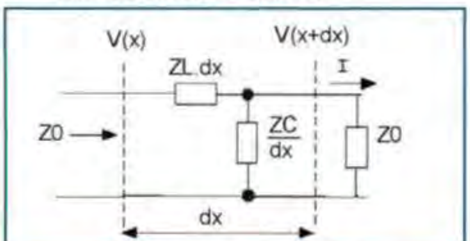


***Figure 6:** Lumped element model this time showing voltage and currents in line*

With reference to **Figure 6**, the transmission line element representing a part of the line dφ has a current flow I to the right, looking into the rest of the line into the impedance Z_0. The voltage across the node is V(x+dx). The voltage into the left hand side of the element is therefore

$$V(x) = I.Z_0 + I.Z_L.dx$$

A phase shift across the element is caused by the inductive and capacitive impedance. The change in phase angle, dφ, for the element dx, is obtained from the relative magnitudes of the imaginary term divided by the real term. This gives

$$d\phi = \frac{\omega L.I.dx}{I.Z_0}$$

Writing Z_0 as, we have

$$d\phi = \omega\sqrt{LC}.dx$$

Integrating along the section,

$$\phi = \omega\sqrt{LC}.x$$

where φ the phase angle for a length of line x. Now, considering the section as a unit length, the phase delay is obtained from the relationship of phase angle as a function of time: the well-known 2πft, to give

$$t = \sqrt{LC}$$

for the line section. This time, multiplying the inductance and capacitance elements for the line section causes the ohms terms to cancel, and the propagation delay is the characteristic time constant for the line, measured in seconds. As the L and C are per unit length, this time constant is the delay time per unit length also. So if you want to delay a signal, you can choose the length of wire needed as appropriate.

SOME REAL TRANSMISSION LINES

Earlier, the capacitance of a parallel pair of wires held 10mm apart with a thin plastic insulating support was stated to be about 15pF/m. The inductance for the pair is about 1.5μH/m. Multiplying the two and taking the square root gives a time delay constant of 4.74ns per metre; and dividing the inductance by the capacitance and taking the square root gives an impedance of 316ohms.

A coaxial cable may have a 0.5mm inner diameter wire and a 5mm diameter outer sheat. The insulating core could be a mixed dielectric of air and plastic, which in practice is achieved by making the plastic insulator from a series of radial fins to give large air gaps between them. The expressions above give figures of 60pF/m and 380nH/m. The characteristic impedance is then 79ohms and time delay 4.77ns per metre.

Perhaps it is not so strange that FM radio aerial feeder cables are designed with 300 ohm impedances; and coaxial cables often with 75ohms, while 50ohms is another common standard. Rather than being "special", it seems that these values are somewhat mundane and emerge from the physical properties of practical wires. Of course, wires will be manufactured to give the precise impedance values of 75 or 300 ohms, as required, in practice.

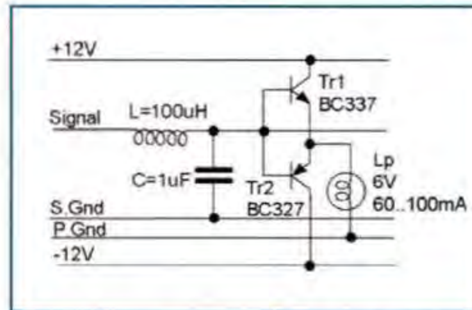


***Figure 7:** Line element of the model. There are 15 such sections.*

THE MODEL

The characteristics of a transmission line can be demonstrated with a lumped element model. In this model, an inductor and a capacitor are used to represent each element of a transmission line. In essence, the values represent a particular length of a line. Values for typical meter lengths of coax or parallel cable give rather short time delays. But it is possible to select a much longer time delay for each section so that the effects can be demonstrated with much lower frequencies. It is useful to demonstrate a transmission line model which has a total delay along the full length which is equivalent to one complete sine wave of a particular frequency. If this frequency is chosen to be within the audio band, an audio power amplifier can be used to drive the line.

To start, a 10kHz signal was chosen. A full wavelength corresponds to 100μs time delay along the line. To be able to demonstrate a full sine wave potential

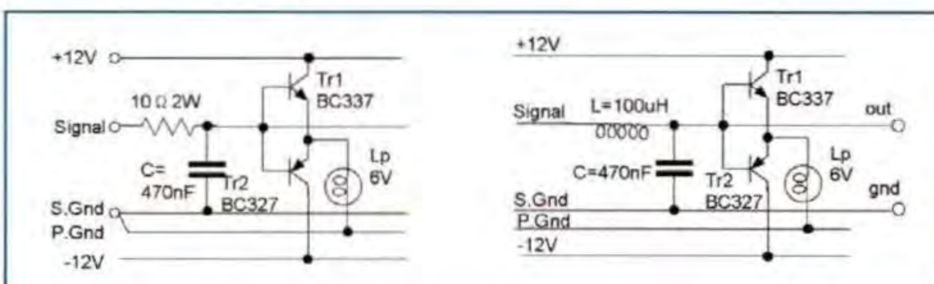


***Figure 8: (a)** First element (input – left)* *(b) Last element (output – right)*

along the line, and have sufficient elements to demonstrate peaks and troughs, the number of elements needs to be divisible by a multiple of two so that half and quarter wavelengths can be illustrated. Choosing 16 elements requires each element to have a time delay of 6.25μs. This sets one of the two characteristics of the model line.

Most audio amplifiers have an output loading intended for 8ohms, so this seems a useful value to chose. Setting Z_0=8ohms and with t_d=6.25μs, solving the two equations simultaneously gives L=50μH and C=0.78μF for each section. Inductors of 50 μH are not so common, but 100μH is. Capacitors nearest the target value are conveniently 1μF. Reworking the calculations gives a characteristic impedance of 10ohms and time delay of 10 μs. Though a little different from the starting point, these are perfectly acceptable.

The transmission line model can now be specified. It will have 16 elements each of 100μH and 1μF respectively. The overall time delay will be 160μs, which means that it will display a full wavelength's potential distribution for a frequency of 6.25kHz, or two wavelengths of 12.5kHz.

To show the voltage on each line element or node, it would be possible to step along the line with an ac voltmeter. A much quicker illustration of the potential distribution along the whole line can be given qualitatively by running an indicator lamp from each node. The brightness of each lamp will give a representation of the potential on its node. If we were to use even a low current lamp of say 6V and 60 mA, the resistive loading on each node would be about 100 ohms. The presence of 16 such lamps on the line would give some considerable attenuation, even for a 10 ohm line. Previously we had assumed that the series resistances and shunt resistances could be ignored. To prevent undue loading on the line, each node is buffered using a pair of transistors to drive the lamp. These transistors will operate effectively in Class B. Transistors such as the BC337 and BC327 are able to drive lamps up to about 100 mA from a dual 12V supply line. Whenever a standing wave occurs on a line, the peak voltage reaches twice the nominal line voltage applied. To prevent the lamps from being overloaded, the input voltage to the line should be restricted to 6V.

Each node section for the model will be as shown in **Figure 7**.

There are a total of five wires running along the length of the transmission line model. Three are carrying the lamp power lines: +12, -12 and power ground; the other two are the signal return line and the signal transmission line, which is broken by each inductor along the way. The transmission line model uses 15 copies of the circuit shown in Figure 7, with all cascaded one after the other. The ends of the model, however, are slightly different.

