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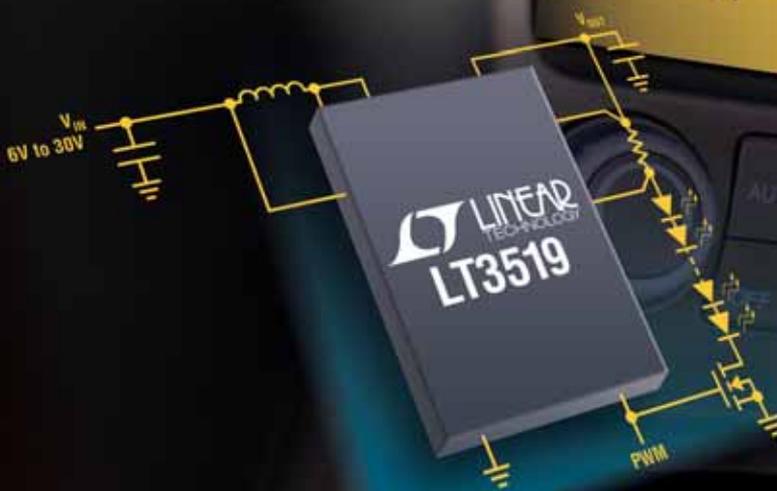
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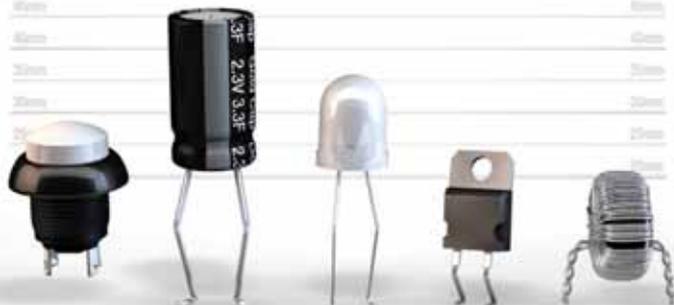
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TOP TRENDS AND TAKEAWAYS FROM THE 2011 CES

The 2011 Consumer Electronics Show (CES) was a feast of tablets, 3DTV, automotive technology, smartphones and everything in between. But looking beyond the innumerable products on display at CES begs the question: What's driving all this innovation and why? Each year, Consumer Electronics Association (CEA), the producer of CES, identifies four strategic trends that capture the spirit of the show. Going well beyond just technology innovation, these trends embody changes in consumer behaviour, deployment of new business models or shifts in content consumption.

To illustrate these points and give us some perspective on the big trends from this year's CES, it's worthwhile to look back at some developments we've highlighted in the recent past. A few years ago in 2008, we identified a trend we called '**360 degree solutions and experiences**', pointing to the increasing number of CE devices paired with content (and content delivery systems) right out of the box. EReaders, like the Amazon Kindle, serve as a good example of product class that eventually launched from this trend.

In 2009, we saw '**Evolving Command and Control**' as a big trend – a commentary on the evolving human machine interface to embrace voice, touch and motion showcased in smartphones, as one product example. Last year, we highlighted '**New Screens Find the Sweet Spot**' illuminating netbooks and the growing crop of mobile solutions. Fast forward to 2011 and we find a new batch of trends that are inextricably linked to the developments of the past few years. So what are the big trends from the 2011 CES?

Our immediate observation from the 2011 CES was demand for portability has created a heavily segmented mobility environment. The show floor was festooned with offerings across form factors and use-case scenarios. We call it '**Portability vs Pocketability**' with tablets emerging as the poster-child of this mega trend. Tablets embody this trend because they span the entire size range from pocketable like a smartphone, to portable like a laptop. Nearly 100 tablets were announced at the show although not all were present. Among the tablets exhibited at CES, the most impressive challengers to Apple's iPad included Motorola Mobility's Xoom, Samsung's Galaxy Tab and the RIM Playbook.

Another clear signal from the CES this year was how smart devices had become through a combination of processors, connectivity, software and interface. We use the phrase '**The Intelligence of Things**' to describe the innovation enabling devices

Clear signal from the CES was how smart devices had become through a combination of processors, connectivity, software and interface

to collect data and operate more intuitively, thereby transforming the user experience. Walking the show floor it was easy to spot numerous examples of this megatrend, with connected TVs, Internet radios, GPS digital cameras. However, smartphones were the most shining example. Increasingly, our mobiles are the chosen point of interface when it comes to communication, content and even commerce. And through an empowering array of sensors and multitude of apps, two trends we'll get to in a moment, the utility of smartphones is virtually infinite.

Automotive electronics is another area where we see this trend unfold. In new vehicles, solutions like Ford's Sync are changing the way we interact with electronics behind the wheel. Here, through connectivity and a user interface combining touch and voice, the focus is as much on safety as it is on communication and entertainment. Vehicle manufacturers worldwide are today deploying similar solutions to deliver a 21st century technology experience from the moment you turn the key.

Our next two trends are a love story between hardware and software. Two innovations that when married in today's devices create an experience people are passionate about. On the hardware side, the megatrend is '**Miniaturization and Sensorization**', which speaks to the fact that sensors, including cameras, accelerometers, GPS, microphones and more are getting smaller, less expensive and more ubiquitous. Microsoft's Kinect for Xbox is great example.

The last trend deals with software and we call it '**From Amplification to Applification**', underscoring how apps developers are changing the face of software and forever altering the CE user experience. Among all the TVs, smartphones, tablets or in-vehicle systems shown at CES, apps were as integral to the conversation as the devices themselves. In addition to driving personalization and greater utility, apps are fuelling new business models, which is the most significant part of this trend. However, CEA market research shows only one-in-five US online adults are willing to pay for apps. Clearly this is space to watch.

By Steve Koenig, Consumer Electronics Association

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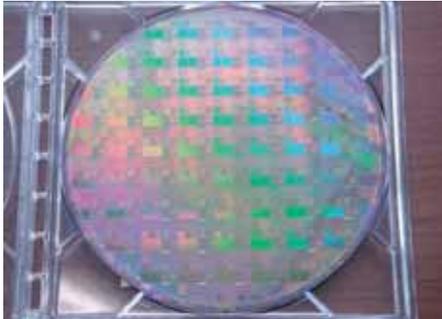
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NEC Works on the World's First Content Addressable Memory that Stores Data Without Using Power



Semiconductor wafer with world's first content addressable memory (CAM) from NEC

NEC and Tohoku University are developing the world's first content addressable memory (CAM) that can maintain the same high-speed and nonvolatile operation when its power is off.

NEC's new CAM is a part of spintronics logic integrated circuit

technologies that utilize the negative properties of electrons and their spin magnetic moment. The new CAM utilizes the vertical magnetization of vertical domain wall elements in reaction to magnetic substances, in order to enable data that is processing within the CAM to be stored on a circuit without using power. This contrasts conventional technologies that require data to be stored within memory. As a result, data can be saved on circuit even when power is cut from the CAM.

Use of the new CAM in combination with existing nonvolatile memory offers greater non-volatility of CPU for electronics and other storage devices. Furthermore, use of this new CAM enables the development of

electronics that start instantly and consume zero electricity while in standby mode.

In order for CAM to be both nonvolatile and maintain a high speed, NEC connected two spintronics devices – spinning in opposite directions to one another – within the same cell. In terms of constructing the circuit, writing is done once by connecting two devices in a series using recently-developed three-pin particles that separate the current path into writing and reading. The new process enables cells to become more compact since the number of writing switches per element is reduced by one. Moreover, the new CAMs achieve the same level of high-speed data retrieval as current CMOS based CAM that feature 5ns

and low power consumption of 9.4mW.

Equally, the newly developed CAM circuits can reduce the number of transistors from eight to three in every two cells by sharing transistors. This results in a 50% CAM area reduction.

In recent years, the use of ICT equipment has steadily increased due to the widespread growth of cloud computing. Most existing equipment requires a short amount of time to get started and internal circuits remain active when the equipment is in standby mode. Therefore, the growing consumption of power by ICT equipment in standby mode has become a serious concern and NEC and other semiconductor companies are seeking to address it.

NEW DEVICE CAPTURES AMBIENT ELECTROMAGNETIC ENERGY TO DRIVE SMALL ELECTRONIC DEVICES

Researchers at the Georgia Institute of Technology in the US have discovered a way to capture and harness energy transmitted sources such as radio and television transmitters, cell phone networks and satellite communications systems. By scavenging this ambient energy from the air, the technique could provide a new way to power networks of wireless sensors, microprocessors and communications chips.

“There is a large amount of electromagnetic energy all around us, but nobody has been able to tap into it,” said Manos Tentzeris, a professor in the Georgia Tech School of Electrical and Computer Engineering, who is leading the research. “We are using an ultra-wideband antenna that lets us exploit a variety of signals in different frequency ranges, giving us greatly increased power-gathering capability.”

Communications devices transmit energy in many different frequency ranges, or bands. The team's scavenging devices can capture this energy, convert it from AC to DC, and then store it in capacitors and batteries. The scavenging technology can take advantage presently of frequencies from FM radio to radar, a range spanning 100MHz to 15GHz or higher.

Tentzeris and his team are using inkjet printers to combine sensors, antennas and energy-scavenging capabilities on paper or flexible polymers. Scavenging experiments utilizing TV bands have already yielded power amounting to hundreds of microwatts, and multi-band systems are expected to generate one milliwatt or more. That amount of power is enough to operate many small electronic devices, including a variety of sensors and microprocessors. In addition, by combining energy-



Georgia Tech School of Electrical and Computer Engineering professor Manos Tentzeris displays an inkjet-printed rectifying antenna used to convert microwave energy to DC power. This grid was printed on flexible Kapton material and is expected to operate with frequencies as high as 10GHz when complete [Credit: Gary Meek]

scavenging technology with super-capacitors and cycled operation, the Georgia Tech team expects to power devices requiring above 50mW. In this approach, energy builds up in a battery-like supercapacitor and is utilized when the required power level is reached.

The researchers have already successfully operated a temperature sensor using electromagnetic energy captured from a television station that was half a kilometer distant. They are preparing another demonstration in which a microprocessor-based microcontroller would be activated simply by holding it in the air.

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- ▶ Passive keyless entry (PKE)
- ▶ Sensor networks



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4W LED Driver Efficiently Drives LCD Displays & Other Applications



By Keith Szolusha, Senior Applications Engineer, Linear Technology

INTRODUCTION

As the number of applications for medium power (1W–4W) LED strings grows, so does the need for compact, efficient, high performance LED drivers. The LT3519 LED driver satisfies the needs of a wide variety of applications, including LCD displays, automotive and avionic applications, architectural and industrial lighting, portable projection and scanners. Its 16-pin MSOP package includes accurate LED current regulation, small size, high efficiency, PWM and analog dimming for brightness control and open circuit protection with fault detect.

EASY LAYOUT: INTEGRATED POWER SWITCH, COMPENSATION COMPONENTS AND SCHOTTKY

The 400kHz LT3519 LED driver features an integrated 750mA 45V peak power switch, integrated compensation components and an integrated low leakage Schottky diode, making designs simple and small. Despite this high level of integration, it can be used in a wide variety of topologies, including boost, SEPIC, buck mode or buck-boost mode. For maximum versatility, the Schottky

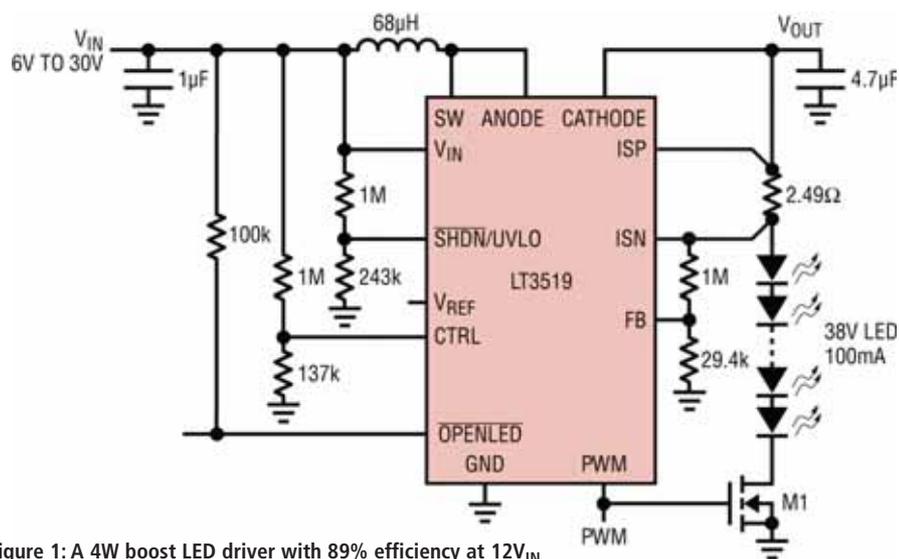
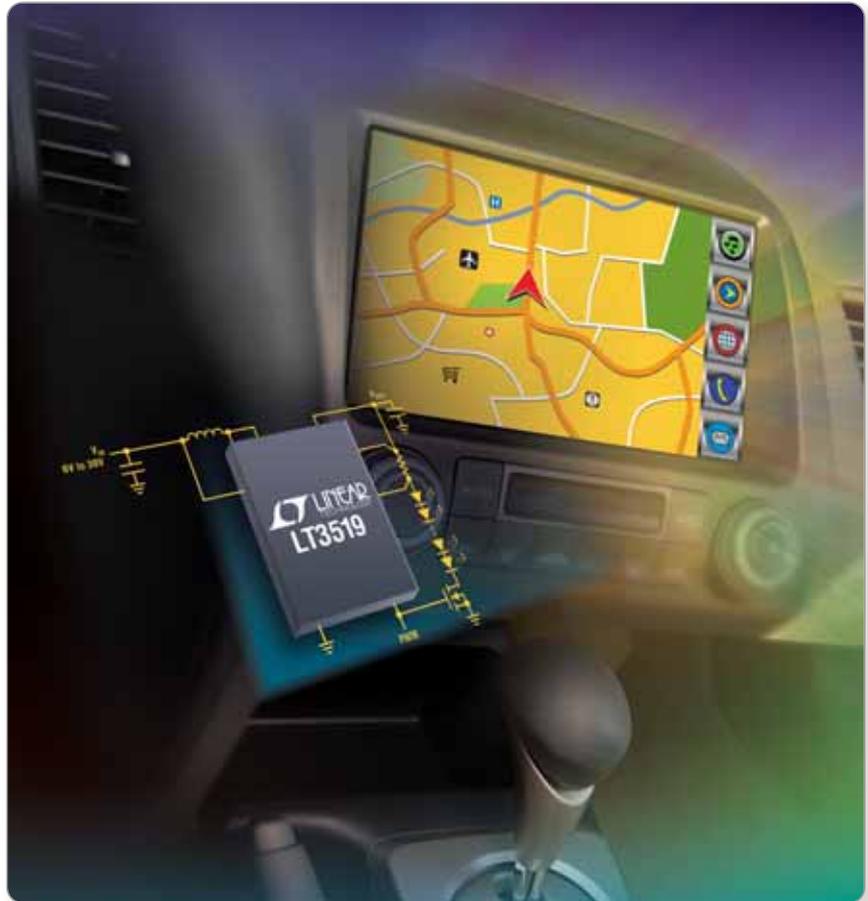


Figure 1: A 4W boost LED driver with 89% efficiency at 12V_{IN}

diode anode (ANODE) and internal power switch emitter (SW) pins are separately pinned out, so a SEPIC coupling capacitor can be inserted between these two.

The internal compensation components are chosen to match the 2.2µF to 4.7µF output capacitors in all of the topologies mentioned above. The integrated compensation network combined with current mode control yields fast and stable transient response.

/OPENLED detection and fault reporting are included. A simple resistor divider sets the over-voltage protection output voltage in case of an open LED string and a small pull-up resistor is all that is needed to assert the open collector /OPENLED output pin during a fault.

4W BOOST LED DRIVER

The simple boost LED driver in Figure 1 drives up to 38V of LEDs at 100mA from an automotive input voltage range. The 400kHz switching frequency is common for automotive, avionic and industrial solutions; it combines high efficiency, small inductor and capacitor size, and high PWM dimming capability while avoiding frequencies in the AM broadcast band. A small inductor with about 750mA saturation current rating, a few ceramic capacitors and several tiny resistors are all that are needed to complete the design. As shown in Figure 2, the tiny PWM dimming MOSFET can be used to provide over 1000:1 PWM dimming at 120Hz using the integrated LT3519 PWM dimming architecture and an extremely low leakage integrated Schottky diode.

A 1000:1 dimming ratio at 120Hz is exceptionally high for a 400kHz switching regulator. It can be tempting to bump up the dimming ratio by choosing a higher frequency driver, since in general, higher switching frequency corresponds to higher PWM dimming ratios. In this case, avoiding the AM band means jumping to 2MHz, which in the end reduces the maximum duty cycle and the efficiency. The 400kHz switching frequency of the LT3519 does what 2MHz converters cannot do: it provides high duty cycle for operation down to $6V_{IN}$ with $38V_{LED}$ and as high as 89% efficiency at $12V_{IN}$. If PWM dimming is not needed, the MOSFET M1 can be removed and the analog dimming (CTRL) pin can be used to adjust the regulated LED current below 100mA for simple brightness control.