The two ends of the model corresponding to the signal input on the left, and output on the right, are different from the intervening elements. Firstly, the terminating capacitors are each of 470nF, rather than 1μF, which keeps the line symmetrically balanced. Effectively, this divides the start and end elements into two part elements. The end termination on the right has a pair of PCB pins or other suitable terminals which can have a wire soldered to each of them. These wires have croc clips on the free ends so that the transmission line can be terminated with a range of loads.

The input side of the model, on the left, has five terminal pins and five associated wires. The two ground wires, one for the lamp power return and the other for the signal line ground, are connected together at the input side. Two pins are used to connect the two auxiliary power lines of + and –12 V. The two 12 V lines and corresponding ground are formed into a triple-twisted wire. The line input signal from the audio power amplifier is connected to the transmission line input using a 10 ohm load resistor. Since this corresponds to the designed characteristic impedance of the line, this prevents reflections on the input side of the line, as will be explained later. The two end elements are shown in **Figure 8** (a) and (b).

The unit is built on a single 450mm long section of tracked copper board, such as Veroboard or equivalent. The +12, -12 and two earth lines run the length of the board. The emitters and bases of the transistors are wired onto common rails, but the copper tracks for these are cut for each section, along with breaks to separate the coil input and output along the signal line. Jumper wires are used to connect the bases to the LC tap, and to connect the emitters to the lamp socket for each node.

Evidently the model requires some supporting electronics. These are a dual 12V power supply and a 6V signal at 12.5kHz. The power supply should be able to provide at least 2A per side. The 6V signal can be supplied from an audio power amplifier driven from an oscillator. A simple 12.5kHz oscillator circuit is shown in **Figure 9** which uses another lamp to

Inset: *Enlarged picture of the sections*

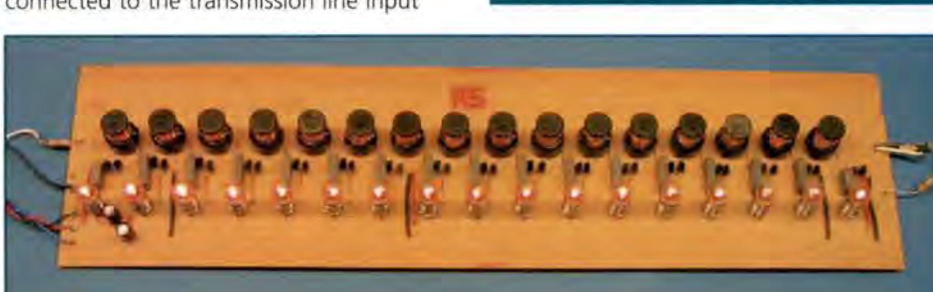


Figure 11: *Board layout on the left are a white and black pair of wires which connect to a power amplifier, through the matching resistor, and a black, red and blue triplet connected to the +/- 12V supplies, with blacks being commoned. On the right is the load resistor clipped to the output*

stabilise the oscillation. Ideally, the power amplifier, oscillator and auxiliary supplies would be built into an aluminium box as a single unit. As hi-fi performance is not required, a possible amplifier for this purpose is shown in **Figure 10** which could run from the same +/-12V power rails.

A photo of the transmission line model is shown in Figure 11.

DEMONSTRATIONS

To set up the model for a demonstration, connect a 10 ohm resistor to the load end. Connect the 12 V power lines to the 12V supplies. The adopted colour scheme is black=zero, blue=-12V and red=+12V. Connect the 12.5 kHz oscillator to the amplifier and, using the volume control, set the amplifier output voltage to 6V. Then the amplifier terminals can be connected to the signal lines of the model.

When a transmission line has a passive termination resistor which is equal to its characteristic impedance, there is no difference electrically from the line appearing to be infinitely long. This means that no reflections can occur, as a signal propagating down the line would effectively disappear into infinity. In practice, the 10 ohm load absorbs the signal power. A transmission line conveying a signal terminated at the input and output by its characteristic impedance simply allows the signal to traverse from left to right. As a result, each node sees the same voltage, but at slightly different times. In this case, the lamp intensity will be uniform along the line as can be seen in **Figure 11**.

If the impedance at the end of the line were not equal to the characteristic impedance, then waves can be reflected. If no energy is absorbed, all of the signal will reflect back. It is possible to predict what will be observed by drawing a sinewave travelling from left to right, superimposing a second sinewave travelling from right to left, and adding the two to give the overall potential. The result of two opposing signals is a standing wave. Some points along the line have no potential, while others see a potential equal to twice the incident wave. The standing wave value can be anything between the input signal and twice as great, depending on the degree of reflection. The extreme value of twice the normal voltage is created for a short circuit and an open circuit termination on the line.

A short circuit terminated line is shown in **Figure 12.** To demonstrate this the termination pins are just shorted together. The intensity of the lamps replicates a sinewave, which is illustrated by sketching a sinewave aligned to the transmission line model. The bright lamps correspond to the peak of the sinewave, while the lamps which are extinguished correspond to the "zero" positions along the line. In practice a standing wave oscillates up and down, the bright lamps oscillating between the positive and negative peak voltage, while the zeros see no voltage at all.

If the termination of the transmission line is an open circuit, standing waves are also generated but with a phase shift from the shorted termination. **Figure 13** shows the standing wave pattern of the open circuited termination. Although there is a quarter-wave shift in the standing wave pattern compared to Figure 12, the reflection to achieve this is 180 degrees out of phase with the short circuit reflection.

REFLECTIONS

In this final section, some of the basic equations describing reflections in the line are discussed. Reflections can be characterised by a reflection coefficient, which indicates by how much the signal reflects in terms of a ratio between zero and 1, or 1 in the case where there is a signal inversion. Sometimes this is given the symbol Γ, the Greek capital gamma.

Consider a line with characteristic impedance Z_0 which is terminated in an arbitrary impedance Z_1. The voltage incident on the termination is Vi, there is a reflected voltage Vr, and the voltage appearing on the load is V1, with current I1 as shown in Figure 15.

The voltage across the load has a magnitude and direction associated with the incident and reflected waves:

$$V_1 = V_i + V_r$$

But the incident and reflected currents oppose:

Figure 12: Short circuit terminated line, with sinewave superimposed. The line length corresponds to a total delay of two cycles of a 12.5 kHz signal

Figure 13: Open circuit terminated line, with sinewave superimposed. The brightest lamps are now at the line ends compared with Figure 12

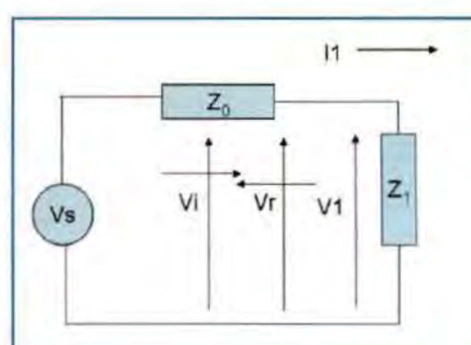


Figure 15: Incident and reflected waves

$$I_1 = \overrightarrow{I_i} - \overleftarrow{I_r}$$

which can be written

$$I_1 = \frac{V_i}{Z_0} - \frac{V_r}{Z_0}$$

Rearranging,

$$V_i = \frac{V_1 + I_1 Z_0}{2}$$

and

$$V_r = \frac{V_1 - I_1 Z_0}{2}$$

Dividing the incident by the reflected waves, taken to be represented by the voltages, gives the reflection coefficient

$$\Gamma = \frac{V_1 - I_1 Z_0}{V_1 + I_1 Z_0}$$

and as V1=I1xZ1,

$$\Gamma = \frac{Z_1 - Z_0}{Z_1 + Z_0}$$

which is the well-known RF-line reflection coefficient expression.

Using the reflection coefficient for the loads, if $Z_1=Z_0$, there is no reflection, and Γ =0. This is why the line is fed through a 10 ohm load, and shows uniform voltage along the line when terminated in a 10 ohm load, since, for the model line, Z_0=10. If Z_1=0, then there is a reflection coefficient of Γ =-1, meaning that all waves are reflected with a phase inversion; and if $Z_1=\infty$, Γ =1, meaning that all waves are reflected without a phase change. In case of difficulty with this last calculation, you can approximate infinity with a 10 kilo-ohm resistor: with a 10 ohm characteristic impedance, the ratio is then 9990/10010, or almost 1, and so the reflection can be seen to tend to 1 as the load impedance approaches infinity.

Different loads can be placed on the model line, including capacitors and inductors. The phase shift of the reflected signal will be indicated by the intensity of the lamps, but it may not be so easy to distinguish between an inductively or capacitively originated shift without using an oscilloscope to compare with the reference signal or input from the amplifier.

The reflections on a line as demonstrated can be measured in terms of phase and potential. Therefore, it is possible to deduce the load impedance for a given frequency. S-parameters are essentially measurements of these signals. They are widely used to characterise high frequency devices, with a considerable advantage that the connections to the device are made through, effectively, a resistive load of typically 50 ohms, which being neither inductive nor capacitive, nor open nor short tends to reduce the possibility of oscillation. From the reflection properties, the effective impedances of a device can be extracted.

It is worth finishing on with a mention of the Smith chart. The Smith chart is able to plot the reflection coefficient as a function of phase, and handles zero and infinity being on opposite sides of a circle. This is about the only time when these extremes can be plotted together on a graph – electrical engineers have thus had the ability to plot infinity, since the 1940s! (The catch is that there is almost no resolution between values above about ten times the characteristic impedance and infinity). There is not enough space to describe the Smith chart in detail, but it is perhaps worth sneaking a diagram into this final paragraph labelled up to correspond to the transmission line model. ■

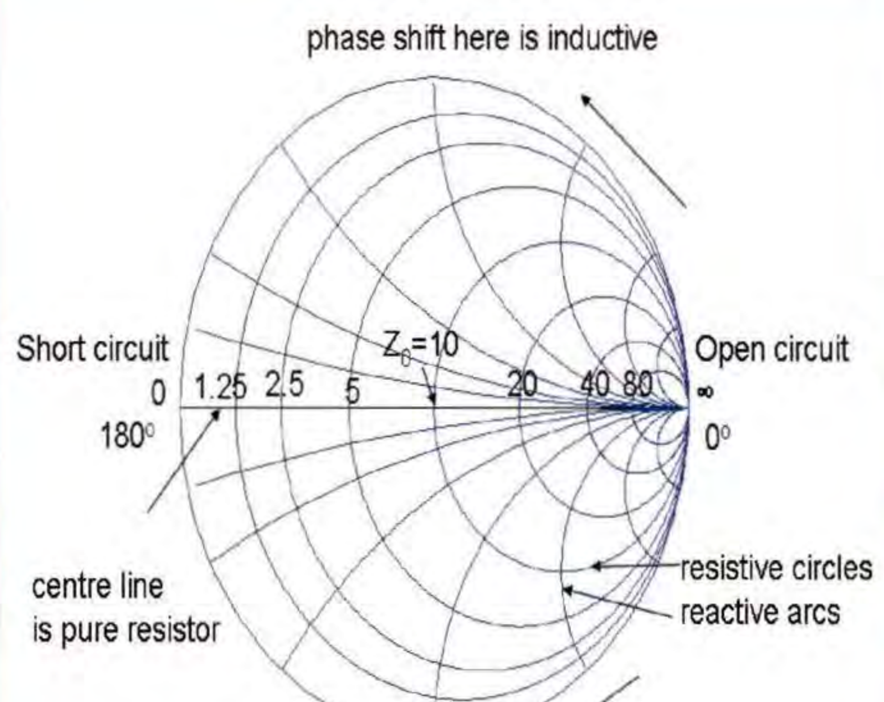


Figure 16: *Smith chart, centred on 10 ohms for use with the Transmission Line Model*

A NEW HIGH-OUTPUT-IMPEDANCE, TRANSADMITTANCE TYPE OTA-BASED UNIVERSAL FILTER

A new transadmittance, biquad filter circuit is presented here. The circuit uses only five operational transconductance amplifiers and two capacitors and can realise lowpass, highpass, bandpass, allpass, notch, highpass notch and lowpass notch responses from the same topology.

The gain and the parameters ω_o and $\frac{\omega_o}{Q_o}$ enjoy independent electronic tunability. Experimental results are included.

In many applications, designers face the problem of interfacing voltage-mode with input and output voltages, and current-mode circuits with input and output currents. While it is easy to use voltage-to-current converters to facilitate this interfacing, it would be advantageous if signal processing can also be performed during this process. Thus, there is a need for a transadmittance-type filter where voltage-to-current conversion and filtering can be performed by the same circuit.

Inspection of the open literature shows that only one such filter circuit has been published by A. Toker, O. Cicekoglu, S. Ozcan and H. Kuntman in the International Journal of Electronics, Vol. 88, pp. 1085-1091, 2001, entitled *"High-output-impedance transadmittance type continuous-time multifunction filter with minimum active elements"*. This circuit uses three plus-type second-generation current-conveyors (CCII+s), two capacitors and three resistors and can simultaneously realise lowpass, highpass and bandpass transfer functions. While a notch can be realised by adding the lowpass and highpass outputs, this requires inversion of the lowpass output.

Moreover, a realisation of the allpass transfer function is feasible, but it also requires inversion of the highpass response. In both cases certain conditions must be imposed on the values of the passive components. Furthermore, independent electronic tunability of the centre frequency and the bandwidth of the filter realisations is not feasible.

On the other hand, due to their structural simplicity, ease of monolithic integration, electronic tunability, high frequency capability, operational transconductance (OTA) based active filters are attracting the attention of many researchers. Inspection of such published OTA-based filter realisations clearly shows that voltage-mode and current-mode circuits are available for realising the basic five filter functions: lowpass, highpass, bandpass, allpass and notch. No circuit realisation is available for realising OTA-based transadmittance-type lowpass, highpass, bandpass, allpass, notch, lowpass notch and highpass notch transfer functions.

While, these realisations can be obtained from the general circuits proposed in M. T. Abuelma'atti and A. Bentrecia's *"A novel mixed-mode OTA-C universal filter"* published in the International Journal of Electronics, Vol. 92, pp. 375-383, 2005, and M. T. Abuelma'atti and A. Bentrecia's *"A novel mixed-mode OTA-C filter"* published in FREQUENZ, Vol. 57, pp.157-159, 2003, both circuits require six OTAs.

Moreover, the circuit proposed in the latter solution requires multiple-output and multiple-input OTAs. Obviously, this requires additional active elements as such OTAs are not commercially available. Therefore, it is the major intention of this paper to propose a new OTA-based transadmittance-type filter structure, with input voltage and output current, that can realise lowpass, highpass, bandpass, allpass, notch, lowpass-notch and highpass-notch transfer functions using OTAs. The proposed circuit uses only five commercially-available single-output dual-input OTAs and two capacitors.