2.4W SEPIC LED DRIVER

When the LED string voltage is within the input rail voltage range, a SEPIC topology is called for. The SEPIC produces a high PWM dimming ratio and also gives short-circuit protection. The SEPIC in Figure 3 drives 16V LEDs at 150mA from a 4V to 24V input range. Since the anode of the integrated catch diode (ANODE) is made available at a pin independent of the NPN power switch emitter (SW), the coupling capacitor is easily inserted between the two. The maximum voltage that the SW pin sees is a little above

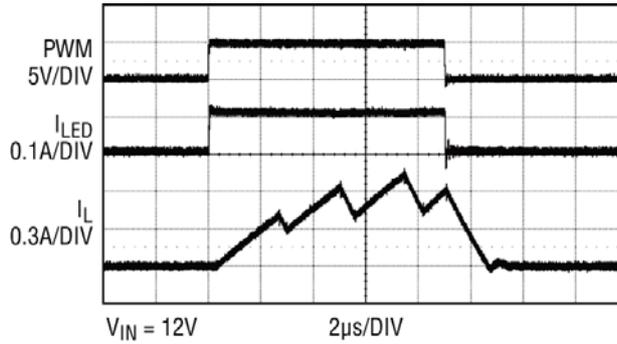


Figure 2: Integrated PWM dimming yields 1000:1 dimming at 120Hz

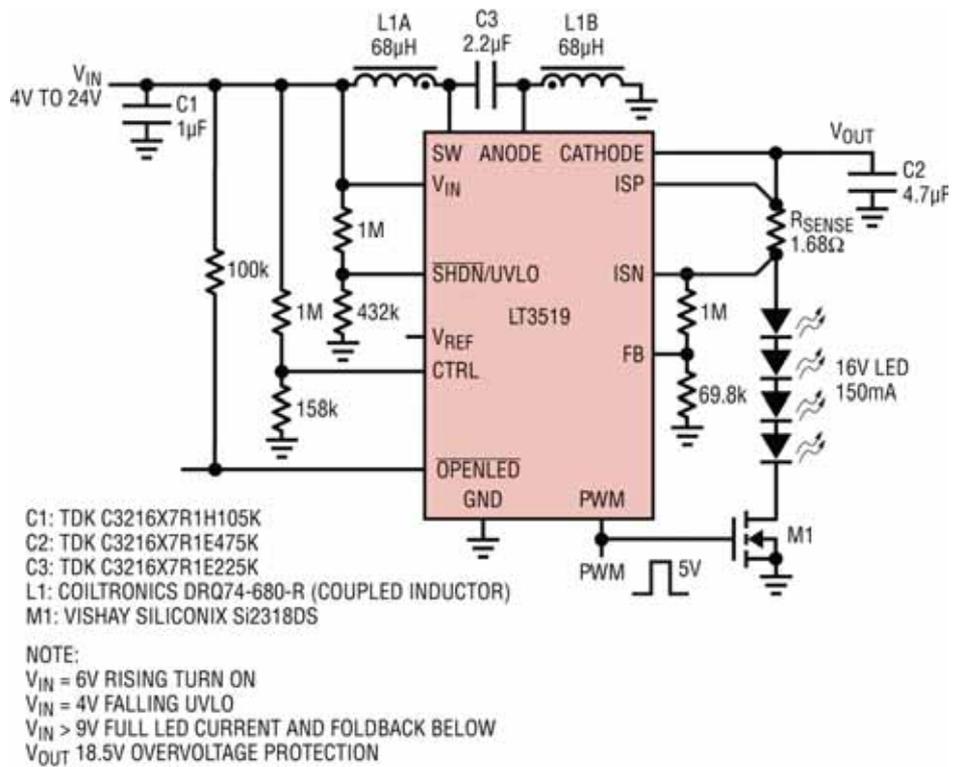


Figure 3: A SEPIC LED driver with short-circuit protection

the input voltage plus the output voltage, so the 45V 750mA integrated power switch is a perfect match for these specifications.

CONCLUSION

The 400kHz LT3519 is a 4W LED driver that integrates a number of required components, including a 45V, 750mA power switch, a low leakage Schottky diode and compensation components. It

also features PWM dimming, overvoltage protection and /OPENLED fault detection, making it a small, simple, and efficient choice for automotive, avionic, industrial and other LED driver applications. ●

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Lighting and Legislation

GARY NEVISON, HEAD OF LEGISLATION AT FARNELL EUROPE, PROVIDES A SUMMARY OF LIGHTING LEGISLATION REQUIREMENTS IN THE EUROPEAN UNION (EU) AND THE EUROPEAN ECONOMIC AREA (EEA)

Cree MR4 lighting module assembly



Lighting products, comprising lamps, luminaires and associated controls, have been within scope of the WEEE directive (2002/96/EC) since August 2005. This means that the “producer” is primarily responsible for ensuring proper treatment and must finance the process. All products must be marked with the crossed wheelie bin symbol. The producer must register in each EU State where they place product on the market – this will not be the manufacturer in every case but the importer into that State – and join a compliance scheme covering every geographic area where they place products on the market. It is not likely that a “large-scale fixed installation” exclusion (WEEE or RoHS) would include lamps.

Substance Restrictions

Two requirements exist: they are REACH (1907/2006) and RoHS (2002/95/EC). RoHS has restricted six substances in lighting products since 1st July 2006. In certain cases exemptions exist and there is an extensive list of these.

There are several exemptions relating

specifically to lamps (numbers 1 to 4), all of which concern the allowable concentration of mercury in the lamp gas. In the latest revision of the exemptions many of the concentration values have been reduced and/or made more specific to lamp power, and several lamp applications have mercury restrictions for the first. This trend will continue under future revisions. Mercury restrictions arising from eco-design regulations have been implemented through revisions in RoHS exemptions.

The new RoHS Directive was published in the Official Journal on July 1st this year and has become law on 21st July. Governments then have 18 months to transpose into national law

(2nd Jan 2013). All products within scope will then be subject to the conformity assessment (CE marking) regime.

In general, REACH applies to all lighting products without exception. There are two essential aspects to REACH:

1. Restriction

The marketing and use of products containing certain substances is prohibited. For example cadmium has been banned in most applications for almost 20 years. Restrictions may have certain exemptions and may contain limits or simply just prohibit a use.

2 Authorisation and Substances of Very High Concern (SVHCs)

Authorisation would prohibit the manufacture or placing on the market of an SVHC. As this only applies to the substance itself it would not affect lighting products made outside the EU and imported. No authorisations are in place yet.

Where an SVHC is present at >0.1% by weight of a product as placed on the market it is declarable to the customer:

B2B: The supplier must inform the recipient automatically of the name of the SVHC and steps required to ensure safe use (if any).
B2C: The vendor must provide the customer with this information within 45 days of request.

Most manufacturers are apparently struggling to fulfil this requirement according to recent surveys.



Farnell has an LED Lighting microsite for design engineers

The comprehensive LED lighting website offers design engineers one source for transaction and information on the latest LED lighting products including product and solution-based guidance for applications such as street lighting, MR16s, solar power signals and RGB colour mixing, as well as access to a wide range of design and collaboration tools via element14, its eCommunity site for design engineers.

The microsite can be found at: <http://www.farnell.com/lighting>

Farnell has a new microsite aimed at lighting design engineers

Enforcement action would not be surprising as a result.

46 SVHCs already exist. Of these about 20 are used in engineering products. Several commonly used phthalates are SVHCs and might be found in housings.

Eco-Design and Energy Labelling

The eco-design (2009/125/EC) creates a legal framework for subsequent implementing measures (regulatory or self regulatory). The focus is on reducing energy consumption in use both on and off-load. All products regulated are subject to conformity assessment (CE marking). Lighting is covered as follows:

Tertiary lighting (office and public): A regulation (245/2009 and amendment 347/2010) entered into force 14 Apr 2009. The first requirements applied from 14 Apr 2010. The regulation covers:

- a) Fluorescent lamps without integrated ballasts, and ballasts and luminaires able to operate such lamps,
- b) High intensity discharge lamps, and ballasts and luminaires able to operate such lamps,
- c) Lamps designed for office lighting, and ballasts and luminaires able to operate such lamps,
- d) Lamps designed for public street lighting, and ballasts and luminaires able to operate such lamps.

Fluorescent lamps include both linear and compact types.

Annex II lists the types of lamps and luminaires excluded from this regulation, such as directional lighting, certain UV and infrared lamps, the types of lamps used as LCD backlights and luminaires for emergency lighting and those covered by specified existing EU directives.

The eco-design requirements for groups a) and b) above are given in Annex III. This comprises 12 pages with 14 tables and is very complex. It lists requirements for luminous efficiency

(lumens/watt) for each nominal wattage of each type of lamp; lamp lumen maintenance factors (ratio of light emitted after a specified period of use; and light emitted when new) and survival rates (fraction which continue to operate after a given time).

There are also requirements for ballasts and luminaires. Annex III defines what information needs to be provided in the technical documentation file, with the product and on a company's website or other product literature. All of the above parameters must be reported plus mercury content, colour rendering and temperature and optimum operational ambient temperature.

Non-directional lighting: The scope of the measure (244/2009) is essentially white light, non-directional

lamps for household use or similar sold for non-household use, or when part of other energy-using products (e.g. an oven). It does not cover fluorescent lamps without integrated ballast and high intensity discharge lamps (as this is covered by 245/2009), high intensity tungsten halogen (> 10000 lumens), certain low voltage ($\leq 60V$) lamps and lamps able to operate at high ambient temperature ($\geq 300^{\circ}C$).

The requirements are similar to those already agreed for office lighting:

Labelling: A+++ to G.

Minimum efficacy

(lumens/watt): Except for very low power/brightness lamps and a number of incandescent lamps with certain caps (power



**LIGHTING'S
NECESSARY
REQUIREMENTS**

THE FOLLOWING REQUIREMENTS APPLY 1, 3 AND 8 YEARS AFTER COMING INTO FORCE (I.E. DATED FROM 14 APRIL 2009):

1 year – Requirements result in phasing out of T8 type halophosphate and high pressure mercury lamps. These can be replaced using the same luminaires.

3 years – Phase out of T12 and T10 halophosphate lamps, some luminaires will also need to be replaced. The least efficient sodium and metal halide lamps will also be phased out but this will not affect their luminaires. Luminaire obligations will begin phasing out magnetic ballasts and inefficient lamps.

8 years – Inefficient replacement lamps and magnetic ballasts will be phased out even if luminaires also need to be replaced.

It is planned to review this measure after five years and so changes to the obligations at 8 years could be made or brought forward.

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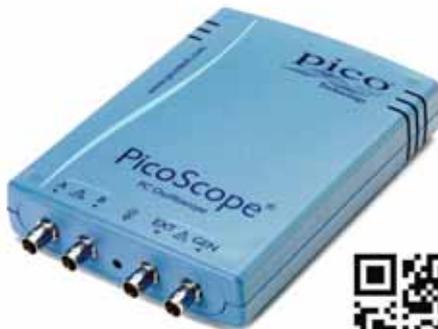
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THE UPDATED BATTERIES AND ACCUMULATORS DIRECTIVE (2006/66/EC) ENTERED INTO FORCE ON THE 26 SEPTEMBER 2008. AS SOME LIGHTING CAN CONTAIN BATTERIES THIS IS RELEVANT. RELEVANT REQUIREMENTS:

Substance restriction (like RoHS) it restricts:
Hg < 0.0005% by wt (but button cells < 2% ok)
Cd < 0.002% by wt

Batteries must be "readily removed" from products: Equipment supplied with installed batteries must include instructions on how they can be changed.
Exclusions: Batteries used for military/national security or space.

Cd ban does not apply to: Emergency and alarm systems, including emergency lighting medical equipment and cordless power tools (exclusion may be removed later).

Disposal requirements (like WEEE): There is some variation across the EU; in the UK, for example, you must register and join a compliance scheme (B2C) or ensure batteries are recycled (B2B) if the equipment you put on the market contains batteries.

Eco-design (labelling and information to consumers): Labelling, capacity marking and substance restrictions should largely be sorted out by the battery manufacturer (but the party putting the lighting on the market needs to ensure this is so).

terminations) or vibration resistance. The first stage of these requirements applied from 1st September 2009 and tightening annually thereafter.

Lamp functionality: Limits are set from the 1st September 2009 for rated lamp life and how many must still be working at that point, ability to maintain their original brightness, switching life, speed of start-up, premature failure rate, colour rendering, power factor and more. These limits tighten further 4 years later.

Information to consumers: Much of the above must be made available to end users when they buy and also on the web. Major emphasis is on giving the purchaser adequate information to form a proper understanding of the relative performance of lamps based on functionally important parameters, such as perceived brightness (called nominal luminous flux) being displayed more prominently than power consumption.

Directional lighting: This covers all general purpose lighting not covered by the non-directional measure. A regulation is not yet in place but is likely to emerge early in 2011. Requirements will be similar to that for other lighting: labelling, minimum efficacy, lamp functionality, information to consumer, energy labelling etc. The effect will also be similar – forcing off the market the least efficient products as technologies like LED and OLED mature. ●



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There's a **pin** missing

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A conventional low-power wireless module, when considered in block diagram form, pretty much equates to the classic model of a radio transceiver, as found on the pages of almost every communications textbook ever written (a transceiver is considered here, because the receiver and the transmitter can be considered as sub-sets of the more complex diagram).

On the one side there is the RF connection to the antenna, on the other the user interface, comprising power, control and, all importantly, the modulator input and the demodulator output: the baseband analogue signal path.

Few users ever have a problem with the control part of the interface (easy digital

wishes the module actually resembled. In the simplest case, squaring comparators or limiters are added to produce an approximation to a logic signal (albeit with many restrictions). More sophisticated modules add further signal processing and data buffering, translation, formatting, coding and decoding, until the interface resembles that of a telephone line modem and the basic radio baseband signals are completely hidden from the user behind a wall of digital circuits.

Unfortunately, this sophistication isn't always desirable. Some applications actually require that the user has access to the real, dirty, analogue signals:

- Transmission of analogue, real-time audio (speech, music, sonar or

towards a simpler method, with filtering and conditioning being applied to the waveform before transmission of an un-coded analogue signal over the radio path.

This finally brings me back to the title of this article: increasing numbers of low-power radio modules are appearing in the market without any user accessible baseband analogue input or output signal connections. In part, this is a desire to simplify and to emphasize the easily-implemented nature of a good digital data interface, but it is also being driven by the increasingly common "transceiver on silicon" devices. These chips typically use low or zero IF receiver architectures with balanced I/Q signal paths. The demodulator circuits used frequently quantize straight to a binary stream, without the device providing a "demodulated audio" output at all.

On the transmit side, binary modulators (frequently integral to a sophisticated fractional-N and sigma-delta PLL synthesizer) are increasingly common, often with some form of occupied bandwidth limiting baseband digital filtering being applied downstream of the (binary) input.

Not every new module has this limitation, but it is becoming more common, as "radio modem" type devices supplant older "raw interface" modules. Many users will not notice, but there is a sizeable niche in our industry where analogue transmission is the only viable method and where the choice of wireless hardware is beginning to look very sparse indeed.

Sometimes, you really need those "missing pins". ●

It is all too easy to ignore analogue transmission and blithely assume that any inconvenient real-world waveforms will be digitized and coded

pins, in the simplest case just enable signals for the receive-and-transmit blocks, rarely rising in complexity above an SPI interface to a PLL synthesizer), and fewer still fail when faced with a DC power supply connection. The RF path is usually feared enough that it is carefully conducted to a suitable aerial, and otherwise shunned; which leaves the baseband path – a bandwidth limited, often noisy and usually (at some point) AC-coupled signal path.

An immense amount of effort is put into making this imperfect medium of communication approximate to the well-behaved "piece of wire" that every user

- seismograph signals);
- Tone signaling protocols (DTMF, CTCSS and similar);
- Modem baseband signals (where user equipment already includes a legacy modem);
- Slow scan-rate video;
- Non-binary (duo-binary or 4-level) data streams.

It is all too easy to ignore analogue transmission and blithely assume that any inconvenient real-world waveforms will be digitized and coded, but the limitations (in bandwidth, processing power and circuit complexity) of real low-power radio applications frequently point

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BASEBAND DESIGN CONSIDERATIONS

DOUG STUETZLE, SENIOR DESIGN ENGINEER AT LINEAR TECHNOLOGY, REVIEWS THE IDEAS OF VOLTAGE AND POWER GAIN AS THEY APPLY TO 2-PORT NETWORKS AND GIVES IDEAS, ALONG WITH ADDITIVE NOISE MODELS, TO SHOW HOW NOISE PERFORMANCE CAN BE COMPUTED WHEN THERE IS NO CONSISTENT SYSTEM IMPEDANCE

W

ith the advent of high-speed op-amps and analog-to-digital converters (ADCs), RF engineers have found themselves dealing with these devices at HF and VHF frequencies. Familiar parameters such as G_p (operating power gain) and noise figure can easily be misused in this environment because the characteristic impedance is often far from 50 ohms.

RF design has traditionally presupposed a 50-ohm system impedance, which reduces elements such as amplifiers and filters to 2-port networks that are easily cascaded. When the system impedance is not 50 ohms, or when the system impedance changes as we proceed through the cascade, then the traditional RF methods of analysis can produce erroneous results.

The first part of this article will review the ideas of voltage and power gain as they apply to 2-port networks. The second part will apply these ideas, along with additive noise models, to show how noise performance can be computed when there is no consistent system impedance.

Part 1: General Approach – Voltage and Power Gain

Consider a general case where there is no consistent system impedance. The power source might be a high impedance source, the amplifier could be an operational amplifier configured for a finite voltage gain, and the load could be an arbitrary resistance. A modest amount of circuit analysis will reveal the voltage and power gain of the amplifier with specific source and load resistances.

This set of three basic elements can be analyzed by using the method of Thevenin (or Norton) equivalents. The power source can be represented by the equivalent circuit as shown in Figure 1.

The amplifier can similarly be modeled by a set of Z parameters as shown in Figure 1. Assume the amplifier is unilateral. The parameters of this network are the input and output resistances, and the Thevenin voltage gain a . To compute the power gain from source to load, first compute the power absorbed by the input of the amplifier:

$$\begin{aligned} P_{in} &= V_{in}^2/R_{in} \\ &= V_s^2 R_{in}/(R_s + R_{in})^2 \end{aligned} \quad (1)$$

Compute the power absorbed by the load:

$$\begin{aligned} P_L &= V_{out}^2/R_L \\ &= [aV_{in}R_L/(R_{out} + R_L)]^2/R_L \\ &= (aV_sR_{in})^2 R_L/[(R_s + R_{in})(R_{out} + R_L)]^2 \end{aligned}$$

The power gain is then:

$$\begin{aligned} G_p &= P_L/P_{in} \\ &= a^2 R_{in} R_L / (R_{out} + R_L)^2 \end{aligned} \quad (2)$$

To compute the voltage gain, first compute the voltage V_{in} . The input impedance of the amplifier is equal to R_{in} , so the voltage V_{in} is:

$$V_{in} = V_s R_{in} / (R_s + R_{in})$$

Now compute the voltage at the output of the amplifier:

$$\begin{aligned} V_{out} &= aV_{in}R_L/(R_{out} + R_L) \\ &= aV_sR_{in}R_L/[(R_s + R_{in})(R_{out} + R_L)] \end{aligned}$$

The voltage gain is then:

$$G_v = aR_L/(R_{out} + R_L) \quad (3)$$

Usually the amplifier is specified in terms of its available power gain G_A , which is defined with the source and load impedances equal to R_{in} and R_{out} , respectively. Equation 2 can be used to give the Thevenin voltage gain in terms of the available power gain G_A . Set R_s equal to R_{in} , R_L equal to R_{out} , and solve for a :

$$a = 2 * \sqrt{(G_A R_{out} / R_{in})} \quad (4)$$

Using this substitution, the power gain and voltage gain can be expressed in terms of G_A :

$$G_p = 4G_A R_{out} R_L / (R_{out} + R_L)^2 \quad (5)$$

$$G_v = 2R_L * \sqrt{(G_A R_{out}) / [R_{in} (R_{out} + R_L)]} \quad (6)$$

Note that if the input, output and load resistances are all equal, the insertion power gain reduces to the available power gain. The voltage gain becomes the square root of the available power gain.