The Proposed Circuit

The proposed circuit is shown in **Figure 1**. Routine analysis yields the transfer function given by:

$$I_{out} = g_{m1}\frac{\frac{g_{m2}g_{m3}}{C_1C_2}V_1 - \frac{g_{m3}}{C_1}sV_2 + V_3s^2}{\frac{g_{m3}g_{m4}}{C_1C_2} + \frac{g_{m5}}{C_1}s + s^2} \qquad (1)$$

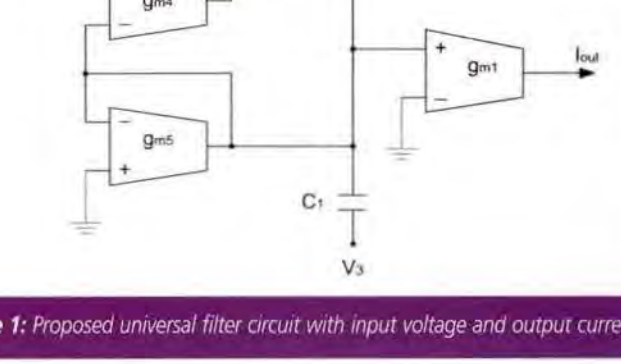


Figure 1: *Proposed universal filter circuit with input voltage and output current*

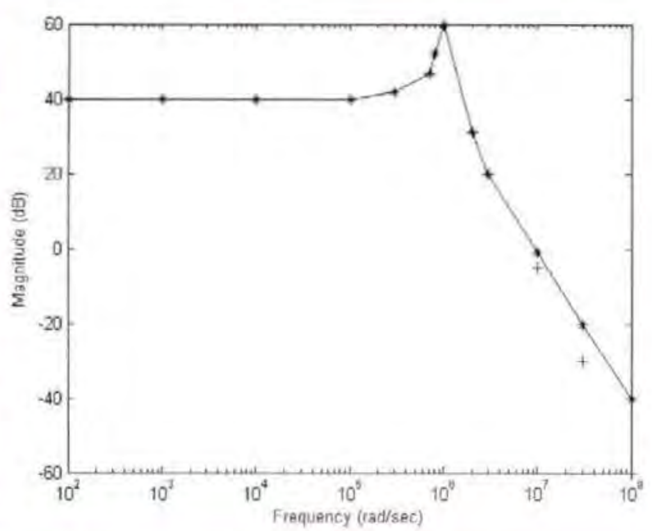


***Figure 2:** Simulated frequency responses of HP, BP and LP*

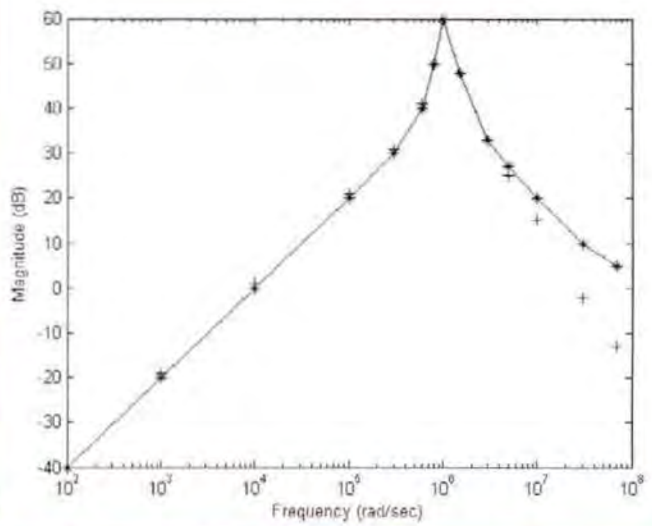


***Figure 3:** Experimental (+) and calculated (*) results obtained from the bandpass realisation*

Inspection of **Equation 1** shows that the following mixed-mode, with input voltage and output current, transfer functions can be obtained:

(a) a non-inverting lowpass-filter (LPF) with $V_2 = V_3 = 0$ and low-frequency transconductance gain given by:

$$G_{LP} = \frac{g_{m1}g_{m2}}{g_{m4}} \quad (2)$$

(b) an inverted bandpass-filter (BPF) with $V_1 = V_3 = 0$ and transconductance gain at the centre frequency given by:

$$G_{BP} = \frac{g_{m1}g_{m3}}{g_{m5}} \quad (3)$$

(c) a non-inverting highpass-filter (HPF) with $V_1 = V_2 = 0$ and high-frequency transconductance gain given by:

$$G_{HP} = g_{m1} \quad (4)$$

(d) a non-inverting notch filter (NF) with $V_1=V_3$, $V_2=0$ and $g_{m2} = g_{m4}$ with low-frequency and high-frequency transconductance gain given by:

$$G_{NF} = g_{m1} \quad (5)$$

(e) a non-inverting highpass-notch (HPN) with $V_1 = V_3$, $V_2 = 0$ and $g_{m2} < g_{m4}$ with low-frequency and high-frequency transconductance gains given by:

$$G_{LHPN} = \frac{g_{m1}g_{m2}}{g_{m4}} < g_{m1} \quad (6)$$

and: $$G_{HHPN} = g_{m1} \quad (7)$$

(f) a non-inverting lowpass-notch (LPN) with $V_1 = V_3$, $V_2 = 0$ and $g_{m2} > g_{m4}$ with low-frequency and high-frequency gains given by:

$$G_{LLPN} = \frac{g_{m1}g_{m2}}{g_{m4}} > g_{m1} \quad (8)$$

and $$G_{HLPN} = g_{m1} \quad (9)$$

Inspection of Equation 1 shows that in all cases the parameters ω_o^2 and $\frac{\omega_o}{Q_o}$ are given by:

$$\omega_o^2 = \frac{g_{m3}g_{m4}}{C_1C_2} \quad (10)$$

and:

$$\frac{\omega_o}{Q_o} = \frac{g_{m5}}{C_1} \quad (11)$$

From **Equations 10** and **11** it appears that the centre frequency ω_o can be adjusted by controlling the transconductances g_{m3} and/or

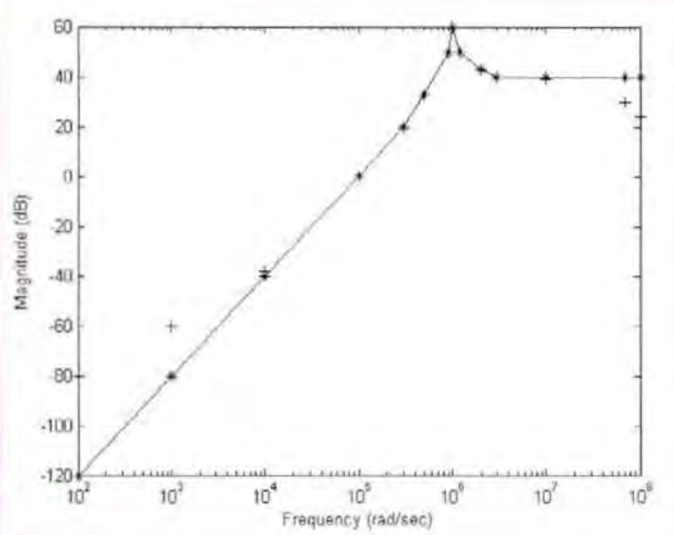


Figure 4: *Experimental (+) and calculated (*) results obtained from the highpass realisation*

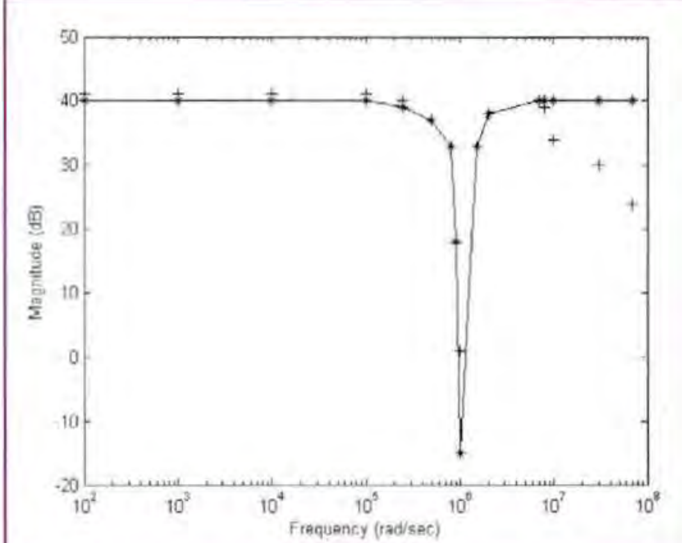


Figure 5: *Experimental (+) and calculated (*) results obtained from the notch realisation*

g_{m4} without disturbing the bandwidth $\frac{\omega_o}{Q_o}$ and the latter can be adjusted by controlling the transconductance g_{m5} without disturbing the centre frequency ω_o. Thus, the proposed filter structure enjoys the attractive feature of independent electronic tunability of the centre frequency and bandwidth. Moreover, inspection of **Equations 2** to **9** clearly shows that the transconductance gain of the proposed filter structure can be electronically controlled by adjusting the transconductance g_{m1} without disturbing the centre frequency and the bandwidth. Thus, the proposed filter structure enjoys independent electronic tenability of its gains, bandwidth and centre frequency.

Furthermore, for the lowpass and highpass realisations, the input voltage $V_3 = 0$. Thus, for these two realisations, the proposed filter structure will use two grounded capacitors. This is attractive for high frequency realisations. However, for other realisations, the input voltage $V_3 \neq 0$ and one of the capacitors will be floating. On the other hand, the input resistance is high for input voltages V_1 and V_2. However, this is not the case for the input voltage V_3 as the input impedance is frequency dependent.

While these two drawbacks – the floating capacitor and the frequency dependent input impedance – can be solved if needed, obviously this requires additional active elements. Finally, it is worth mentioning that the output resistance of the proposed circuit is high and that a voltage mode circuit can be easily obtained using an additional OTA configured as a grounded resistor.

Using Equations 2 to 11, it is easy to show that all the passive sensitivities of the gains, and the parameters ω_0 and $\frac{\omega_o}{Q_o}$ are lesser than or equal unity. Thus the proposed circuit parameters enjoy low passive sensitivities.

Experimental Results

The proposed circuit was tested using the 3080 OTA. The results obtained with $C_1 = C_2 = 1nF$, $g_{m1} = 10mA/V$, $g_{m5} = 0.1mA/V$ and $g_{m2} = g_{m3} = g_{m4} = 1mA/V$ are shown in **Figures 2** to **5**. For the notch realisation, $g_{m5} = 1mA/V$. The output current was sensed using a $10k\Omega$ resistor connected to the output of OTA1.

Figures 2 to 5 also show the calculations made using Equation 1. It appears from Figures 2 to 5 that the experimental and calculated results are in fairly good agreement.

Conclusion

In this paper a new transadmittance type universal filter has been presented. The circuit uses only five commercially available single-output OTAs and two capacitors and can realise lowpass, highpass, bandpass, allpass, notch lowpass notch and highpass notch transfer functions.

The parameters of the realised filters enjoy electronic tenability; thus, the centre frequency, the bandwidth and the gain can be electronically tuned without disturbing one another. The circuit also enjoys high output impedance and the use of grounded capacitors for the lowpass and bandpass realisations.

In order to confirm the operability of the proposed circuit, experimental results reported in this paper were obtained using relatively large capacitors. However, for integrated circuit implementations, these capacitor values are not appropriate. Thus, in order to work within the bandwidth of the OTAs, transconductances values may be reduced.

Muhammad Taher Abuelma'atti and **Abdulwahab Bentrecia**
Saudi Arabia

FROM THE DARK INTO LIGHT

By Chris Williams, UKDL

It is hard for us in the developed world to understand that more than two billion people across the globe have no access to electricity for lighting, heating or cooking. The history of the 19th and 20th centuries shows that having access to electricity in all its manifestations is one of the prime movers for a nation to move from poverty to a state of greater wealth, and for the people of a nation to become educated and to contribute to the creation of more wealth.

In the rural, remote areas of the developing world, there is simply no access to mains electricity. Flick a switch and we have light – that basic assumption we have in the west is a far-off dream for far too many people. It is to our shame that too many people around the world must rely on the kerosene lamp as their sole source of lighting in the hours of darkness.

This primitive type of light is not only dangerous with its live flame a continual fire risk; the emitted sooty residues are a major environmental hazard and significant contributor to greenhouse gas emissions. One lamp may not be thought of as much of a hazard, but there are likely to be more than one billion of these lamps in use at any time around the globe. It is a matter of national and international concern that alternative, more efficient ways of generating light are developed and widely distributed to hasten the demise of the kerosene lamp off the world scene.

BATTERIES CAN BE MAJOR SOURCES OF POLLUTION WHEN IT COMES TO EVENTUAL END-OF-LIFE, SO IT IS ESSENTIAL TO MAKE SURE THAT A MAJOR IMPLEMENTATION PROGRAMME LIKE THIS IS ENTERED INTO WITH AN UNDERSTANDING OF THE FUTURE RISKS

An example of how this problem can be effectively addressed is well demonstrated in India by the co-coordinated actions of industry, government and international finance organisations. The Indian economy is growing strongly and the wealth of the nation is increasing. However, this growth brings with it considerable problems: those sections of society that are creating wealth wish to invest part of their net earnings into new electrical goods, increasing the demand on the national supply grid.

At the same time, almost half of the Indian population, living in poor or remote areas, has no electricity at all. This problem is compounded by the fact that where there is electrical supply, most domestic and commercial lighting is still met by the use of low efficiency incandescent bulbs. It is estimated that there are more than 900 million light sockets in India using GLS incandescent bulbs today.

The Indian government is addressing this problem with a pragmatic approach – develop high-efficiency solutions for electrical items in use in the developed parts of the country and implement a programme of alternative energy solutions to provide light and power to remote areas, where the supply of electricity from the grid is impossible or economically unsustainable.

This is a massive project – to replace 900 million incandescent bulbs with, say, compact fluorescent light (CFL) bulbs is no trivial problem. The existing domestic manufacturing capacity for CFLs in India is of order 60 million pieces per year. Even at these high production rates, it would take more than a decade to retrofit existing lamps, and that rate isn't fast enough to provide the energy savings that are needed to match the growth in the economy.

Figure 1: *Typical kerosene lamp, still used today in the developing world countries*

In addition, CFLs of their own cannot replace a kerosene lamp, so radical product designs are necessary to meet these requirements at a price that the country can afford. A number of Indian manufacturers have designed and are manufacturing High Brightness LED (HB LED) street lamp assemblies and luminaires for commercial and industrial use. Even the kerosene lamp itself now has serious, long-term competition from inorganic LEDs.

White LEDs from a number of offshore manufacturers are being housed into individual lanterns and these are, in turn, matched with small solar cells linked to an internal rechargeable battery. The solar cell recharges the battery during the day and the battery drives the LEDs at night. Simple! Now the challenge is to control the costs to drive the purchase price down and manufacture 400 million of them.

Individual lantern assemblies are relatively simple to understand and to develop. The challenge will be to

Figure 2: *Integrated lantern comprising solar cell, rechargeable battery and array of white LEDs*

manufacture cheaply and distribute such huge numbers of devices. Plus, batteries themselves can be major sources of pollution when it comes to eventual end-of-life, so it is essential to make sure that a major implementation programme like this is entered into with an understanding of the future risks that will be met when the first generations of lanterns come to the end of their lives and must be disposed of.