It is also useful to know V_s in terms of P_{AVS} . Use Equation 1, with the assumption that the load impedance is equal to R_s :

$$V_s = 2 * \sqrt{R_s * P_{AVS}} \quad (7)$$

RF Approach – Voltage and Power Gain

When the source, load and port impedances of the cascade are all the same real value (R_0), the traditional power-based method of cascading elements can be used.

This method almost always uses the decibel (dB). In the most general terms, the decibel is defined as the logarithm of a ratio. A parameter such as power gain is a ratio, so it can be converted to dB as follows:

$$G_{(dB)} = 10\log(G)$$

A parameter such as power is not a ratio, but it can be expressed in terms of its relation to a reference power level; typically 1mW is used as the reference level:

$$P_{(dBm)} = 10\log(P_{mW}/1mW)$$

The decibel is fundamentally useful because it allows us to add quantities such as gain, power and noise figure, rather than multiply them. Indeed, the assumption of a fixed system impedance and use of the decibel allows us to simply “snap together” the cascaded elements and compute gains, power levels and noise figure. To compute the output power to the load, multiply the source power by the 2-port power gain:

$$P_{out} = P_{AVS} * G_p$$

This can also be done by adding decibel units:

$$P_{out(dBm)} = P_{AVS (dBm)} + G_{p(dB)} \quad (8)$$

Consider an example as shown below in Figure 2.

The power available from the source is 5mW, which is +7dBm. Using Equation 8, the load power is +21dBm. Note that the value of R_0 is irrelevant; it is only important that the system impedances be some consistent value.

The RF Approach – It Does Not Always Work For Voltage and Power

This method of computing the voltage and power gains of cascaded networks begins to fall apart, however, when the impedances at the interfaces between the source, networks and load vary from R_0 . Typically the RF engineer will account for this by including the effect of impedance mismatch, or Voltage Standing Wave Ratio (VSWR) in the cascade analysis.

The idea of impedance mismatch deals with how the signal power is transferred from source to load at each interface. When the load impedance is not the complex conjugate of the source impedance, the power absorbed by the load is less than the power available from the source. It is possible to account for these power transfer losses and compute the overall power gain from the source to the ultimate load in this manner. But now the networks no longer simply “snap together” to yield the overall result.

To illustrate this, revisit the example from Figure 2 with different values for the port impedances as shown in Figure 3.

The source power and amplifier power gain have not changed. The actual power gain from the source to the load is, however, far from 14dB. To compute the true power absorbed by the load, start with the specific circuit model parameters:

$$\begin{aligned} P_{AVS} &= 5 \text{ mW} \\ R_s &= 50 \Omega \\ V_s &= 1 \text{ VRMS} \end{aligned} \quad \text{from Equation 7}$$

$$\begin{aligned} G_A &= 14 \text{ dB} \\ &= 5 \text{ V/V} \\ R_{in} &= 100 \Omega \\ R_{out} &= 200 \Omega \\ a &= 10.58 \text{ V/V} \end{aligned} \quad \text{from Equation 4}$$

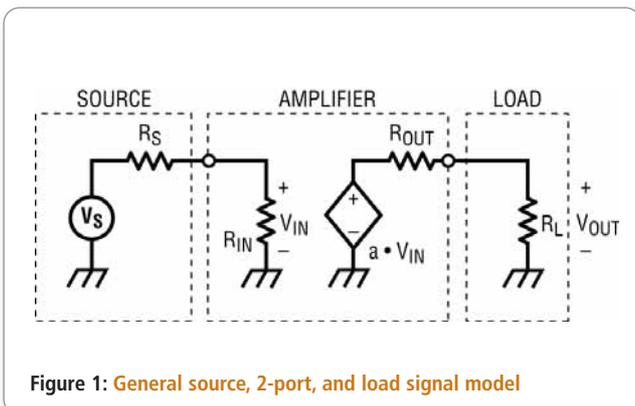


Figure 1: General source, 2-port, and load signal model

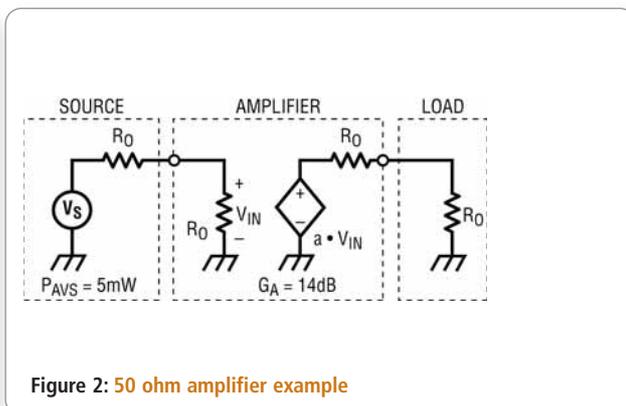


Figure 2: 50 ohm amplifier example

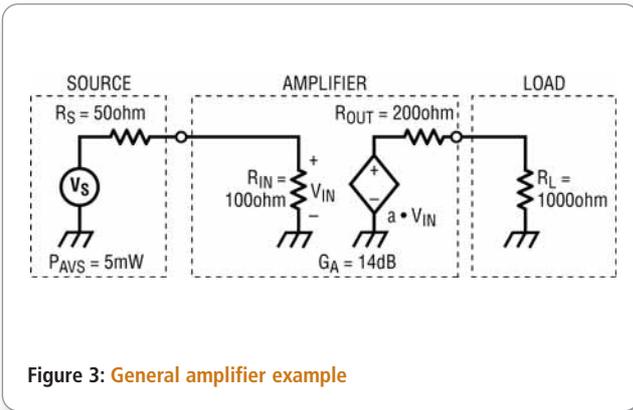


Figure 3: General amplifier example

Use equation 2 to compute the power gain:

$$G_p = 7.77 \text{ mW/mW}$$

$$= 8.9 \text{ dB}$$

This result is very different from the 14dB result obtained by adding the source power to the amplifier gain in dB. This is because the port impedances are not fixed at some value R_0 . The power available from the source is different from the actual power delivered to the amplifier. And the available power gain of the amplifier is greater than the actual power gain into the load. This is often the case with elements such as operational amplifiers, which are well defined in terms of their voltage gain. Their input impedances are often far from 50 ohms, and their outputs are usually low impedance voltage sources.

Part 2: General Approach – Noise

The noise characteristics can also be modeled by Thevenin equivalents and Z parameters; see Figure 4.

The source model is simply the equivalent noise voltage e_s of the source resistance in series with a noiseless resistance R_s . To find the equivalent noise voltage, start with the noise power of this source. The noise power is defined as the power that the source resistance would deliver to a matched load:

$$n_s = (e_s/2)^2/R_s$$

The noise power n_s is simply the thermal noise of the source resistance. This is equal to kT , where k is Boltzman’s constant and T is the source temperature in Kelvin degrees. Use this substitution to find e_s in terms of R_s :

$$e_s = \sqrt{4R_s kT} \tag{9}$$

Note the actual noise power delivered to the input of the network is not the same as n_s if the source resistance is not matched to the input resistance:

$$N_{in} = e_s^2 R_{in}/(R_s + R_{in})^2 \tag{10}$$

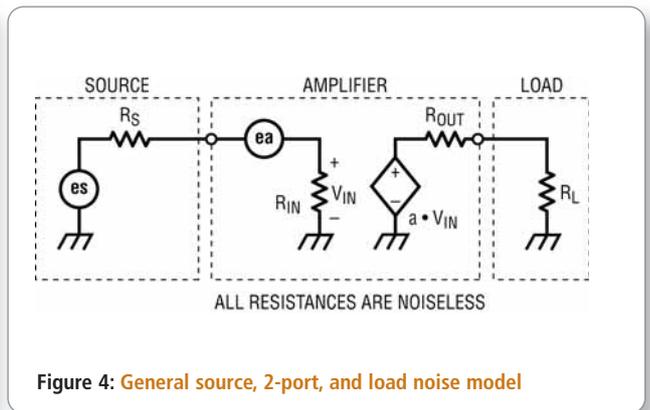


Figure 4: General source, 2-port, and load noise model

Inside the 2-port network, the noise voltage e_a represents the noise added by the network. If the noise figure of the network is known, we can compute the value of e_a . We will determine this value from the noise figure later in this section. To find the total noise power delivered to the load, first combine e_s and e_a at the input of the 2-port model. These noise signals are uncorrelated, so they add on an RMS basis:

$$e_n = \sqrt{(e_s^2 + e_a^2)}$$

Now refer this noise voltage to the V_{in} node of the 2-port:

$$e_{in} = \sqrt{(e_s^2 + e_a^2)} * R_{in}/(R_s + R_{in})$$

The noise voltage that appears at the output terminals of the network is then:

$$e_{load} = \sqrt{(e_s^2 + e_a^2)} * aR_{in}R_L/[(R_{out} + R_L)(R_s + R_{in})] \tag{11}$$

From the noise voltage we determine the noise power delivered to the load:

$$N_{out} = (e_s^2 + e_a^2)a^2R_{in}^2R_L/[(R_{out} + R_L)(R_s + R_{in})]^2 \tag{12}$$

Many amplifiers, however, are specified for noise characteristics in terms of noise figure rather than input noise voltage. Specify noise figure with the source impedance set equal to R_{in} ; see Figure 5.

Noise figure is defined as the input signal to noise ratio divided by the output signal-to-noise ratio under this set of conditions shown in Figure 5. Compute the input signal-to-noise ratio as follows:

$$\text{Input signal power} = [(V_s/2)^2]/R_{in}$$

$$\text{Input noise power} = [(e_s/2)^2]/R_{in}$$

$$\text{Input S/N} = (V_s/e_s)^2$$

Now compute the output signal to noise ratio:

$$\text{Output signal power} = [(aV_s/4)^2]/R_{out}$$

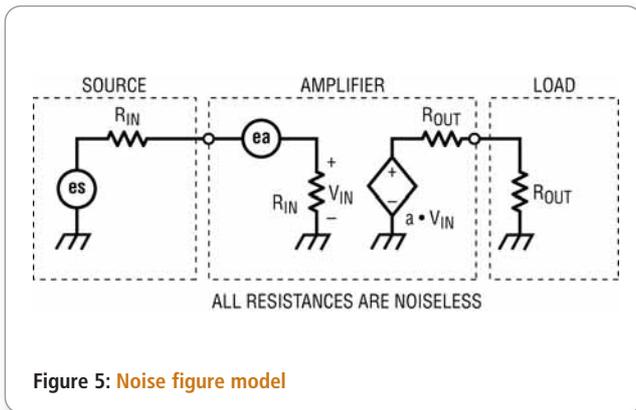


Figure 5: Noise figure model

$$\text{Output noise power} = [(e_s^2 + e_a^2)(a/4)^2]/R_{out}$$

$$\text{Output S/N} = V_s^2/(e_s^2 + e_a^2)$$

The noise figure is then:

$$F = (e_s^2 + e_a^2)/e_s^2 = (4kTR_{in} + e_a^2)/4kTR_{in} \tag{13}$$

Use Equation 13 to express e_a in terms of noise figure:

$$e_a = e_s \sqrt{F - 1} = \sqrt{[4R_{in}kT(F - 1)]} \tag{14}$$

When the source resistance does not equal the input resistance, the effective noise figure will change. In general, then, the effective noise figure is equal to:

$$F_{eff} = (4kTR_s + e_a^2)/4kTR_s \tag{15}$$

RF Approach – Noise

Here again, when the source, load and port impedances of the cascade are all the same real value (R_o), much simpler formulas can be used to cascade elements. If the source noise power is kT , then the following apply:

$$N_{out} = FG_p kT$$

$$N_{out(dBm)} = F_{(dB)} + G_{p(dB)} + kT_{(dBm)} \tag{16}$$

An example appears in Figure 6.

The source noise power is 3.98×10^{-21} W/Hz, or -174dBm/Hz. The power gain of the amplifier is 14dB; its noise figure is 6dB. The noise power delivered to the load is, by equation 16, equal to -154dBm/Hz.

The RF Approach – It Does Not Always Work for Noise

Here again, if the network impedances vary from R_{in} , this method will yield inaccurate results. Refer to Figure 7, which shows the same example with different values for the port impedances.

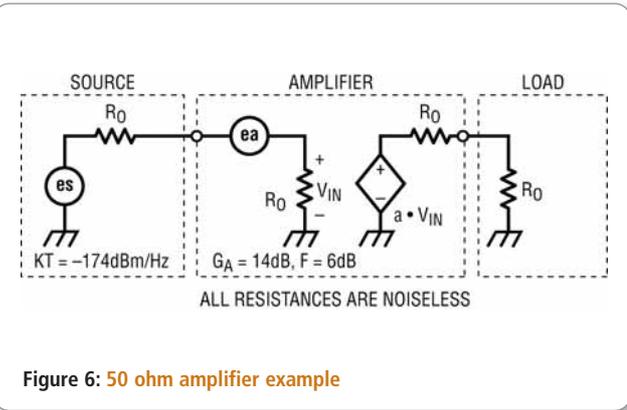


Figure 6: 50 ohm amplifier example

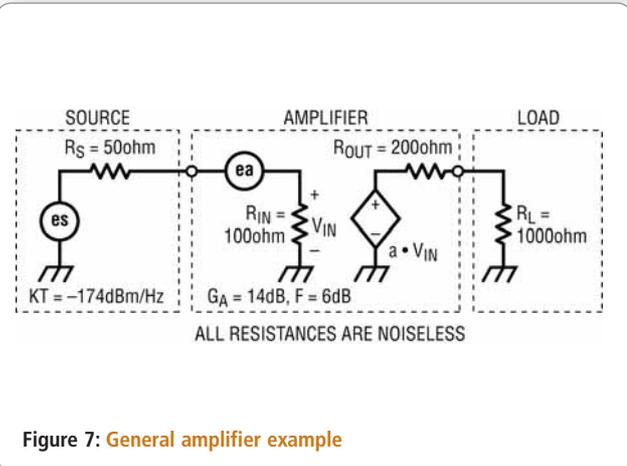


Figure 7: General amplifier example

The source power and amplifier power gain have not changed. The actual noise power delivered to the load is, however, far from -154 dBm/Hz. To compute the true power absorbed by the load, start with the specific circuit model parameters.

$$n_s = 4.14 \times 10^{-21} \text{ W/Hz}$$

$$R_s = 50 \Omega$$

$$e_s = 0.89 \text{ nV}/\sqrt{\text{Hz}} \text{ from Equation 9}$$

$$G_A = 14 \text{ dB} = 5 \text{ V/V}$$

$$R_{in} = 100 \Omega$$

$$R_{out} = 200 \Omega$$

$$a = 10.58 \text{ V/V} \text{ from Equation 4}$$

$$F = 6 \text{ dB} = 3.98 \text{ mW/mW}$$

$$e_a = 2.23 \text{ nV}/\sqrt{\text{Hz}} \text{ from Equation 14}$$

$$R_L = 1000 \Omega$$

Use equation 12 to compute the noise power at the load:

$$N_{out} = 1.99 \times 10^{-19} \text{ W/Hz} = -157.0 \text{ dBm/Hz}$$

This is less than half the noise power obtained by using Equation 16. The reason is that the terminal resistances are no longer all equal to one another. Put another way, the effective noise figure of the amplifier is not 6dB:

$$F_{\text{eff}} = 7.33 \text{ mW/mW} \\ = 8.65 \text{ dB} \quad \text{from Equation 15}$$

Note that the noise power delivered to the load can be accurately computed using the effective power gain and noise figure. To do this, first compute the noise power delivered to the network input:

$$N_{\text{in}} = 3.52 \times 10^{-21} \text{ W/Hz} \quad \text{from Equation 10} \\ = -174.5 \text{ dBm/Hz}$$

Add to this the effective power gain plus the effective noise figure:

$$N_{\text{out}} = -174.5 \text{ dBm/Hz} + 8.9 \text{ dB} + 8.65 \text{ dB} \\ = -157.0 \text{ dBm/Hz}$$

The method of adding decibels is now valid because the effective power gain and noise figure are used. The effective values are different than the values specified in a 50 ohm measurement system.

Accurate Computing Ways?

If the port impedances are all the same, 50 ohms for example, then the “snap together” RF approach is a quick and accurate way of computing voltage, power and noise throughout the signal chain. In the case of the example shown in Figure 3, however, this is not true. Although the available power gain of the amplifier is 14dB, the actual power gain is only 8.9dB. This is a large error because the port impedances are far from 50

ohms. Similarly, Figure 7 shows an example of an amplifier with a nominal noise figure of 6dB. The effective noise figure of this amplifier with the source and load resistances shown is actually 8.65dB. Here again, the non-standard port impedances make for a nontrivial calculation of the noise behaviour.

Traditional RF methods for computing voltage, power and noise work well for cascaded 50 ohm amplifiers, filters and the like. But when it comes to high-speed op-amps and analog-to-digital converters, for example, these methods produce results that are entirely inaccurate. In these cases a true 2-port analysis technique such as the one suggested herein must be used.