The greater challenge is to develop off-grid solutions for community lighting projects in remote areas. Here, the demand is for reliable sources of lighting for assemblies of people in halls and other public places. An assumed solution would be to install diesel or gasoline powered generators driving conventional lighting systems. A reasonable first generation solution, but one that of itself faces many challenges. In remote areas, how can the fuel to power the generators be economically and reliably delivered?

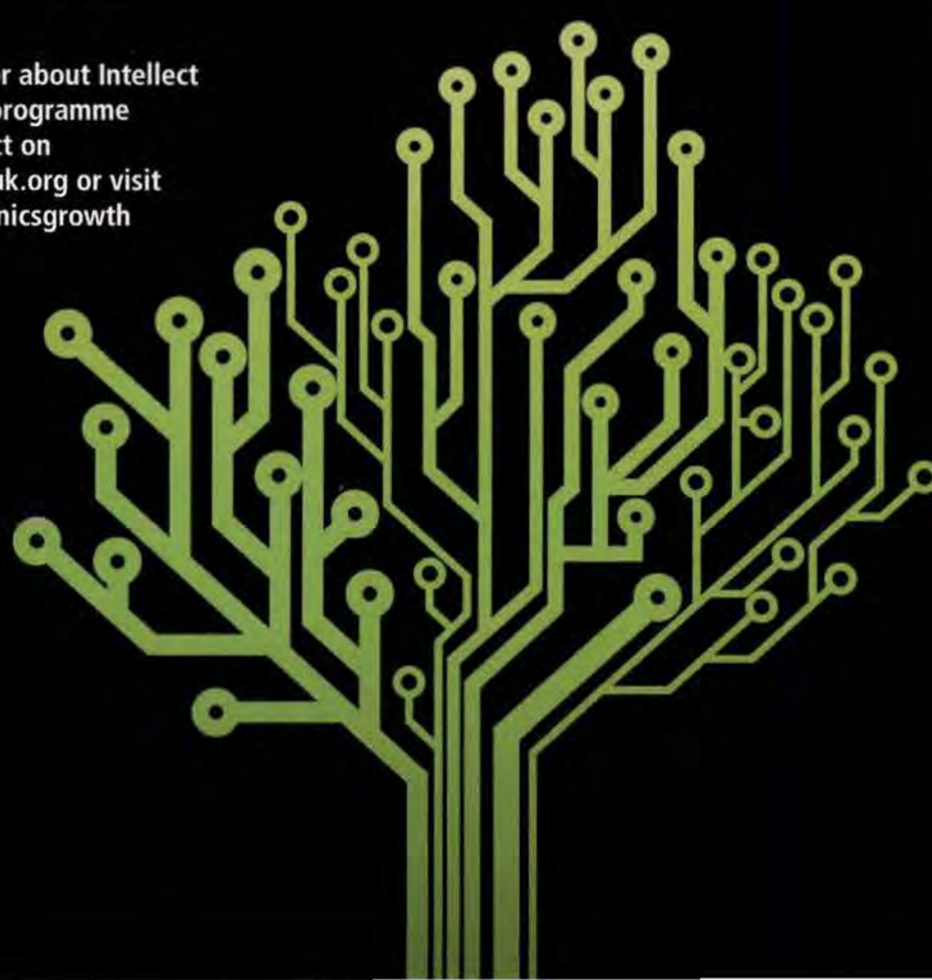
Microgeneration systems using a variety of alternative energy sources are the modern solution. Within the realms of power generation "microgeneration" is the term reserved for power generation of 50kW or less. Combinations of photovoltaic cells, micro-wind turbines, micro-hydro turbines and even anaerobic waste material digesters are all under development or are currently available to supply power levels from 500 watts up to 50kW.

Improving the availability of these systems is allowing electricity dependent systems, such as mobile phone repeater stations, to be installed in even the most remote and difficult areas, allowing the communities that they will serve to be catapulted forward into the 21st century. Smaller systems will allow communities to install various ultra-efficient lighting technologies and to use power-efficient appliances, thereby experiencing the benefits of more "advanced" civilisations without the need to build a conventional power station.

The major developing nations of Africa, India, China and Brazil are all committed to implement energy-efficient heating, lighting and general electrical power solutions, using the best of the technologies that have been developed by the industrialised nations.

In the next half-century we will truly have a chance to help the poor nations of the world share in the technological benefits that we enjoy every day. In return, these nations will offer a manufacturing resource that will, if we join with them in partnership, allow us to control the costs of the technologies that we wish to use ourselves. ■

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



TIP: SLOW RESPONSE SERVO CIRCUIT

By Jim Mahoney, Associate Design Engineer, Linear Technology

You have just spent $10,000 and put in hundreds of hours to build the latest true turbojet-powered, radio-controlled, scale model of an F104 Star Fighter, a model that weighs 30 pounds and that will fly at 250 miles an hour. What you don't need is an engine flame out due to throttle mismanagement!

The circuit presented on the next page controls the rate at which a miniature turbojet engine can be throttled. Increasing or decreasing the throttle too quickly on a miniature turbojet engine, or any jet engine, can lead to quick failure in flight causing expensive repairs and potential safety problems due to flameouts. This circuit can be used as an analogue backup circuit in a microcomputer-based throttle controller or as the primary throttle rate controller. The response rate, servo direction, CW and CCW gain (end points) and servo centering parameters are adjustable.

CIRCUIT DESCRIPTION

This circuit takes a received radio control, incoming, positive-going pulse, which varies from 1 to 2ms (the standard for most aircraft radio control systems), at a fixed frame rate of 20ms, integrates it over time and uses the output of the integrator to control the output pulse width of a 555-based monostable. The rate of pulse width change is determined by the effective integrator time constant, R24 and VR1 in series, C1, and the duty cycle of the incoming pulse stream. Q1 is switched on for the duration of the positive going pulse applying +5V to the integrator input resistor, R24 and VR1 in series.

The circuit is designed such that a point will be reached where the effective charge rate, based on the input pulse width, and the reset/discharge rate of integration capacitor C1 by R1 balance out for each positive pulse duration, and the output of integrator U3 stabilises at a DC value as a function of the received pulse width.

An LTC2054 Zero-Drift op-amp is used for the integrator. The LTC2054 has an ultra low input bias current, ±1pA typical ±150pA Max, offset voltage of 3µVand a drift spec of 30nV/°C Max. An open-loop gain of 140dB typical, a PSRR and CMRR of 130dB typical and a low noise spec of 1.6µVP-P typical, all add up to an excellent op-amp for the integration function.

The LT1120A low voltage regulator includes a reset output used to hold off any output from U5 until the integrator output has had time to reach an output after one full time constant. The low dropout regulator delivers a well-regulated 4V from a 4.8V NiCad battery, even when the battery voltage is pulled down to 4.2V under heavy loads, such as using high current digital servos.

U4: A provides gain and the ability to independently adjust the CW and CCW end-point travel. Diodes D1 and D2 effectively split the feedback path when the input signal is above or below the 2.35V Ref level on pin 5. This circuit is a basic precision rectifier used as a gain splitter.

U4: B buffers and sums the CW and CCW signals.

U4: C, a ±1 gain amp, adds the servo reverse function as will as providing a servo centre position adjustment.