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UNDERWATER WIRELESS NETWORK

MARK HOFERITZA, FIELD APPLICATIONS ENGINEER AT AUSTRIAMICROSYSTEMS AG, SAYS THAT SCUBA DIVERS CAN BENEFIT FROM UNDERWATER WIRELESS NETWORKS BASED ON SHORT-RANGE RF TECHNOLOGY USED IN AIR TODAY, AND DESCRIBES THE RESULTS OF TESTS CONDUCTED UNDERWATER WITH ONE SUCH COTS TECHNOLOGY

Consumers have shown themselves eager to be rid of cabling and wires connecting them to devices situated or worn near or on the body. From athletic monitoring devices to headphones, computer mice to cellphone hands-free kits, manufacturers have met a demand for connectivity without wires achieved through the application of short-range RF technology.

When meant for 'in air' conditions, the operation of RF devices is well understood. But there are underwater activities that could equally benefit from such wireless technology. Scuba divers, for example, need to monitor equipment such as air tanks, where underwater sensor arrays would benefit from being connected wirelessly. Can the short-range RF technology used in air today operate as successfully under water?

This article describes the results of tests conducted in several underwater locations, using a low-frequency (LF) radio device from austriamicrosystems. The aim was to discover more about the behaviour of commercial off-the-shelf (COTS) RF components under water. Aspects considered in conducting the tests included:

- What is the range limitation?
- Which frequencies are best suited for underwater use?

RF has well-defined propagation characteristics in air, and each frequency range has certain beneficial and detrimental attributes. Those attributes no longer apply in water

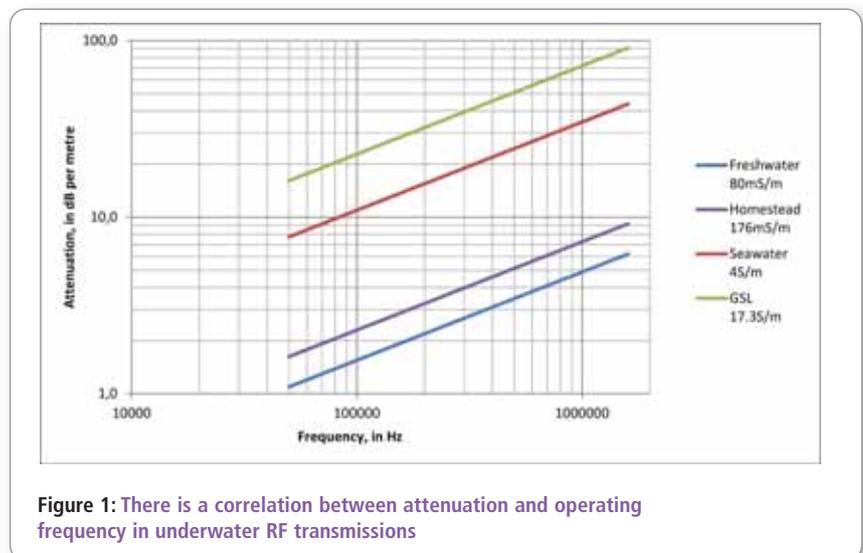


Figure 1: There is a correlation between attenuation and operating frequency in underwater RF transmissions

- Are there other frequency considerations?
- Which modulation modes are well suited to underwater use?
- Are there data rate limitations beyond normal bandwidth constraints?
- Does the end user need to take account of regulatory requirements?

The Behaviour of RF Energy in Water

RF has well-defined propagation characteristics in air, and each frequency range has certain beneficial and detrimental attributes. Those attributes no longer apply in water. Propagation in water, unlike air, does not depend on ionospheric conditions; water has its own set of rules. In particular, RF energy is greatly attenuated in water, so the effective range is reduced.

The conductivity of water and frequency are the two factors determining how well RF energy will

propagate. The following equation shows how attenuation changes with conductivity and frequency:

$$\alpha = 0.0173 \sqrt{(f\sigma)}$$

where:

α = attenuation in dB/metre

f = frequency in Hertz

σ = conductivity in Siemens/metre

This shows that attenuation increases as frequency rises. This suggests that underwater applications will support lower-frequency transmissions and a reduced expectation for effective range, compared to the equivalent RF system in air.

The author of this article set out with the intention of discovering whether an effective range of 1m was possible for a small RF device intended for a body-area network or similar application. Tests were carried out in water sources local to the author's home in Utah, US. The Great Salt Lake acts as a worst-case



Figure 2: Demo kits placed in dry bags

example – after the Dead Sea, it is the saltiest known body of water in the world. High saline content causes greater RF attenuation. Homestead Crater is also unusual because it is fed by a hot spring with high mineral content, which also affects attenuation.

Scientific publications on freshwater indicate that its conductivity is in the range 50-100mS/m. (1mho = 1 Siemens.) In the test, freshwater was evaluated at 80mS/m. Publications on seawater state that the conductivity is 4-5S/m. A value of 4S/m at selected frequencies is assumed for the data in Figure 1.



Figure 3: Testing RF performance under water at Great Salt Lake

The Great Salt Lake is an extreme case and used here as a data point and not as a practical environment for underwater RF communications. The conductivity of Great Salt Lake water obtained from the Utah Division of Water Quality ranges from 146mS/cm to 200mS/cm. This translates to 14.6S/m to 20S/m. The average value of 17.3S/m was selected for this example.

In all underwater environments, there is a correlation between frequency and attenuation (see Figure 1), but the problem of attenuation is particularly acute at high frequencies in salty water. Attenuation is substantially less in freshwater than in sea water. It can be concluded that a higher usable frequency is possible in freshwater.

There might be other operating frequency considerations to take into account. In recent years, amateur radio operators have begun to use the VLF and LF bands. Numerous experimental radio stations around the world now make very low-power broadcasts at frequencies from around 150kHz up to several MHz. It is unlikely that such stations will interfere due to the limited air-to-water RF transmission at these frequencies, but this phenomenon must be considered in any full-scale implementation.

A further consideration relates to regulatory requirements: regulatory organisations such as the Federal Communications Commission in the US might have certification requirements. A review of local governmental agencies should be conducted before starting an end product design.

Practical Considerations in Transmitting RF Signals Under Water

Underwater data transmission has mainly been implemented through acoustic transducers, since water is a benign medium for sound waves. There are many examples of acoustic modes, most notably SONAR.

There are also many RF modes available to the engineer for underwater data transmission. For the purposes of the tests for body area networking applications, Amplitude Shift Keying (ASK) modulation was used for the RF signal because it is easily implemented by a microcontroller with little firmware. ASK represents the digital information – a ‘1’ or ‘0’ – by varying the amplitude of the carrier.

The data to be transmitted was in the

form of infrequent small packets, so a slow data rate was adequate. Higher data rates can be realised at higher frequencies, but at these frequencies the designer will have to battle with the challenges of achieving adequate range at a viable output power. Other than in freshwater, satisfactory operation might be impossible.

Just as the propagation of radio waves in water is different from in-air transmission, so antenna design is different. As with attenuation, wavelength is affected by the conductivity of water and is expressed by the following formula:

$$\lambda = 1000 \sqrt{10/(f\sigma)}$$

where:

λ = wavelength, in metres

f = frequency, in Hertz

σ = conductivity, in Siemens/metre

From this equation the reader can see that underwater wavelength is less than the wavelength in air at the same frequency. An additional consideration is that the antenna cannot be in direct contact with the water. A waterproof barrier such as a plastic coating is needed to allow the electromagnetic wave to be launched. There are many underwater antenna configurations currently in use, from wires trailing behind a submarine, to directional loop antennas, to omnidirectional loop antennas.

In this investigation, a simple transmitter antenna is used, the Grupo Premo KGEAWT680703B0332J. In the tests, the receiver system antenna selection was greatly simplified because the AS3933 receiver IC offers automatic antenna tuning.

Operation of the Underwater RF Tests

The equipment used to test the operation of short-range RF transmissions under water was a demo kit, the AS3933 Development system, from austriamicrosystems AG. The kit consists of an AS3933 3-axis LF wake-up receiver board, a 125kHz transmitter board, power supply, documentation and software.

Three experiments were undertaken. An open air test was performed to determine a baseline for the water tests. Two in-water tests and one shore-based event were also carried out. The open-

air test yielded a transmission distance of 2.9m (7.5'). This provided a baseline for the performance of the system under water.

The first in-water test was a dive event at Homestead Crater in Midway, Utah. This is a 19.8m (65') mineral spring-fed body of water inside a volcanic dome crater with a high average water temperature of 35°C (95°F).

The receiver board and transmitter board were placed in separate waterproof dive bags (see Figure 2). Measurements were taken at 7.6m (25') and 15.24m (50'), which allowed the test to determine whether depth affected the range.

The demo kit used is capable of transmitting a wake-up signal consisting of a 32-bit Manchester-coded ASK wake-up pattern with a data rate of 1.35kbaud, repeating at intervals of one second. The transmitter is powered by two AA batteries, providing a relatively low-power output. The AS3933 wake-up receiver is programmed with this same Manchester code pattern. As this pattern is transmitted, the AS3933 listens for the signal. If a signal is received and the patterns match, the AS3933 accepts the transmission.

The AS3933 can determine the received signal strength in the form of

The demo kit used is capable of transmitting a wake-up signal consisting of a 32-bit Manchester-coded ASK wake-up pattern with a data rate of 1.35kbaud, repeating at intervals of one second

an RSSI value, which is indicated with five LEDs on the receiver board; each bit is equivalent to 2dB. This was the indicator used to gauge the distance of the transmission. Three other LEDs indicate on which axis the signal was received. The benefit of a 3-axis receiver is that no matter which orientation the transmitter and receiver are in, there is always a receiving antenna to capture RF energy.



Figure 4: Testing RF performance under water at Great Salt Lake

There was no difference in the range of transmission at the two test depths. This distance was measured at approximately 1.85m (6').

The shore-based test took place at Great Salt Lake. This time, the test equipment was suspended below the surface of the water from two PVC poles (see Figure 3). The receiver was set at a fixed depth of approximately 6cm (2.4") below the surface. The second pole was used to lower the transmitter into the water and gradually extend the distance between the transmitter and the receiver, until the RSSI indicator showed 0. Surprisingly, given the high saline content of GSL, the transmission distance was 1.5m (5').

Based on the results of the two tests, it seems reasonable to conclude that RF transmission underwater over a short distance is possible using commercial off-the-shelf RF ICs available today. Given that the transmitted power of the test set-up was limited by the small power output available from the batteries, it is also reasonable to conclude that a greater distance would be achievable with modified equipment.

Clearly the sensitivity of the receiver is important as well: the AS3933 offers best-in-class sensitivity of 80µVrms. This will have contributed to the ability of the system to achieve a greater range than was expected. Add a higher power transmitter and this writer believes a greater transmitter-to-receiver range can be achieved.

End Product Applications for Underwater RF

It is possible to envisage a wide range of applications for underwater RF devices. In fact, hydrologists from the United States Geological Survey (USGS) encountered during the testing at Great Salt Lake described their requirement for submerged sensor arrays that do not require tethering to a surface buoy for data collection. Such a sensor array could be realised using the technology described in this article.

Other potential applications could include wireless monitoring equipment for Scuba gear and a simple 'buddy call' system to allow a pair of divers to alert one another when visual cues are obscured by lack of eye contact or poor visibility. The 3-axis topology of the AS3933 could support the provision of indicators to point the receiver towards the transmitter.

What is proven beyond doubt by the tests described here is that LF radio operation is possible under water with battery-powered ICs available on the market today from manufacturers such as austriamicrosystems. With a transmitter and receiver, both interfaced to simple microcontrollers, an effective underwater RF communications system can be implemented, with transmission range up to 1.8m possible. Numerous applications can no doubt be found in the arenas of scientific, recreational and personal safety equipment to make use of this technology. ●

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COMPARISON OF PROPRIETARY RF AND **BLUETOOTH FOR HID** **APPLICATIONS**

ANITHA TG, APPLICATIONS ENGINEER, AND **SAI PRASHANTH CHINNAPALLI**, SENIOR APPLICATIONS ENGINEER, BOTH AT CYPRESS SEMICONDUCTOR, COMPARE THE BLUETOOTH 4.0 WIRELESS TECHNOLOGY WITH PROPRIETARY PROTOCOLS FOR THE HUMAN INTERFACE DEVICE (HID) MARKET



Figure 1: Wireless HID device from Cypress Semiconductor

With the penetration of wireless technology into the human interface device (HID) market, an increasing number of sophisticated HID products are now coming onto the

market with integrated wireless technology (wireless keyboards, wireless mice, etc.). Often, developers are limited in their options: they have to either follow a popular wireless standard like Bluetooth or to develop a proprietary protocol optimized for their application.

While wireless standards provide the benefit of interoperability, they also introduce complexity and overhead that an application may not require, resulting in a higher system cost. On the other hand, a proprietary protocol gives developers flexibility to customize applications at the expense of requiring developers to take on the development process.

The key RF requirements for selecting a PC HID are cost (the PC HID market is extremely cost-sensitive), security, range, power consumption, latency, interference, co-location and ease of use. In general, standards win in the market because of interoperability of the devices. However, in case of PC HIDs until 2009, only proprietary protocols have dominated the

market. This can be attributed to the lack of any wireless standard optimized for the PC HID market in terms of cost, power and efficiency. With the advent of Bluetooth Low Energy Wireless technology aimed at low power applications, we can foresee a new wireless standard occupying the PC HID market.

Proprietary RF Solution

To get a reliable communication link in the 2.4GHz RF band, proprietary RF networks make use of their own protocols. A network operates in quiet channel to ensure that the bridge receives packets from nodes. If the channel becomes noisy, the network will hunt for a clean channel and settle there to resume with successful transmissions. If hardware supports Direct Sequence Spread Spectrum (DSSS) transmission, the protocol switches to this mode when interference is detected before starting to hunt for a quieter channel. As these protocols do not follow any IEEE standards, they are computationally lightweight and optimized for specific

applications with respect to power consumption and packet overhead.

Low Energy Bluetooth

Bluetooth wireless technology is a short range communication system intended to replace the cables connecting portable or fixed electronic devices and is an established IEEE standard. There are two forms of Bluetooth wireless technology systems: Basic Rate (BR) and Low Energy (LE). Both systems include device discovery, connection establishment and connection mechanisms. The LE system includes features designed to enable products that require lower current consumption, lower complexity and lower cost than BR. The LE system is also designed for use cases and applications with lower data rates and has lower duty cycles. Devices implementing both systems can communicate with other devices implementing both systems as well as devices implementing either system.

The Wireless HID market is extremely cost sensitive. Wireless HID product



Figure 2: Bluetooth and proprietary RF technology solutions

developers are often concerned about selecting a cost-effective microcontroller as the RF Baseband controller for their application. The same microcontroller also needs to have enough Flash memory to hold the wireless protocol stack. As Bluetooth LE is a standard, the code size is far greater than proprietary protocols and increase cost because of the amount of extra Flash memory required.

The Wireless HID market was dominated by proprietary protocols because of their lightweight protocol stacks. However, these proprietary networks also require an external bridge to be connected to the PC/Host so that they can talk to the other devices in the network. As Bluetooth is an established wireless standard, most of the PCs, mobile phones and other handheld devices with high processing capabilities will have an integrated Bluetooth bridge with dual-mode support (BR and LE support) in the future which eliminates the need for an external bridge. The key to Bluetooth LE, unlike the Bluetooth that we're all used to today, is its "always-off" technology. This allows designs implemented with Bluetooth LE to achieve years of battery life through the use of small coin-cell batteries. As Bluetooth is a standard maintained by the Bluetooth SIG (Special Interest Group), any Bluetooth compliant device should be qualified by this certification board, incurring further development costs.

Power Consumption Concerns

Proprietary RF chip manufacturers do not fully disclose power consumption on datasheets. They specify that the power consumption depends on the duty cycles.

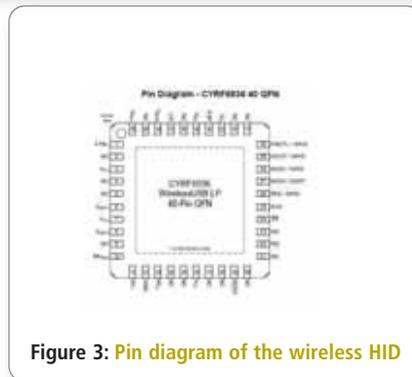


Figure 3: Pin diagram of the wireless HID

Developers must, therefore, obtain their own power consumption data using experimental board set-ups and their respective firmware test environments.

As power is the main concern in wireless HID market, the Bluetooth low-energy standard specifies that an application should not consume more than 20mA of peak current and 15mA in coin cell applications for a maximum of 3ms data transfer. Devices using Bluetooth low energy wireless technology will consume a fraction of the power of other Bluetooth-enabled products. In many cases, products will be able to operate more than a year on a button-cell battery without recharging. In this way, it is possible to have, for example, small sensors operating continuously and communicating with other devices like a cell phone or PDA.

Small devices like watches and sports sensors based on a standalone Bluetooth low energy implementation will enjoy many low-power consumption advantages. Dual-mode implementations, supporting Bluetooth and Bluetooth low energy, will use parts of the existing Bluetooth hardware, sharing one physical radio and

antenna. Dual mode implementations will basically keep the same power consumption as classic Bluetooth technology.

Reliability and Security

The ability to resist interference from other technologies sharing the same frequency band is extremely important as this also impacts end-user performance. Robustness to interference in the 2.4GHz world means the ability to reliably co-exist with 802.11b/g, Bluetooth, Wireless USB, and a host of cordless phones and microwave ovens. Only an intelligent coding scheme with a good channel hopping methodology can ensure data reliability.

While some radio devices like the CYRF6936 can employ DSSS (Direct-Sequence Spread Spectrum) along with FHSS (Frequency-Hopping Spread Spectrum) transmission schemes, Bluetooth LE uses only adaptive frequency hopping technology common to all versions of Bluetooth technology. DSSS ensures data robustness while FHSS allows the wireless signal to hop to new channels once interference becomes too great. Lack of DSSS in Bluetooth is also a drawback compared to proprietary protocols as proprietary RF can co-exist in noisy environments without having to hop to a quieter channel. Bluetooth LE offers full AES-128 encryption to provide strong encryption and authentication of data packets. At the same time, this also consumes a considerable amount of packet overhead. To ensure a reliable and secure system, it is the developer's discretion to adopt an existing proprietary protocol or a

Only an intelligent coding scheme with a good channel hopping methodology can ensure data reliability

standard like Bluetooth based on the hardware capabilities of the device and the security level requirements of the application. For applications such as wireless mice, for example, little if any security is required.

Range and Speed

Wireless HID applications usually communicate within a short range and, hence, the need for a range of more than 10 meters is very rare. If the desired range

of communication is more, the power consumption level of the device will also increase. While proprietary RF protocols claim to support longer range with the help of external power amplifiers, Bluetooth LE spec suggests a possible range of over 100 meters.

Bluetooth LE supports an over-the-air data rate of 1Mbps, which is sufficient for wireless HID applications. However, application throughput is only 256kbps due to overhead. Proprietary protocols have the advantage of limiting packet overhead as per application requirements and, hence, may be able to support higher throughput. For applications like gaming mice, audio applications and touch applications which require an effective throughput of greater than 250kbs, implementing Bluetooth LE will fall short of proprietary standards.

Topology

Most Wireless HID applications require either a point-to-point network (i.e. wireless keyboard or mouse) or a star network (i.e. sensor networks). Proprietary protocols optimize the protocol for a particular topology. Depending upon the targeted microcontroller and the methodology of addressing a slave device in the system, the number of slave devices that can be connected in a network is limited.

Bluetooth LE technology is optimized for one-to-one connections while allowing one-to-many connections using a star topology. With the use of quick connections and disconnections, data can move in a mesh-like topology without the complexities of maintaining a mesh network. For example, a user using an integrated Bluetooth BR/LE phone can record the pulse rate from a wrist watch, burnt calories value from his shoes and

outside temperature from his cap when all these appliances are integrated with Bluetooth LE.

Applications

Any application can easily make use of a proprietary RF given the ease of modifying the protocol. In this way, applications can be modified to adapt to their environment by changing power output levels, activating a more robust means of communication, or by moving to a quieter environment to communicate.

In a market full of narrow, local, proprietary connectivity solutions, Bluetooth LE technology differentiates itself through the following:

- Ease of implementation and multi-vendor interoperability;
- Ultra-low peak, average and idle mode power consumption;
- Low cost of integration;
- Power handling;
- Resistance to interference.

Bluetooth LE technology extends the personal area network (PAN) to include Bluetooth-enabled devices that are powered by small, coin-cell batteries. With low energy technology, sports and health care equipment, HIDs and entertainment devices are enhanced. The technology can be built into products such as watches, wireless keyboards, gaming and sports sensors, which can then connect and communicate with to host devices such as mobile phones and personal computers.

The other hallmark features of Bluetooth LE include low cost and greater range. Since new Bluetooth LE chips are so small and inexpensive, this expands the feasibility of implementing them into everyday consumer products. For example, devices can be inside the sole of a shoe to track a person's speed, distance, pace and other statistical information. By utilizing a

low power wireless standard like Bluetooth LE chip embedded in the sole, the battery life of these new chips exceeds the average life span of a pair of running shoes.

Going Ahead with a Promising Technology

Though Bluetooth LE looks like a promising technology for many applications, there are certain concerns that the industry needs to address before adopting this technology for HID applications. Certainly there is the advantage of eliminating the need of external bridge. However, there is the question of when the electronics industry will be ready with integrated dual-mode Bluetooth radios.

Integrating a dual-mode/single-mode Bluetooth radio into hosts also raises the question of co-existence with WiFi, WiMax, Classic Bluetooth and other 2.4GHz technologies. This could be a major challenge for the developers to provide the complete solution. Until then, a short-term solution could be having an external bridge shipped with the PC. As Bluetooth LE is still in the development phase, the profiles for all applications are not finalized. This will impact the penetration of Bluetooth LE into the wireless HID domain for a considerable length of time.

Although Bluetooth is a standard protocol, it is not free from drawbacks in its binding methodologies. For example, imagine a classroom environment where many students are using Bluetooth mice and all of them try to get their mice bound at the same time to their respective PCs. Cross binding may occur with one mouse talking to another PC instead of the one to which it is intended to bind. Proprietary protocols like the ones offered by Cypress Semiconductors avoid these issues by using KISS (Keep It Simple Solution) bind, Manufacturing bind and Auto binding techniques. Developers need to implement similar binding methodologies if they are targeting Bluetooth LE for these sorts of HID applications.

Like any product, adaptation is a vital component to success. With its low cost and low energy usage, Bluetooth LE seems to be a good competitor in the wireless HID market. However, while Bluetooth LE is enticing many companies to enter the wireless HID market, Bluetooth LE cannot succeed until it competes and implements better features than what proprietary protocols have been successfully implementing over the past decade. ●

BLUETOOTH CERTIFICATION

THE BLUETOOTH SPECIAL INTEREST GROUP (SIG) IS THE BODY THAT OVERSEES

THE DEVELOPMENT OF THE BLUETOOTH STANDARDS AND LICENSES BLUETOOTH TECHNOLOGY AND TRADEMARKS TO MANUFACTURERS.

To become a licensee, a company must become a member of the Bluetooth SIG. The SIG also manages the Bluetooth SIG Qualification program, a certification process required for any product using Bluetooth wireless technology and a pre-condition of the intellectual property license for Bluetooth technology. The main tasks of the SIG are to publish the Bluetooth specifications, protect the Bluetooth trademarks and evangelize Bluetooth wireless technology. An overview of the qualification process, including steps of the qualification process and qualification types and fees, is available on the Bluetooth SIG public portal. In case of proprietary protocols, many manufacturers provide the qualification specification nearly free of cost so that product developers can qualify the protocol at their end to minimize development expense and time.

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- Active current sharing for parallel operation
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PAK650	41 x 127 x 249mm
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BARRY MCKEOWN,
DIRECTOR AT DATOD,
EXPOSES THE ISSUES
RELATED TO FRACTIONAL
FREQUENCY INFORMATION
IN CURRENT SIGNAL
PROCESSING PRACTICES

SPECTRUM ANALYSIS: OPENING ANOTHER CAN OF WORMS

In the August 2010 edition of Electronics World, I brought the readers' attention to technical issues pertaining to the mathematical modelling of the presence of time domain FM "spikes" and why it is necessary to recover these artifacts for analysis. I also outlined ongoing regulatory issues pertaining to the current Spectrum Management Framework.

What are not always appreciated are the various reasons why signals are analysed and how these practices have arisen. Such as it may be possible to represent an apparently complex signal waveform by a limited set of parameters, which are then sufficient to describe or model the signal for the application in mind, as in determining whether or not the signal may be faithfully transmitted through a particular communication channel.

More importantly, as scientists and engineers we find that a careful analysis of a signal may be of use in discerning information about the source which produced it, i.e. certain detailed characteristics of a signal which are not immediately apparent can often give important clues to the nature of the source, or to the type of processing which has occurred between the source and the point at which the signal is recovered or detected, over an 'observation interval' (OI).

In that Electronics World article I included the following comment: "Such an analysis stage could only be applied digitally. It also would be required to manipulate fractional frequency information which current FFT algorithms cannot process, especially in an OFDM(A) environment for 4G". Detailed in Figure 1 is a generic architecture of an OFDM sub-system, at the heart of which resides the

Fast Fourier Transform. The purpose of this article is to expose these issues relating to fractional frequency information in current signal processing practices.

In engineering, since the mid 1960s it has been the custom and practice to adopt discrete Linear Time Independent digital formats for what were previously Continuous Time analogue sub-systems. Underplaying this approach is Transform Analysis, which has a long convoluted history with origins back to Pythagoras. However, not all researchers have ascribed to or adopted this philosophy.

I would just call attention to the following statement from Marie Farge, a well known expert in signal processing: "A very common pitfall when using any kind of transform, is to forget the presence of the analysing function in the transformed field, which may lead to severe misinterpretations, the structure of the analysing function being interpreted as characteristic of the phenomenon under study."

The significance of this statement shall become apparent.

Fourier Analysis Signal Approximation

It has been stated that Fourier Analysis and, in particular, the Theory of Fourier Series is largely the study of the interplay between assumptions about smoothness and conclusions about convergence. The signal processing issues therein pertain to the mathematical concepts of the Principle of Superposition and Linear Independence.

The "original" Fourier approach can best be summarised as follows:

- Fourier Analysis gives a systematic approach to signal approximation.
- The mean square error is minimised at every stage in the approximation.

- The mean square error is progressively reduced as more sinusoids are added.

- In principle, any signal over a finite OI can be represented by a Fourier Series.

Historically, the engineering problems associated with "Discrete" Fourier Analysis have fallen broadly into the study of two artifacts: those relating to Aliasing effects and those associated with Truncation of the data, whether periodic or otherwise over the Observation Interval.

Furthermore, over the past twenty years, concentrated effort in signal processing research has been applied on the following related artifacts and their associated standard benchmark data sets, originated by David Donoho and others at Stanford University:

- Gibbs Phenomenon – Blocks Data Set,
 - Edge Detection – Heavisine Data Set,
 - Inter-scale Correlations – Doppler Data Set,
 - Peak Shrinkage – Bumps Data Set,
- and which are all downloadable via WaveLab.

Much of this contemporary signal processing research effort has focused on wavelet and multi-resolution analysis techniques. What has become clear from a review of the literature is that these artifacts and their origins as with the FM "spikes" case are not well understood nor have the inherent consequences – as with the FFT approximations accuracy – been understood either.

Fractional Frequency Information

A Fractional Frequency may be defined as: whenever a signal is anything other than a whole number of sinusoid cycles over the Observation Interval. In Figure 2 is detailed the consequences imposed by applying the FFT to a given number of sampling points over an Observational Interval, for each of a

whole number and a fractional number of signal cycles.

In Figure 3 is the benchmark data set introduced into the literature by Fredric J. Harris and William Cameron. Also in Figure 3 is introduced our Datod benchmark data set of 11 fractional frequencies, composed such that the normalised magnitude data can be displayed without recourse to logarithmic scales, over an Observation Interval. We have taken the liberty of manipulating the Stanford Bumps Data Set and transposing its setting from the Time Domain to the Frequency Domain.

In this figure we specifically draw the reader’s attention to the difficulty of obtaining signal amplitude information. Ronald N. Bracewell identified two artifacts that can be attributed to Truncation: namely a smoothing error and a so-called spectral leakage error. Also E. O. Brigham, in his classic book on the FFT, states that: “To reduce leakage it is necessary to employ a time-domain truncation function which has side-lobe characteristics which are of smaller magnitude than those of the sinc function.”

Historically the above approach has been followed but as the Nobel Laureate Dennis Gabor stated in 1946, although mathematically it is “beyond reproach, even experts could at times conceal an uneasy feeling when it came to the physical interpretation of results obtained by the Fourier method. The building block of the Fourier analysis are sines and cosines, which oscillate for all time. In this framework of infinite time, ‘changing frequency’ becomes a contradiction in terms”. Indeed!

Cameron’s Paper

I would now draw the readers’ attention to a paper by William L. Cameron entitled “Precise Expression Relating the Fourier Transform of a Continuous Signal to The Fast Fourier Transform of Signal Samples”, IEEE Transactions on Signal Processing 43(12) December 1995. This paper has been a fundamental influence on the thinking of Datod when investigating the problems associated with the FFT and signal analysis. Cameron is a practising engineer, with the Boeing Company since 1982, who understands very well the limitations of the FFT approach to analysis.

In his process, Cameron is seeking to acquire a more accurate estimate of the

peak-to-peak information on fractional frequency signals as much as -40dB down on a fundamental spectral component.

Cameron’s paper cites for this purpose the benchmark data sets introduced by Harris in his classic exposition paper on Windowing from 1978. Cameron’s process outperforms the FFT with and without a Hamming Window in estimating both, the magnitudes and phases of the underlying signal components, and his process is capable of resolving frequency to a fraction of an FFT frequency bin, albeit with certain limitations not documented in his paper or commented on further here.

Cameron makes some very important

observations in his paper. Indeed, Cameron states the following: “Sampling $s(t)$ and restricting its domain introduces a number of artefacts into its FFT. The traditional method [Bracewell], [Brigham] used to analyse these artifacts is difficult to justify physically and mathematically owing to the use of impulse response functions.”

Cameron further states that: “Many misconceptions of the relationship between the continuous and discrete Fourier transforms arise from the assumptions that continuous time signals can be treated as a finite collection of integer frequency components.”

Figure 1: Transmitter (above) and receiver (below)

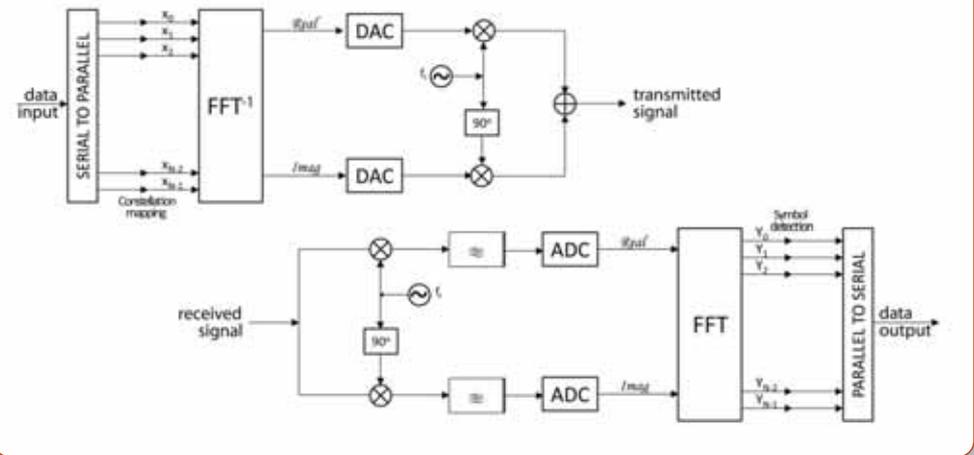
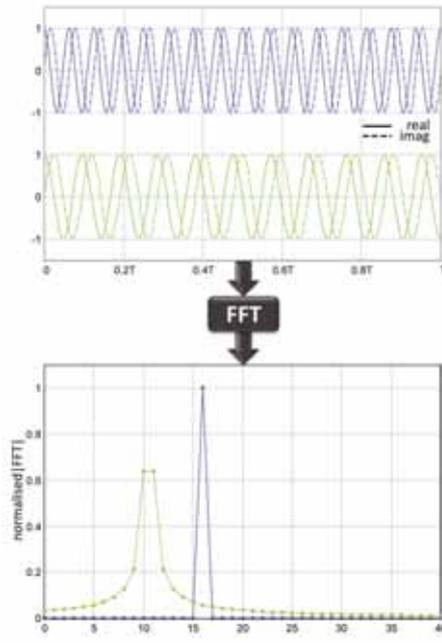


Figure 2: Spectrum analysis



Two individual sinusoids, each of unit amplitude (and zero initial phase) are shown :-
 ■ the signal in blue has exactly 16 cycles over the Observation Interval,
 ■ the signal in green has exactly 10.5 cycles over the Observation Interval.

When the FFT is applied to 512 time-domain samples of the 16-cycle signal, the output behaves as expected in that there is a single peak with amplitude 1.0 at the desired frequency, while all other output values are zero.

However, when the FFT is applied to 512 time-domain samples of the 10.5-cycle fractional frequency, the output is non-zero at all frequency components, and the signal amplitude is not attained.

Figure 3: Cameron's signal

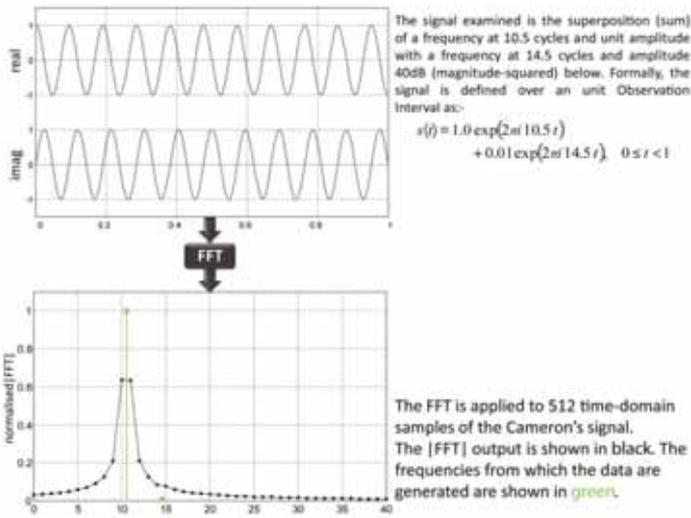


Figure 4: Datod test signal

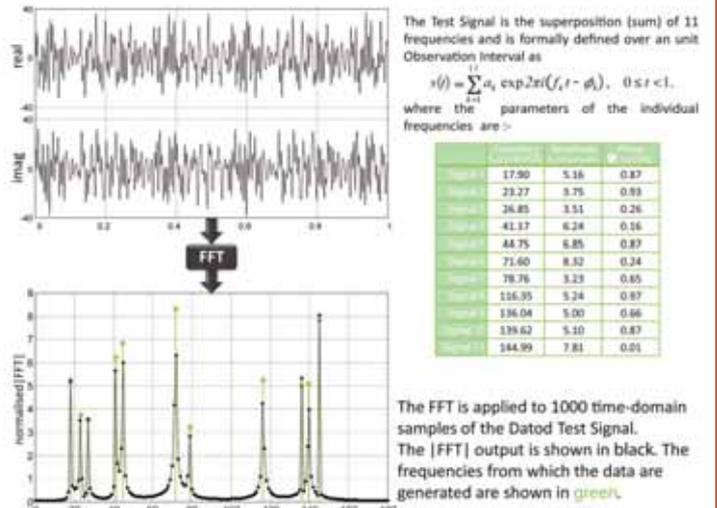


Figure 5: Hamming window + FFT

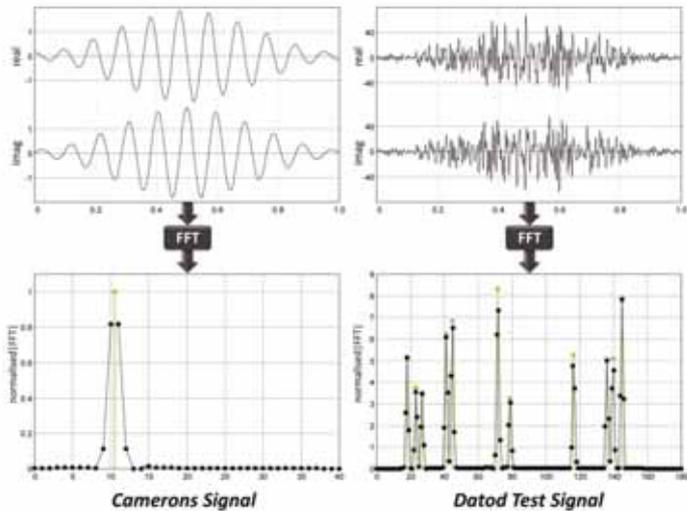
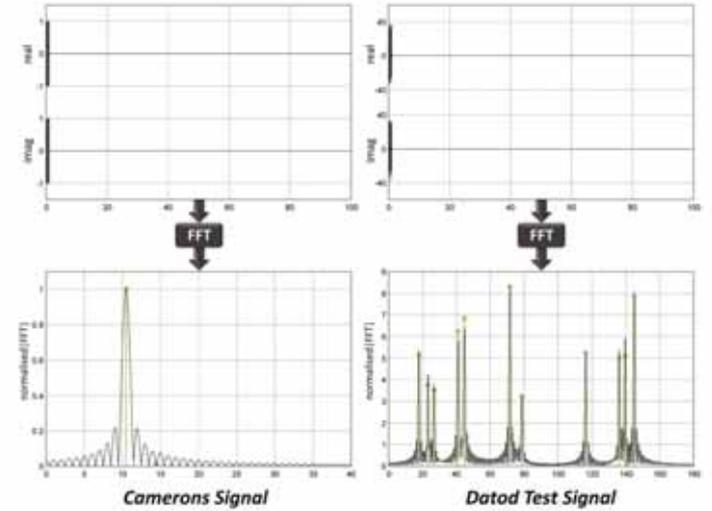


Figure 6: Zero padding + FFT



He then goes on to state that: “An important consequence of (his equation 52) is that signals composed of a single non-integer frequency must violate the Nyquist criterion”.