Op-amp U4: D and resistors R11 and R12 generate the 2.35V pseudo-ground reference for the single supply op-amps. The 2.35V value is chosen to be centered within the op-amp's input common mode range to give symmetrical output swing. The centering adjustment VR4 sets the input control voltage of the 555 Timer to its input control voltage mid-point. An LM334 constant current source set to 16ua, charges timing capacitor C11 with a constant current to achieve linear response to the input pulse. D3 and R14 are used to negate the 10mV/^{0}C temperature coefficient of U6 the LM334. The circuit is rounded of with two LMOS TC7S14F Schmitt inverters for signal buffering.

CONCLUSION

The circuit described here provides a very smooth adjustable servo response without having to use a high value electrolytic capacitor or very large value resistors. Servo centre adjustment, servo direction and independent end-point adjustments are included.

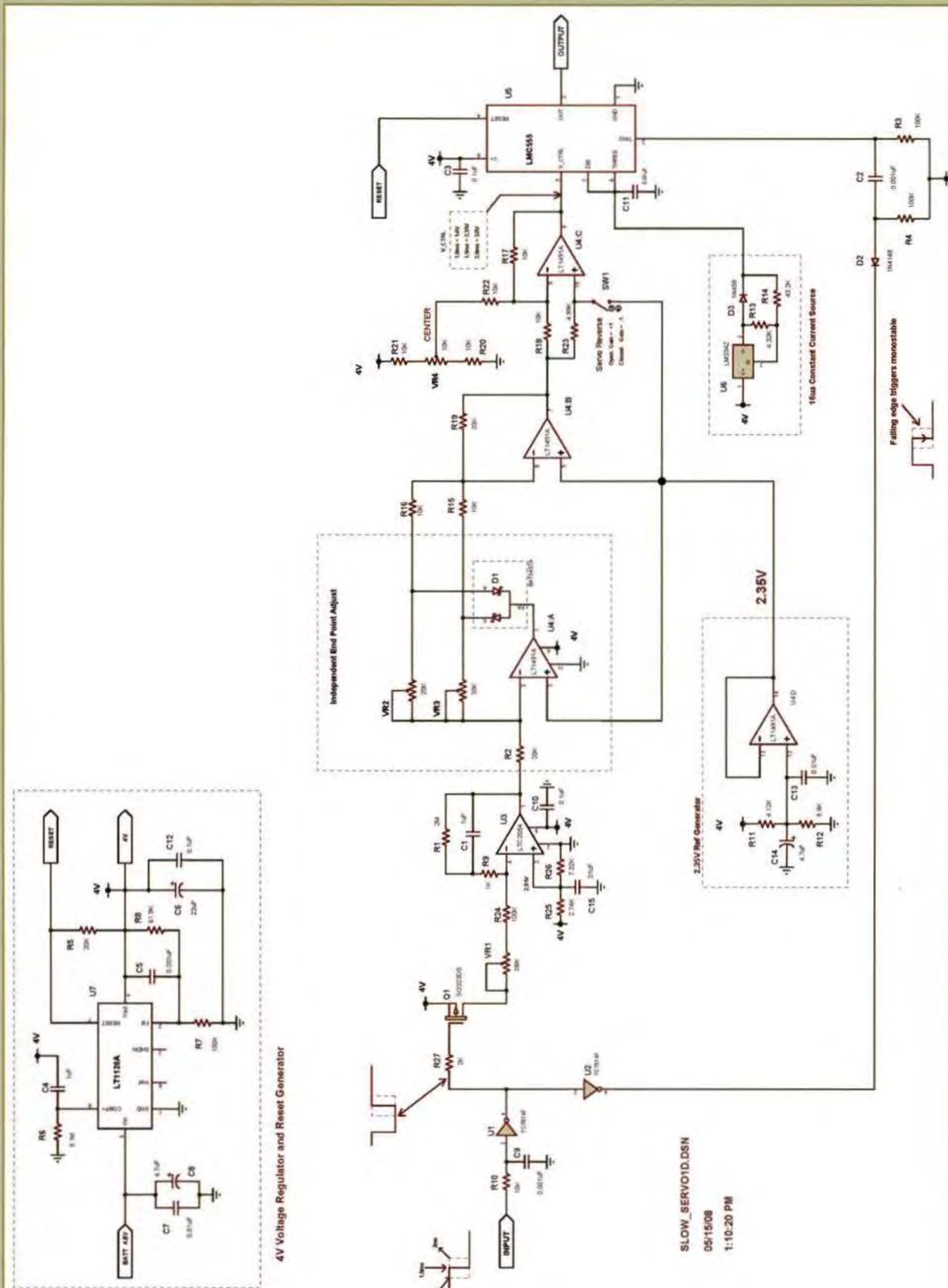


Figure 1: Design schematic

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Broadcast Equipment Programmable Switches

Arrow has announced the availability of a broad range of switches ideally suited to the requirements of audio visual and broadcast equipment. The range of illuminated switches from manufacturers such as NKK (Nikkai) Switches and C&K Components provide a variety of colour options, while programmable devices offer the flexibility to display application-specific text or even moving images.

Among the NKK switches available from Arrow is the HB2 series of subminiature pushbutton devices offering full-face illumination with a choice of red/green or red/yellow bicolour LEDs and the UB and UB2 series of low-profile pushbuttons. The UB series features bright and superbright LEDs and has a body height of just 10mm, while the UB2 series offers a wide selection of illumination effects with single and bicolour, one- or six-element LEDs.

The C&K Components family of illuminated switches from Arrow incorporates the 8020 and 8060 series of momentary pushbuttons, the K5V and K5AT series of tactile devices, and a variety of key switches from the K6, K12 and Digitast ranges. Arrow also offers the C&K ELUM, a right angle latching pushbutton with central LED illumination and a low PCB mounting height.

www.arrow.com

Hand Controller Enclosures with Trigger Action

OKW has added two new models to its 'SENSO-CASE' series of hand controller enclosures. These new models have an integrated pushbutton switch, in the natural trigger position on the underside of the case, which ensures logical fatigue-free operation of the unit for activation and logging functions. Typical applications will include measuring and control units, machine and robot controllers, stock and sales logging equipment, medical and laboratory technology and opto-electronics.

The 'SENSO-CASE' enclosures have an ergonomic hand grip profile with a large head section, and are moulded in off-white or lava grey ABS (UL 94 HB). The external dimensions are 180mm x 86mm x 45mm.

The design consists of four parts: top, base, battery compartment lid and an end panel. Screw pillars are provided inside for mounting PCBs, keypads, cable clamps etc. The new models are supplied with a single pole push-button switch (max. 28V/100mA), assembly elements for the switch, and an orange rubber button cover moulded in soft TPE.

'SENSO-CASE' enclosures permit both right and left-handed operation and can be used as mobile units with battery power or connected via a cable.

www.okw.co.uk/senso

Micropower Hall-effect Latch IC

The new A1174 from Allegro MicroSystems Europe is an ultrasensitive micropower Hall-effect latch IC with internally or externally controlled sample and sleep periods for use in portable devices that employ rotational speed and direction sensing systems, such as tracker balls or scroll bars for PDAs, mobile phones or MP3 players.

The new device, which is designed for use in systems with a power supply voltage between 1.65V and 3.5V, has a single push-pull output structure and does not require an external pull-up resistor for reliable operation. When a sufficient positive magnetic field is present on the device, the device output switches to the low state and is latched in this state until a negative field of sufficient strength latches the device output into the high state.

The A1174 is not just a simple micro-power latch. It has different clocking modes that can be used to control the average power consumption in portable applications, while optimising it for a particular application. Average current consumption in dual or external clocking modes is more than ten times lower than the average micro-power latch.

www.allegromicro.com

Complex Transistor DTDG Series

ROHM presents its new complex transistor DTDG series which is developed for the drive circuit of solenoids, motors and relays, integrating resistors and a Zener diode.