Oh dear! These are clearly significant statements, in a prominent peer reviewed journal, which express doubt concerning current mathematical approaches to signal processing and especially sampling. So has the signal processing community been in denial for the last fifteen years?

Sadly, the subtle differences between the Fast Fourier Transform, Discrete Time Fourier Transform, Discrete Fourier Transform, Continuous Fourier Transform and Cameron's paper are too numerous to be

detailed here; though it is important to state that the DTFT and Finite Fourier Series are the actual mathematical duals, and what connects them is the Sampling Theorem(s). Similarly, subtle issues with respect to the Real Number System, the Complex Number System and Oddness and Evenness arise.

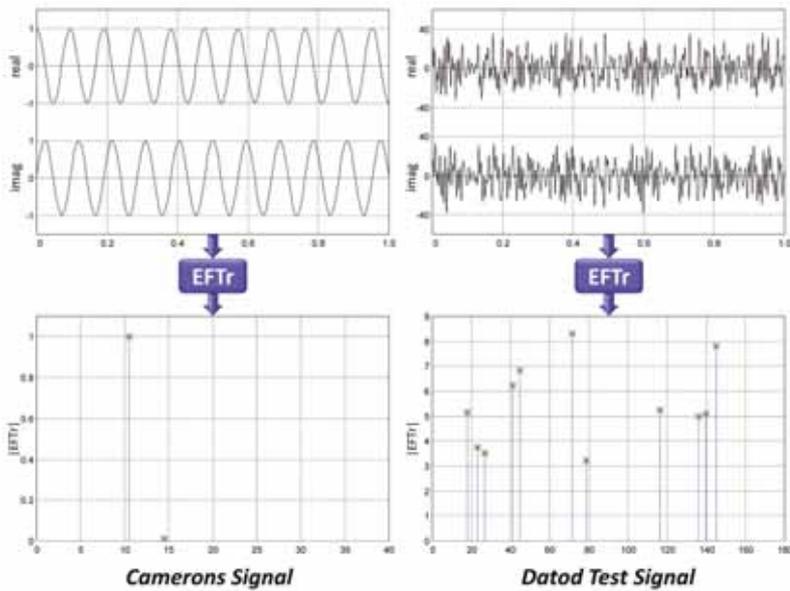
Window Functions & Zero Padding

We now consider two traditional co-processing techniques applied with the FFT. In Figure 4a is detailed the consequences of applying a window function to the Harris/Cameron and Datod benchmark data sets. Observe that applying a window in the time-domain has successfully reduced the

frequency-domain “skirts” as intended, but at the expense of introducing further confusion in the accuracy of the peak magnitude information processed. Also observe the consequences imposed on the original time domain data by the window.

In Figure 4b is detailed the consequences of applying zero padding to the Harris/Cameron and Datod benchmark data sets. Zero padding is normally applied in the time-domain and consists of supplementing a given time-domain dataset by appending a number of trailing zero entries as is the case here. A factor of x100 is applied in order to attain a “perceived spectral resolution” of two decimal places, as specified in the Datod

Figure 7: Datod EFTrunc



Test Signal parameters.

Observe that while the ‘peaks’ of such a function appear to be located reasonably close to the underlying fractional frequencies of which these Test Signals are composed, the amplitude of the normalised-|FFT| output is still not representative of the amplitude of the underlying frequencies.

In Figure 5 is detailed the application of the Datod EFTrunc process to the amplitude

identification problem. Observe that by this approach accurate peak amplitude information is attainable, as is phase information and, importantly, the correct fractional frequency component. This particular Datod benchmark example demonstrates advances on the sequential differencing algorithms including residual error and other deficiencies outlined in Cameron’s paper.

Comparison of Dynamic Range of Techniques

In Figure 6 we overlay the frequency spectrum for each of the implemented techniques to enable an appreciation of the dynamic range constraints. What are not disclosed here are the differenced residual EFTrunc spectrums, which in these particular two examples are shown in Figure 7.

Let us now assume that added to the Datod benchmark data is a 12th fractional frequency component -60dB down. We then pose the question: how well could each of the above techniques be able to accurately recover this spectral component information and furthermore does it matter? Those readers with access to an FFT package should try and see how far down you reach, especially with the other window functions and their associated (so-called) “scalloping loss” detailed in Harris’s paper.

Open Questions

Tables 1 and 2 detail the numerical performance of the FFT and co-processing techniques in relation to a Datod analysis technique for fractional frequency, amplitude and phase identification. Indeed, we have shown that the FFT is inadequate and inappropriate for accurately estimating or interpolating amplitude information from fractional signals: confirming Cameron’s case and observations.

In fact, the issue portrayed exposes

Figure 8: Comparison of the techniques graphed on a logarithmic (dB) scale

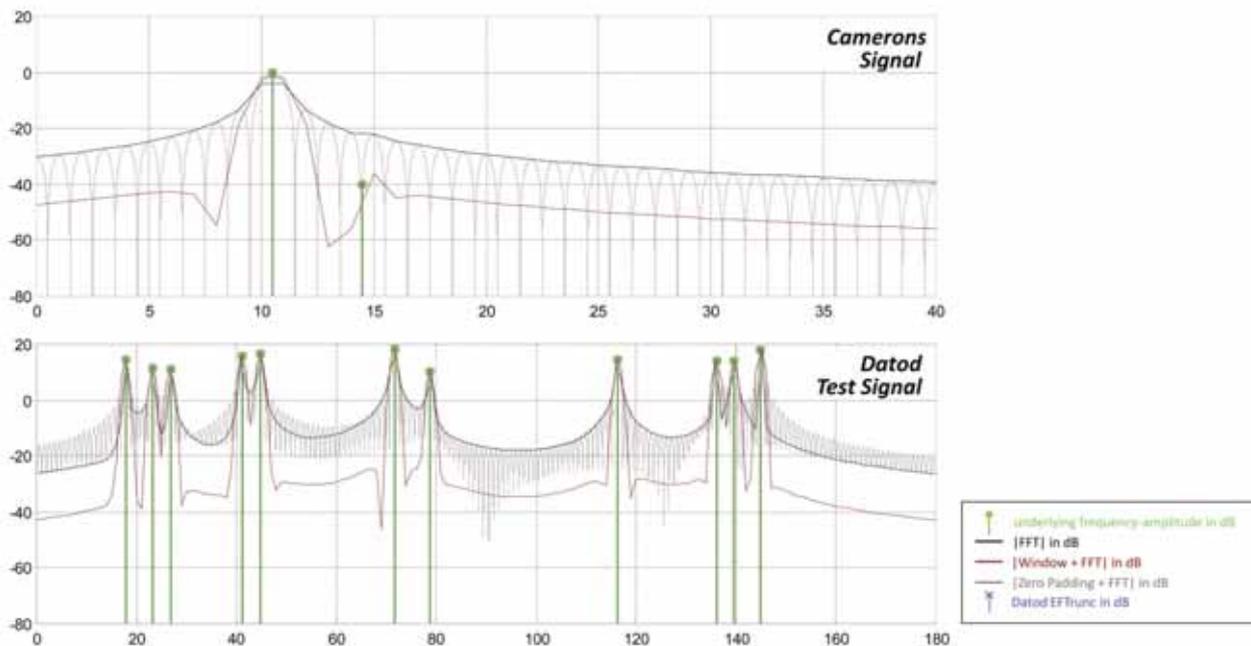


Table 1: Cameron’s signal

	Frequency f_c (cycles/OI)					Amplitude a_c (linear units)					Phase θ_c (cycles)				
	Underlying frequency	FFT	Window +FFT	Zero Pad +FFT	EFTrunc	Underlying amplitude	FFT	Window +FFT	Zero Pad +FFT	EFTrunc	Underlying phase	FFT	Window +FFT	Zero Pad +FFT	EFTrunc
Signal 1	10.5	10.0000	10.0000	10.5000	10.5000	1.00	0.6373	0.8179	1.0000	1.0000	0.00	0.7402	0.7402	0.9897	0.0000
Signal 2	14.5	—	15.0000	—	14.5000	0.01	—	0.0155	—	0.0100	0.00	—	0.2354	—	0.0000

Table 2: Datod test signal

	Frequency f_c (cycles/OI)					Amplitude a_c (linear units)					Phase θ_c (cycles)				
	Underlying frequency	FFT	Window +FFT	Zero Pad +FFT	EFTrunc	Underlying amplitude	FFT	Window +FFT	Zero Pad +FFT	EFTrunc	Underlying phase	FFT	Window +FFT	Zero Pad +FFT	EFTrunc
Signal 1	17.90	18.0000	18.0000	17.8900	17.9000	5.16	5.2621	5.1423	5.3705	5.1600	0.87	0.9066	0.9105	0.8523	0.8700
Signal 2	23.27	23.0000	23.0000	23.3000	23.2700	3.75	3.5215	3.5585	4.2342	3.7500	0.93	0.7888	0.7841	0.9394	0.9300
Signal 3	26.85	27.0000	27.0000	26.8100	26.8500	3.51	3.5629	3.4594	3.8264	3.5100	0.26	0.3168	0.3210	0.2193	0.2600
Signal 4	41.17	41.0000	41.0000	41.1400	41.1700	6.24	5.6494	6.0775	5.8087	6.2400	0.16	0.0602	0.0549	0.1320	0.1600
Signal 5	44.75	45.0000	45.0000	44.7900	44.7500	6.85	6.0013	6.5077	6.4181	6.8500	0.87	0.9695	0.9723	0.8616	0.8700
Signal 6	71.60	72.0000	72.0000	71.6000	71.6000	8.32	6.3243	7.3228	8.3501	8.3200	0.24	0.4025	0.4038	0.2069	0.2400
Signal 7	78.76	79.0000	79.0000	78.7200	78.7600	3.23	2.8287	3.0704	3.2148	3.2300	0.65	0.7136	0.7284	0.5189	0.6500
Signal 8	116.35	116.0000	116.0000	116.3500	116.3500	5.24	4.2402	4.7506	5.2024	5.2400	0.97	0.7328	0.7364	0.9100	0.9700
Signal 9	136.04	136.0000	136.0000	136.0900	136.0400	5.00	5.3371	5.0185	5.4264	5.0000	0.66	0.5632	0.5711	0.6067	0.6600
Signal 10	139.62	140.0000	140.0000	139.5800	139.6200	5.10	3.9861	4.5436	5.8760	5.1000	0.87	0.9943	0.9905	0.7845	0.8700
Signal 11	144.99	145.0000	145.0000	144.9900	144.9900	7.81	8.0615	7.8383	8.0627	7.8100	0.01	0.9455	0.9429	0.9406	0.0100

questions as to whether accurate amplitude information when applying window functions and zero padding is attainable: as such these are inappropriate signal processing solutions as neither address the root problem, which is the presence of an analysing function in the full transformed spectrum. Thereby standing on its head conventional wisdom about introducing additional signal processing techniques in order to augment deficiencies in the FFT or, indeed, any other transform process. The initial quotation from Marie Farge demonstrates she is, indeed, very wise.

While not demonstrated here, any additional filtering (high, low or band pass) operation would merely exacerbate the fractional information determination problem. So, why is the FFT considered unreasonably effective and a ubiquitous tool? One answer is how the FFT has been traditionally applied in science and engineering, such that the spectral components are all relatively attenuated or amplified with respect to a given frequency band and power level, thus any filtering operations accomplishing this are applied with consideration to the noise floor. So do we need to altogether re-think filtering operations, which intentionally suppress information, when both Cameron and Datod have shown that for fractional information to

be processed accurately you require access to all the acquired signal samples?

Put simply, all traditional thinking has been based on noise and interference rejection considerations, which either ignore or obscure the presence of an analysing function in the full transformed spectrum. But how can any traditional transform-based process identify interference and noise for removal, or phase noise, jitter and Doppler artifacts, if inherently it cannot accurately identify fractional frequency information in the first instance? Indeed, what happens when dispersive, non-homogeneous media are introduced as in physical reality? Unfortunately the concepts of the Principle of Superposition and Linear Independence now raise their ugly mathematical heads and whether they are, indeed, ‘above reproach’.

So how do fractional frequency information accuracy and the “spike” issue affect OFDM systems in the time and frequency domains? What would the current experts in the 4G communication field say? Indeed, has the issue been considered outside the defence community?

Even worse, what of the limitations induced by fractional frequency peak amplitude information accuracy affecting other more onerous engineering applications of the FFT such as obtaining Free Inductive Decay (FID) pulse information for Magnetic Resonance

Imaging and Spectroscopy, where exponential decays are inherent in the acquired data, over the Observational Interval, inducing spectral line broadening. What would Pierre-Marie Robitaille, the leading MRI scientist whose work featured in the “*Signal Analysis by Fact or Fiction*” article in the March 2010 edition of Electronics World have to say on the subject? For it is not just the FFT but also principal and independent component analysis (PCA/ICA), singular valued decomposition (SVD) and correlation signal processing techniques routinely applied in MRI and Spectroscopy that have consequential issues, especially when imposing localised line fitting algorithms.

I would trust that the material presented in this article has, to an open-minded scientist or engineer, raised concern in their own mind about the limitations associated with the traditional Fourier approach. Sadly, wavelet and multi-resolution techniques and their derivatives all essentially suffer from the similar pitfall which Marie Farge identified.

So are those engaged in traditional signal processing in denial and pursuing an approach doomed to failure by applying models on top of models, or is just a para-primitive re-think needed?

Finally, the issue of addressing Aliasing and the other Stanford benchmarks is for the future. ●

THE ELECTRONICS BEHIND LIGHTING – PART 4

HAKKI CAVDAR FROM THE KARADENIZ TECHNICAL UNIVERSITY IN TURKEY PREPARES THIS FIVE-PART SERIES ON LIGHTING ELECTRONICS – THE FUNDAMENTALS, THE TOPOLOGIES AND THE TYPES OF BALLAST CIRCUITS USED. IN THIS FOURTH PART HE FOCUSES ON HIGH-INTENSITY DISCHARGE (HID) LAMPS AND THEIR BALLAST CIRCUITS

H

igh-intensity discharge (HID) lamps are used in indoor and outdoor applications, and especially in street lighting and automotive headlamps and projection applications.

HID lamps offer high brightness and are efficient; they are about five times as efficient as incandescent lamps and their lamp life is 20 times longer compared to incandescent lamps. They have high lumen output per watt, cool color appearance, long life and low operating cost among others.

Examples of HID lamps include: Mercury vapor lamps, metal halide lamps, ceramic metal halide lamps, sodium vapor lamps and Xenon short-arc lamps. All these have similar

characteristics but different power ratings that range from 30W to 500W.

HID lamps have a negative resistance characteristic, as shown in Figure 1.

Due to this characteristic, HID lamp ballasts must be designed carefully.

Before the normal steady-state operation, HID lamps need ignition. The ignition voltage may be 3-4kV when the lamp is cold, and up 20kV when the lamp is hot. HID lamps need an AC voltage of about 100V for steady-state operation.

Lamp currents depend on their power ratings. The AC operating voltage across the lamp may be of high frequency (up to 100kHz). Above 1kHz, the HID lamps suffer from acoustic resonance, which can damage them. If using such frequencies, the acoustic resonance problem should be solved. One method is to use lower frequency of up to 500Hz, for which there's no need to use extra hardware.

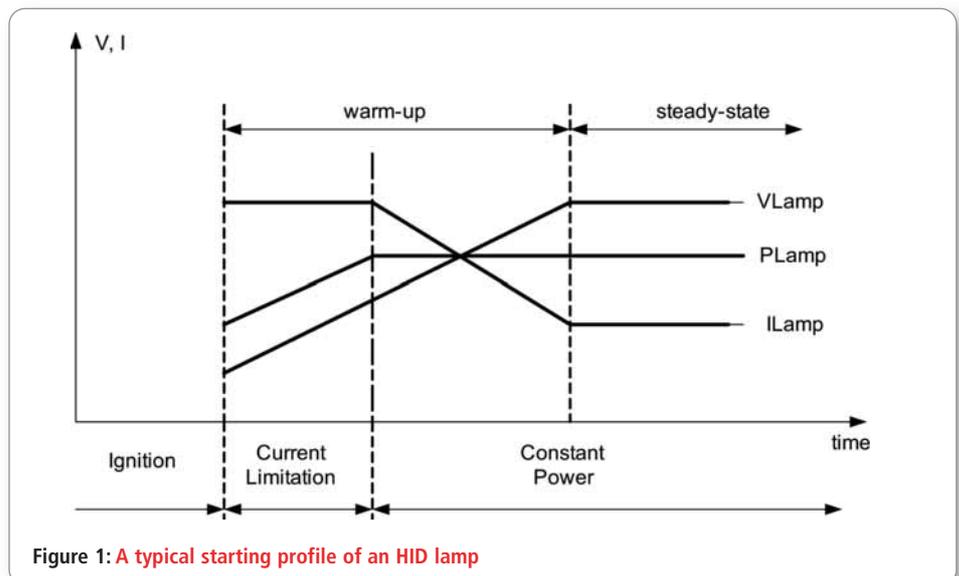
Figure 1 shows the start-up profile for HID lamps. Up to the moment of ignition, the behavior of the lamp is open circuit.

The ignition voltage of an HID lamp may be 3-4kV when the lamp is cold, and up 20kV when the lamp is hot

After ignition, the lamp voltage drops quickly to a very low voltage of 20V due to low lamp resistance. Therefore, the current of the lamp should be limited. If the current of the lamp is not limited, the lamp driver output circuit could be damaged. In other words, the ballast of the HID lamp should include a current limitation circuit.

The HID lamp ballast must overcome all steps of its operating modes: ignition, lamp warm-up and running. For ignition the lamp needs high voltage; after ignition the high voltage drops and current limitation is used at the lamp's warm-up mode, approximately 2-3 minutes after ignition. Finally, in running or steady-state mode the lamp needs only constant power level, voltage and current. The block diagram of a typical electronic ballast of an HID lamp is shown in Figure 2.

The EMI filter and PFC are the common parts of the lighting electronics. The output voltage level of the PFC is about 400VDC. The AC lamp voltage of the HID is typically 100VAC, so it needs a DC/DC converter. The DC/DC converter can be based on the Buck, Sepic or Flyback-isolated topologies. The final stage should be Full-Bridge inverter due to having a low operating frequency that is acoustically resonance-free. Additionally, a current limiter and igniter



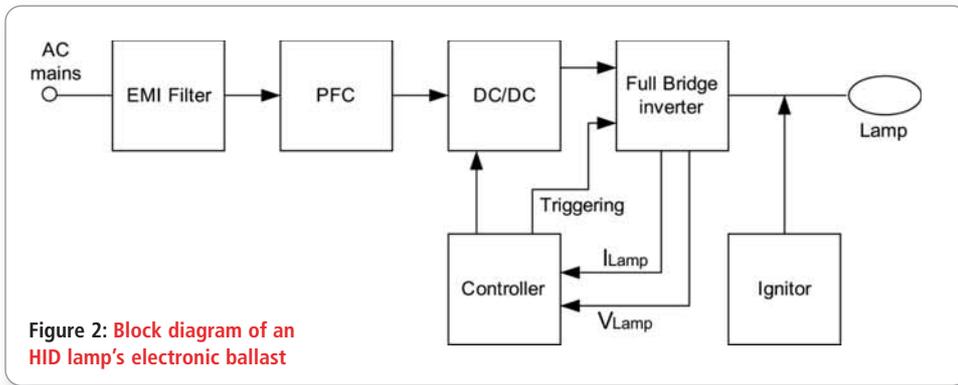


Figure 2: Block diagram of an HID lamp's electronic ballast

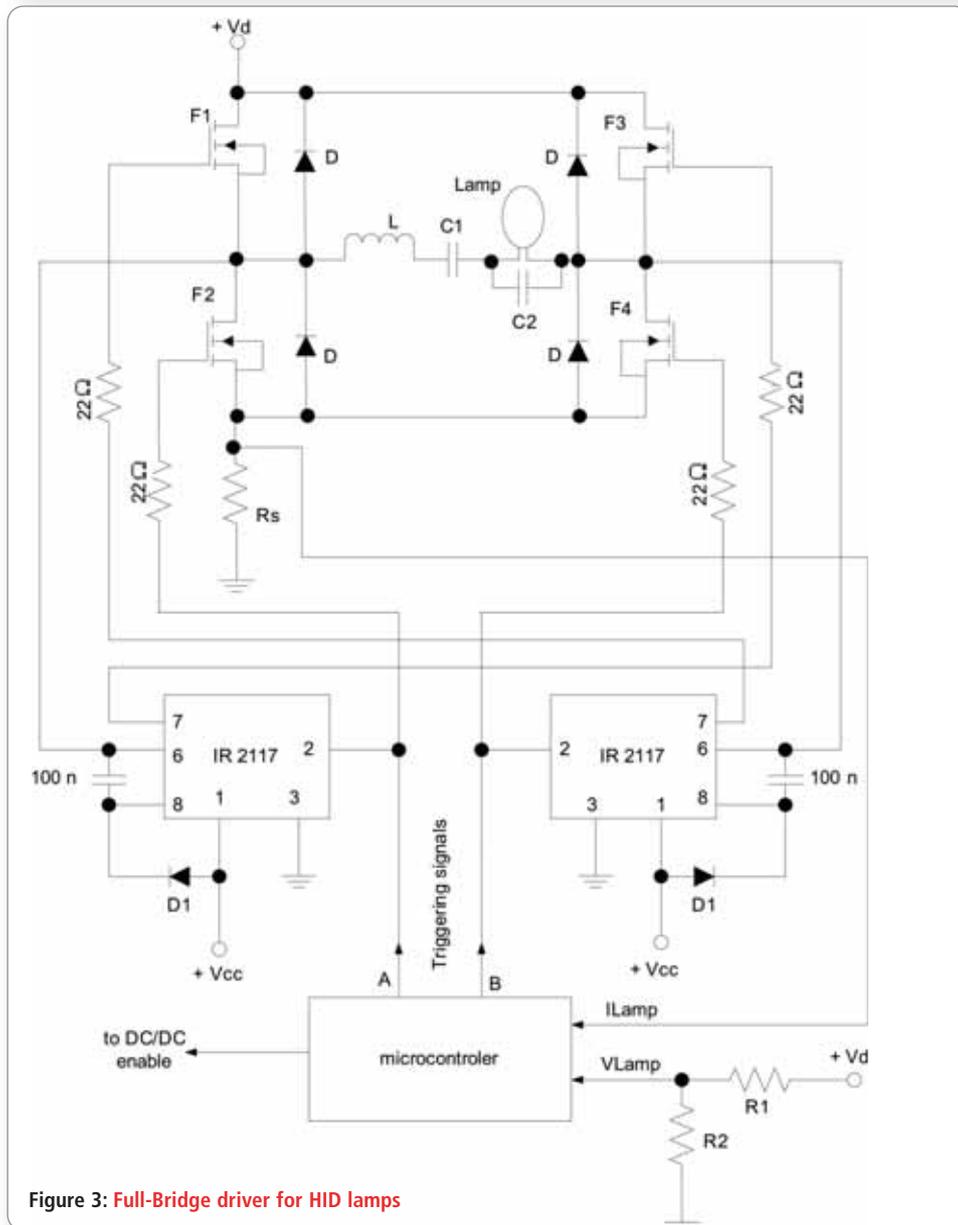


Figure 3: Full-Bridge driver for HID lamps

should be added to the system in order to create full electronic ballast.

The Electronics Design of an HID Ballast

The main stage in the electronics design of an HID ballast is the full-bridge (FB) inverter. An igniter is also placed in the

inverter. There are some off-the-shelf FB inverter ICs, such as IRS2453D by International Rectifier and MX6895 by Clare-IXYS.

Figure 3 shows an FB inverter in an HID ballast with an ignition stage. FB needs four power Mosfets: two of them, F2 and F4, are of the low-side (LS) driver type, whereas the other two power Mosfets, F1 and F3, are high-side (HS) driver type. In order to drive the HS power Mosfets (F1 and F3), IR2117 HS drivers are used in this design.

In Figure 3 the high side power Mosfets are driven with high-side driver ICs, such as the IR2117. In this design the HID lamp works with a 400Hz square wave. Igniters for HID lamps are a very important stage and there are many valuable references available in literature covering them.

Igniters may be designed as an additional circuit as described in T. Ribarich's "Shedding Light on HID Ballast Control", Power Control Technology, pp.34-37, October 2006. In this study, an igniter is designed inside the FB inverter with high frequency (100kHz). At the starting time, 400Hz and 100kHz are presented to the lamp together, as shown in Figure 4. The power stages of the FB inverter are different from each other at 400Hz and 100kHz. The resonance frequency of L-C1 and C2 is 100kHz. So, a high voltage of 3-4kV is obtained across the lamp at 100kHz. This signal form goes on until the lamp ignites; after ignition of the lamp, the combined signal is stopped, and only 400Hz is applied. Following ignition the lamp operates at 400Hz. The values of C1 and C2 can vary to 'tweak' the voltage across L-C1. L may be calculated as the resonance frequency at 100kHz.

A microcontroller is needed in the HID ballasts due to the complex starting profile of the HID lamp. A microcontroller produces the triggering

signals and controls the lamp current and voltage and lamp ignition. The controller reads the lamp current and lamp voltage levels and calculates the lamp power, followed by controlling the DC/DC converter. The software in the controller should provide the starting profile, as given in Figure 1. The warm-up time is around 2-3 minutes. Lamp

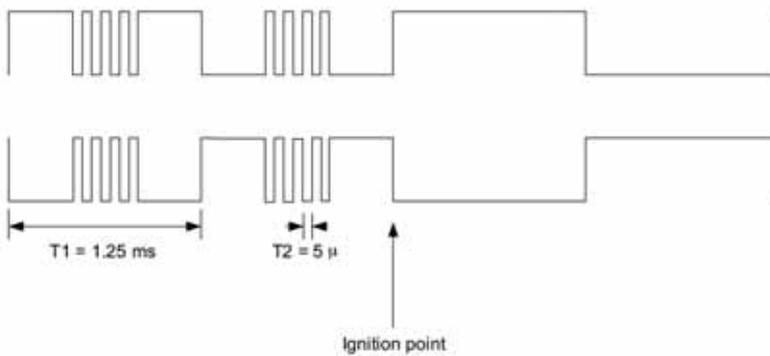


Figure 4: Triggering signals of a Full-Bridge driver

current is taken at the R_s , and a sample of the lamp voltage is taken at V_d via the voltage-divider resistances R_1 and R_2 . All diodes should be selected carefully with operating frequency and current levels in mind.

The other parts of the HID ballasts are the EMI filter, PFC and DC/DC converter. The EMI filter is designed according to the standard requirements and PFC is designed based on the lamp power level. Buck, Sepic and Flyback DC/DC converters

are suitable for HID ballasts, where Flyback DC/DC converters offer lamp isolation.

Critical Design

HID ballast design is a bit difficult and even critical. The igniter and starting profile are the complex side of this lamp. In order to overcome and solve this complexity, a microcontroller should be used.

There are many different HIDs in the view of the physical and power level characteristics required by the design.

These situations will require some changes of the design of the HID ballast, but the main structure of the ballast for all HIDs is similar to the one described here. ●

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How green is your E-READER?

HUW MUNCER OF TE CONNECTIVITY IS ALWAYS ON THE ROAD. AS A SALES MANAGER, HE SEES WHAT ENGINEERS ASK FOR AND NEED, BUT ALSO HOW AN ENGINEER'S JOB HAS CHANGED OVER THE YEARS

One of the topics frequently raised when I am talking to electronics designers is how environmentally-friendly their product is and all the ISO numbers that they have to make it comply with.

When I began selling components many years ago, environmental concerns weren't much of an issue for designers. Today, not only are they involved in developing ever more intricate products that weren't even envisaged back then (think of mobile phones, MP3 players and e-readers), but now the products themselves are becoming obsolete so fast that we need to think of the repercussions of loading up our landfills with "e-waste" when we throw them away.

That set me thinking. Why are the "green" credentials of these electronics – and how they're made – not under more scrutiny?

To help you make an informed choice, new cars are always presented with details about their CO₂ emissions, and new appliances such as fridges and washing machines come with energy ratings. It's also becoming the norm when buying food to look at how and where it is produced (the so-called "air miles" footprint), as well as information to determine whether it is free-range, fairtrade, organic, etc.

This is information that will often influence a purchase since it affects long-term costs, such as less energy use by an appliance translating to lower power bills. But consumers also want to know because they are increasingly conscious of how products affect the

environment, not to mention their own health. They will often pay more for a product with 'green' credentials.

Consumer electronics, on the other hand, are not evaluated in the same way. When buying an e-reader or a new mobile phone we don't consider how it has been manufactured or the way its disposal may impact the environment. We only worry about how much it will cost to buy and use. At best, we might think about how to properly recycle the now-obsolete version of what we have back at home.

The increasingly popular e-reader presents an interesting example of this quandary. There is the on-going debate about which is greener, the e-reader or the traditional book. Of course, since books are made of paper they can be more easily re-cycled and don't become e-waste, but on the other hand, there is

**Electronic devices
should have "green"
manufacturing credentials**

the negative impact of trees felled for the paper and the chemicals used for ink and glue and the energy used to manufacture the book.

Emerging research reflects a complicated picture. A 2011 study by Cal Poly State University in the US, titled "*Electronic Readers Versus Printed Material – An Ecological Comparison*", for example, cites that "with respect to fossil fuels, water use and mineral consumption, one e-book

has 70 times the impact of one printed book in terms of water, materials and recycling issues". The conclusion of the study on which is greener, the e-book or the book, is that it depends on how many books the reader actually reads on the e-reader to make it worth the energy and materials used to create it and, also, on how the consumer recycles the e-reader so that it won't end up in a landfill or be otherwise disposed of improperly.

As for the manufacture of the devices, the study mentions that at least Apple responded to questions about the production of its iPad device by answering that it had established "safe, fair trade factories in which the iPads are assembled in and are routinely checked on for safe practice of workers".

Here in the UK, some of this burden of recycling is accounted for in the Waste Electrical and Electronic Equipment Directive (WEEE) directive of 2007 in which manufacturers can join a compliance scheme to monitor the amount of equipment they have placed in the UK market. They are then responsible for financing the treatment and recycling of this product in household waste sites.

But what about the consumers' responsibility at the beginning of the buying cycle? And, to my point, what about the manufacturing process for different e-readers, or cell phones or every other electronic device? When comparing apples to apples, which of the two similar electronics gadget would tick the environmentalist's box? It would not even occur to most

There is the on-going debate about which is greener, the e-reader or the traditional book

consumers to look backwards down the manufacturing chain to think about the provenance of an electronic item. So, should electronics manufacturers and designers be more concerned about informing the consumer about the design and production process of these products? And, if so, shouldn't the engineers who design a greener, more environmentally sound product get recognition for the effort they put in to meet the stringent standards?

In the electronics industry we already know that the majority of design engineers are using environmental management systems based on International Organization for

Standardization, or ISO, regulations, such as ISO 14001 which provides business management with a structure for managing environmental impact. ISO 14001 is seen as only one of many tools to be used to attain sustainable development. Components manufacturers may also follow standards and guidelines for hazardous materials (RoHS), chemicals (REACH) and Halogen Content.

Why not create some type of labelling or rating system that identifies and rewards a product's (and company's) adherence to green standards and guidelines? In other words, we could use the information we already have to

educate consumers about the effort that went into developing a more environmentally safe electronic device. I find it frustrating that an electronic product's manufacturing "credentials" are not highlighted at the point of sale so that the buyer can compare it to a cheaper product that may have an inferior production process. We know by now that some consumers will pay more for food that has been processed in a more environmentally-friendly and healthier manner. When will we bring in a "fair trade-style" rating for consumer electronics so that the public can make an informed choice – just as they do for their meat and potatoes? ●

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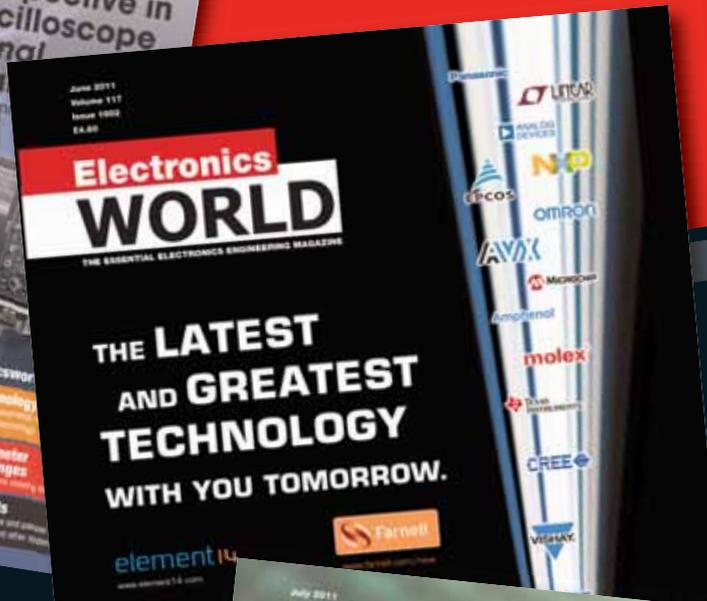
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WHAT THE READERS SAY

PARTIAL CURRENTS

Barry McKeown (Letters, EW, January 2011) wonders why no reader has questioned the mathematics of Ivor Catt's recent series of articles. That omission can be rectified.

If L is the inductance of a length s of twin-conductor cable and C is the capacitance, then the inductance per metre and the capacitance per metre can be defined as:

$$\frac{dL}{ds} \text{ and } \frac{dC}{ds}.$$

Ivor has ignored the fact that current and voltage can vary along the length of the line.

If the initial equations are wrong, then so are any equations derived from them. Conclusions as to the physical nature of current propagation, derived from the use of faulty mathematics, can only be taken with a pinch of salt.

In his opening statement, Ivor declares "We see two electric currents travelling in opposite directions down a single conductor. Conventional electric current is not fit for purpose." He appears to consider the fact that current can travel in two directions along a conductor as an amazing revelation.