Zener diodes have the function of absorbing back electromotive force surge voltage from L-load to avoid the breakdown of the transistor by overload voltage. Therefore, an external protection diode in this case is not necessary. Input resistors are built-in to enable the direct drive by the control IC (DTDG23YP).

The DTDG series is available in different line-ups such as the MPT3 and the TSMT6 with a different range of voltage, IC, hFE and resistance.

The products are available now.

ROHM offers electronic components worldwide. Over 20,000 employees produce a wide range of internationally marketable products, such as integrated circuits, diodes, transistors, resistors, capacitors, display units and special designs in manufacturing plants in Japan, Korea, Malaysia, Thailand, the Philippines and China. ROHM serves the central European market, North Africa and Russia with a staff of 145 in our sales locations all over Europe. For further information please contact:

www.rohmeurope.com

Filter Adaptors For D-Sub Connectors

Harting has introduced a new range of male and female D-Subminiature filter adaptors for effective electronic noise reduction in sensitive applications, such as high-speed digital broadcasting and industrial test equipment.

The new filter adaptors are equally suited to electromagnetic interference correction in existing applications and for quick and easy filter tests during the design phase. They complement Harting's existing range of D-Sub filter surface-mount connectors as a retrofit solution for providing system protection without the need for expensive PCB redesigns.

The filter adaptors are available in male and female versions with 9, 15, 25 or 37 pins, and with four standard filter values from 47 pF to 3900 pF.

The Harting Group develops, manufactures and distributes electrical and electronic connectors, network components, pre-assembled system cables and backplane assemblies. These products are capable of withstanding the harshest demands in industrial environments and provide high data rates for electronic applications.

Harting connectors and network components are used in mechanical engineering and plant manufacturing, in automation systems, energy generation and distribution and in electronic and telecommunication markets. It also offers Ethernet network components and cable systems for both indoor and outdoor networking applications involving power and data.

www.HARTING.com

DC/DC Converters With 4:1 Input

Murata Power Solutions has introduced its new UEI-series of isolated, wide-range DC/DC converters that deliver industry leading 50-60W of power output from a standard 40.6 x 50.8 x 10.16mm (1.6in x 2in x 0.4in) PCB-mounted, open frame package; plastic cased versions are available upon request.

DC/DC converters with 4:1 input deliver 18A/60W regulated 3.3V output in 1.6in x 2in package. Among its features are:

- 9-36VDC or 18-75VDC inputs
- Highest current from Industry-standard open-frame package and pinout
- Start up capability into pre-biased loads
- Extensive self-protection and shutdown features
- RoHS compliant and fully safety approved

The regulated UEI series has an operating temperature range of -40°C to +85°C and is ideal for a wide range of 'current hungry' applications including industrial, wireless and mobile communications, transportation, medical and instrumentation. The offering includes two 4:1 ultra-wide range input voltages: 18-75VDC Vin combined with outputs of either 3.3V @ 18A or 5.0V @ 12A for a total power of 60W, and 9-36VDC input, combined with 3.3V @ 15A, 5.0V @ 10A and 12V @ 4.2A for 50W of output power.

www.murata-ps.com

Versatile, Reliable Panel Mount Solid State Relays

Manufactured by TVS Cherry – a 50/50 joint venture between Cherry Electrical Products and the TVS Group – is a new range of panel mount solid state relays, designed for use in applications such as motor controls, traffic lights and vending machines.

The hugely versatile range of panel mount SSRs are TTL compatible (DC version), offer reverse voltage protection (Input) and are optically isolated (Input/Output). They also feature in-built snubbers, safety covers and zero cross/random turn ON functionality. The devices measure 58x 43x27mm.

The new panel mount solid state relays combine durability, high performance and low cost.

From a heritage as a leading manufacturer of snap action switches, Cherry has expanded its line of products to sensors and controls. Cherry's affordable, high-performance, speed and proximity sensors, electronic oven controls and patented cook top sensors bring greater functionality, efficiency and safety to a variety of everyday products.

Cherry switches and control assemblies allow auto manufacturers to offer their customers products that include door, seat and console controls, intelligent door latch and lock systems, advanced steering wheel and instrument panel controls and leading-edge seat belt sensors.

www.cherry.de

Full Patient Contact 500W Medical Grade Power Supply

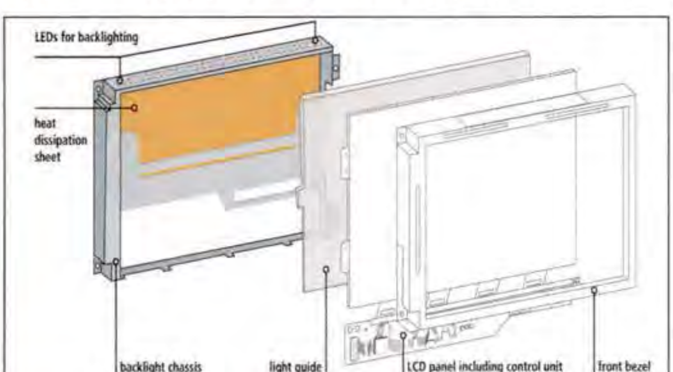
SynQor continues its entrance into the AC/DC marketplace with the introduction of the latest product designed specifically for medical applications. The AcuQor AQ0500M series of off line power supplies packs 500W of useable power into just 3.5" x 5.25" x 1.63", which is one of the the smallest cardiac care, medical grade AC/DC converter for this power level around.

The AcuQor family operates over a universal input range of 85-264Vrms and 47-63Hz. Through the use of SynQor's "QorCool" thermal conduction techniques, full output power is available when attached to a cold plate maintained at 50ºC. It has a transient power rating of 700W for up to 15 seconds. Active Power Factor Correction is incorporated to a level > 0.98, enabling compliance with IEC/EN61000-3-2. Both Line and Neutral are internally fused.

The AQ0500M series includes versions designed for both BF (direct patient contact) and CF (direct cardiac contact) applications in accordance with UL/EN60601-1. Input Earth Leakage Current and type BF/CF Patient Leakage Current are well below the requirements of the standard at < 125uA and 2uA respectively. Conducted noise emissions are below Level B limits of EN55011/55022, FCC part 15.

www.synqor.com

Luminous and Robust Industry LCDs with LED backlight



Sharp has launched an enhanced range of LED backlit liquid-crystal panels for industry applications. The portfolio now incorporates five displays in the screen diagonals of 3.5 to 15 inches.

The new LED backlit displays combine the high resilience required of industrial applications with the benefits of an LED backlight. These include, among others, the prompt response characteristics of the LEDs even at very low temperatures and excellent dimmability over the entire brightness range of the LEDs.

Another important advantage of the LED backlights is the low operating voltage. This means that the high-voltage inverter required for CCFL lamps is no longer necessary. This facilitates the use of the new Sharp industry LCDs wherever high voltage is hazardous, e.g. in areas where there is a risk of explosion. The high image quality of these new Sharp displays is based, among other things, on the high luminosity of the LED backlights of up to 550cd/m^2.

In order to achieve the operating temperatures required for many industrial applications, Sharp has designed the housing of the new LCDs specifically for the LED backlight and equipped it with dedicated heat management.

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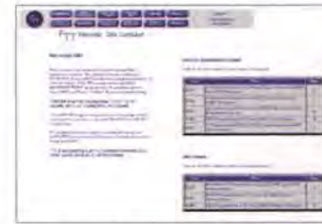

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