There is nothing new in this concept. The phenomenon is described in every textbook on electromagnetic theory. Every designer of radio frequency equipment is well aware that reflections occur at every discontinuity in a transmission line, and that the actual current at any point on the line at any instant is the sum of a number of partial currents. Circuit theory, which

components as it propagates down a transmission line, with one component travelling faster than the other. Further investigation is called for.

It should be possible to devise an experiment which enables the pulse to be observed as it propagates down the line. Close examination of the scope waveforms should allow a model to be produced which replicates the response. Assessment of the model will provide a clearer insight into the electromagnetic coupling mechanisms. Improved understanding of the physics will enable us to control the glitches which bedevil the performance of many logic circuits.

Perhaps Ivor could help in such a project?

Ian Darney

IVOR CATT REPLIES:

In reply to Ian Darney's comment: "Ivor has ignored the fact that current and voltage can vary along the length of the line", I would like to say that the reason why the TEM Wave has been so confusing is because it has been treated as a sine wave. It is much easier to grasp if current and voltage are kept constant, as I do, and as occurs in digital systems. Seeing only sine waves (using Fourier Series), it may not be easy to grasp the obvious flaws in theory illustrated by "The Catt Question" and now in January/February 2011 of Electronics World.

In reply to Darney's comment: "In his opening statement, Ivor declares 'We see two electric currents travelling in opposite directions down a single conductor. Conventional electric current is not fit for purpose'. He appears to consider the fact that current can travel in two directions along a conductor as an amazing revelation. There is nothing new in this concept", I say that the idea that electrons will hop along down a conductor in both directions, waving to each other as they pass, is truly amazing.

In reply to Darney's comment: "Ivor's articles are based on the content of an academic paper in an old journal. The researcher who carried out the original work has not been given any credit. There is no mention of the title of the paper, the name of the journal, nor the date it was published", I say the relevant paper is by Ivor Catt, now at

*"Electricity" is merely the edge of an electromagnetic field.
It no more exists than does the slope of a hill, which is merely dh/dx*

Electromagnetic theory derives formulae for the voltage V between the conductors and the current I in the conductors at any point on the line at time t . If it is assumed that there are no copper losses or dielectric losses, then:

$$\begin{aligned} \frac{\delta V}{\delta s} &= \frac{dL}{ds} \cdot \frac{\delta I}{\delta t} \\ \frac{\delta I}{\delta s} &= \frac{dC}{ds} \cdot \frac{\delta V}{\delta t} \end{aligned} \quad (1)$$

where the symbol δ indicates a partial derivative.

Equations 4 and 5 in the article 'The end of electric charge and electric current as we know them' (Ivor Catt, EW January 2011) can be re-written as:

$$\begin{aligned} V &= \frac{dL}{ds} \cdot I \cdot \frac{ds}{dt} \\ I &= \frac{dC}{ds} \cdot V \cdot \frac{ds}{dt} \end{aligned} \quad (2)$$

is a development and simplification of electromagnetic theory, caters for this effect by the use of mesh analysis.

Ivor's articles are based on the content of an academic paper in an old journal. The researcher who carried out the original work has not been given any credit. There is no mention of the title of the paper, the name of the journal, nor the date it was published. Only the skimpiest description possible is provided of the actual experiment.

There is no data on the equipment used, the setup, the test method, or on the scaling of the oscilloscope traces. It is impossible to repeat the experiment using the information provided by Ivor.

Even so, credit should be given where credit is due. Ivor has identified a phenomenon which is not even alluded to in any book on electromagnetic theory; a short, sharp, transient pulse separates out into two different

<http://www.ivorcatt.co.uk/x0305.htm>.

In my series of articles published in Electronics World in January, I wanted to explain that we have a revolution in science – the relegation of “electricity” along with phlogiston and caloric. No such major scientific advance has occurred for a century. Worldwide, all relevant academic parties have refused to comment on the article. This delays the time bomb.

High-speed digital electronics exposed impossible flaws in the traditional concept, which were not noticed or ignored/suppressed for half a century. “Electricity” is merely the edge of an electromagnetic field. It no more exists than does the slope of a hill, which is merely dh/dx . The real stuff is h and x , as electromagnetic field is real. Nowhere else in the history of science has the mere mathematical manipulation of something real (electromagnetic field) been thought to be real (electricity).

A very narrow voltage/current pulse was injected into the left-hand active conductor adjacent to a parallel passive conductor, with the front of the passive conductor now shorted to ground. Three metres along, the narrow pulse separated out into two pulses, and two equal and opposite pulses appeared on the passive conductor. In Electronics World in January 2011, p20, using Faraday’s Law of Induction and the Law of Conservation of Charge, it was proved that only two wave front patterns can be sustained in such a system. These are the Even Mode, where the two conductors are at the same potential and carry electric current in the forward direction, and the Odd Mode, where the two conductors are at equal and opposite potentials and carry electric current in opposite directions.

The earliest, lowest traces are neither. They show a third, illegal, unbalanced mode. Further, the first, lowest trace on the right must be showing electric currents travelling in opposite directions

Figure 1: Printed circuit board used

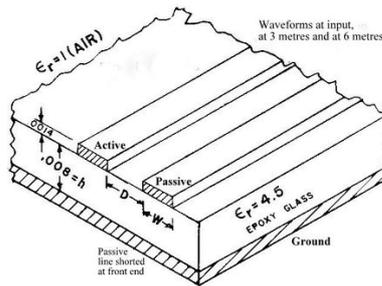
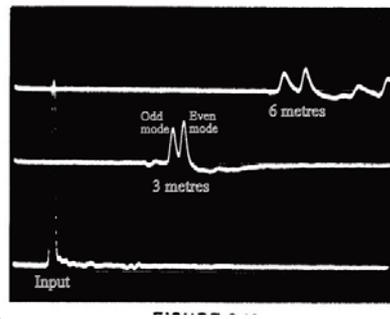


Figure 2: Active conductor at input, 3 metres and 6 metres



along the same conductor at the same time. This is further evidence that electricity is not fit for purpose. Previously, In Electronics World in May 2009

<http://www.ivorcatt.co.uk/cattq.htm>, “The Catt Question” showed us that, in order to get to where it had to, electric charge had to travel at the speed of light – giving it infinite mass. Now we find electric currents travelling in both directions along a conductor. The answer to this nonsense is to get rid of electric charge and current, and reduce them to merely mathematical manipulations of the electromagnetic field. To do this, we might use Maxwell’s Equations, which link field to electricity.

Darney also writes: “Even so, credit should be give where credit is due. Ivor has identified a phenomenon which is not even alluded to in any book on electromagnetic theory; a short, sharp, transient pulse separates

out into two different components as it propagates down a transmission line, with one component travelling faster than the other. Further investigation is called for.”

What is so fascinating is that in 1964 I had to rediscover the two modes, Even and Odd. They were already known – but not proven – in microwave engineering, as a nuisance feature. However, there is no evidence that they knew about the two velocities. This is all very thoroughly

Figure 3: Passive conductor at input, 3 metres and 6 metres

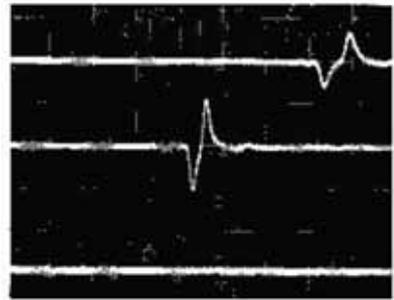
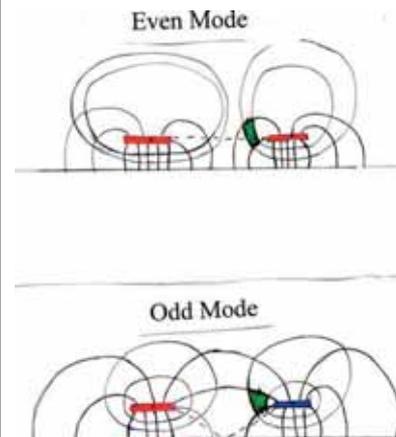


Figure 4: Even mode (above), Odd mode (below)



discussed in my 20 page 1967 IEEE paper now at

<http://www.ivorcatt.co.uk/x0305.htm>

As to not alluding to this in any book, one can go further. As the years go by, books on electromagnetic theory “allude” to less and less of the key factors in electromagnetics, while at the same time advancing from 200pp to 500pp and £20 to £50. Today’s lecturer has no access to much more fundamental information than these two velocities.

Ivor Catt

IF YOU WOULD LIKE TO COMMENT

on this subject on any other that you have read on in Electronics World magazine, please write to the Editor at Svetlana.josifovska@stjohnpatrick.com

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BUILDING A 'SMART DEVICE' USING THE FTDI VINCULUM-II – PART 2

JOHN HYDE FROM FUTURE TECHNOLOGY DEVICES INTERNATIONAL (FTDI) IMPLEMENTS A SERIES OF USB PROJECTS FOR *ELECTRONICS WORLD*

This article continues the description of how to use Vinculum-II to build a subsystem that can be used for record and playback keystrokes and mouse movements. Already we have identified a keyboard and have written a thread that collects keystroke reports. We also created a message containing keystroke information and sent this to another thread that used Vinculum-II's USB slave driver to send keystrokes to a target PC. We built a short circuit but there are other things that can be done with this hardware.

Stage 6: Keycatcher

It is easy to add a thread between the GetReports thread and the SendReports thread, in fact, neither thread will know that we have done this and will operate unchanged. This new ForwardReports thread will forward the KeyboardMessage unchanged and SendReport will return it as before. ForwardReports will use a RecordMessage to make a copy of each keystroke report and will send this to a Record thread that will store the reports, and the time intervals between them, in a Flash memory. The data flow diagram for this Keycatcher device is shown in Figure 1.

I chose an Atmel Dataflash to store the keystroke data. The part uses an SPI interface so we need to add Vinculum-II's SPI Master driver to our project. I built a plug-on board (shown in Figure 2) that connects to C9 of the V2Eval board. I also added a Timer driver that measures the elapsed time between keystrokes. Both drivers are started and initialized in initialize.c.

Load the Stage 6 project and view main.c. I made a small change to the FindkeyboardThread – it initializes the KeyboardMessage.SignalSemaphore to a new semaphore; this will cause GetReports to send completed keyboard reports to a different location. A new thread, ForwardReports, makes a local copy of the keyboard report before sending it off to the SendReports thread.

The ForwardReports thread owns RecordMessage at start-up and uses it to send keyboard reports to another new thread, Record. The Record thread has

the most work to do and it owns writing Entries to the Atmel DataFlash. The definition of EntryType (see main.h) allows Record to save both keyboard reports and mouse reports (these will be added in Stage 9). Elapsed time between keyboard/mouse reports is also recorded so that later playback will be at the same tempo as the original recorded data. The Atmel DataFlash is an impressive part – it saves data in 512 byte blocks and it has two 512 byte buffers to stage data before writing a block. The Record thread fills one buffer then, while this buffer is being copied to flash memory, it fills the other buffer. This approach effectively hides the long flash write time.

Build, download and run the Stage 6 project. Externally you will not see a difference from Stage 5 but, rest assured, data is being written to the DataFlash. I debugged this module using three channels of the USBee DX connected to the SPI lines on V2Eval board: C9. I looked for the Record thread being active then turned up the resolution to see the SCLK, MISO, MOSI and CS signals. The USBee DX includes an SPI decoder so it was easy to check that all signals were correct. We now have the basics of a keycatcher product working. The next stage is to add a button for controlling when data is recorded.

Stage 7: Add a Record Button

We already know how to manage buttons from previous articles but this is not the complexity of this stage. The data-flow diagram of Stage 7 (shown in Figure 3) shows that the Record thread must now respond to two semaphores. This is something that we have not done before.

Load the Stage 7 project and view main.c. Note that I have added a RecordButton thread that signals a RecordControl semaphore when the button is pressed – the button is implemented as a toggle function for Record. I also changed the Blink thread to keep LED3 on during record so that it is easy to know when keystrokes are being recorded.

All of the new work is in the Record thread so you should now focus there. Note that VOS supports waiting at a list of semaphores. A list is created with some control flags – in this example I will wait on any semaphore but you can also wait on all of the semaphores being signalled before proceeding. Use a `vos_wait_semaphore_ex` call to wait on a semaphore list and, when it returns (in ANY mode), it provides an Index into the semaphore list indicating which semaphore was signalled. Since I have only two entries in my list then I will receive an Index of 0 or 1 which my code treats as a Boolean. I will wait on three semaphores in Stage 9. Build, download and run the Stage 7 project. You can now press SW3 to enable and disable recording. LED3 will stay on during recording.

Stage 8: Add Playback

In this stage we add a Playback button which will send the keystrokes we recorded to the target PC. From a data flow perspective, we are adding a Playback thread and a PlaybackMessage that will circulate between the Playback and SendReports threads. The Playback thread initially owns

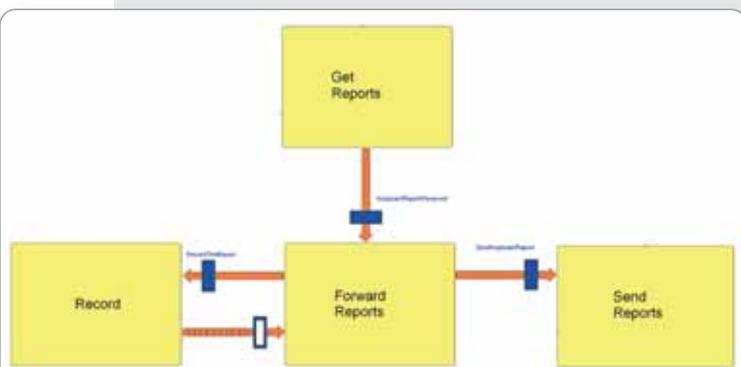


Figure 1: Message flow diagram of Stage 6

PlaybackMessage and it sends keystroke reports that it reads from the Atmel DataFlash to the SendReports thread. The Playback thread is controlled by a Playback button but it does not have to wait at two semaphores simultaneously. The SendReports thread must be extended to monitor two message streams – I use a semaphore list just like the previous stage.

Load the Stage 8 project and view main.c. The Playback thread is also new and you should review that now. Build, download and run this Stage 8 project and press the Playback button. Keystrokes that you recorded in Stage 6 or 7 will now be sent to the target PC as if you were typing them.

Stage 9: Add a Mouse

A boot mouse is similar to a boot keyboard from a software point of view – it is a HID that generates a 3-byte report rather than an 8-byte report. This means that our example code does not have to be extended very much to support the addition of a mouse. In fact, you will see that, in some cases, we will use the same code but will process different data. Figure 4 shows the message flow diagram of Stage 9 with the mouse functions added in a similar way to the keyboard functions. The GetReports(Mouse) thread will own a MouseMessage that it circulates around the ForwardReports and SendReports threads.

Open the Stage 9 project and view slave.c. Note that I extended the descriptors of our slave device to define a composite device with two HID interfaces. Interface0 is our keyboard as before and Interface1 is a boot protocol mouse that uses EP2 for data transfers. I needed a MouseReportDescriptor to define the 3-byte report and this is shown in slave.c. Most of the setup code for the Mouse can use the same code as the keyboard since they are similar HID devices – the only real difference is that I must supply a different report descriptor for Interface1.

Looking briefly at main.c note a new thread called FindMouse that is basically a copy, paste and edit of the FindKeyboard thread. FindMouse will call a WaitForMouse procedure which is in host.c. I converted the original WaitForKeyboard function into a WaitForDevice function with a few additional parameters. I then have two small front-end procedures, WaitForKeyboard and WaitForMouse that both call WaitForDevice but with different parameters. So the additional code for a mouse is minor. In order to additionally connect a mouse to the V2EvalBoard we will need a HUB. Some keyboards have an integrated hub and this is a convenient way to add a mouse.

The WaitForDevice function will correctly find a keyboard and mouse that are connected via hubs – there is no additional programming required for this situation. Going back to main.c and the FindKeyboard and FindMouse threads: Note that they both call GetReports but with different parameters. At runtime we will have two copies of GetReports running, one in the FindKeyboard context and one in the FindMouse context – only one procedure exists in ROM but we are running two copies of it, same code but different data. This is a real savings in code size. For ease of explanation I call these GetReports(keyboard) and GetReports(mouse) threads in Figure 4. The ForwardReports and SendReports threads are extended to accommodate the additional circulating MouseMessage. This involves adding a new semaphore to each thread and extending the semaphore lists in each. The processing of mouse reports is the same as processing keyboard reports.

Finally, the Record thread was extended to include processing of the mouse report which is handled in a similar way to the keystroke reports. Build, download and run the Stage 9 project. Press the record button,

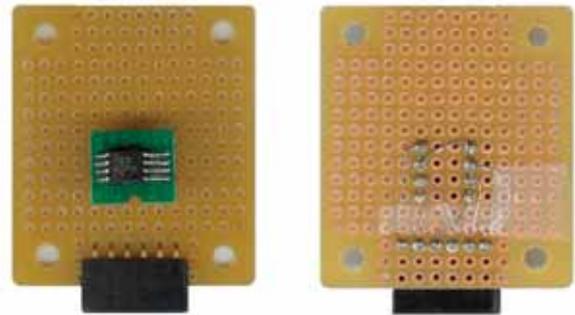


Figure 2: A small add-on board holds the Atmel DataFlash

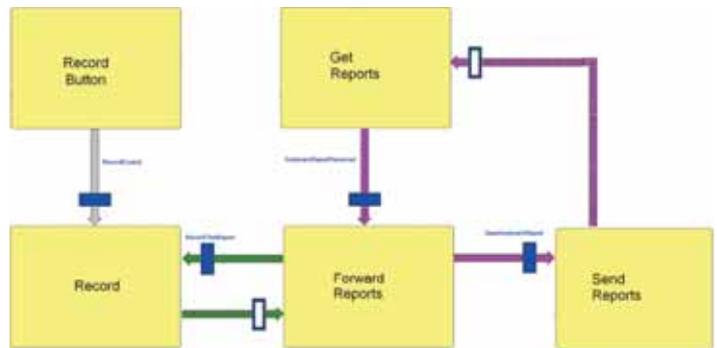


Figure 3: Message flow diagram of stage 7

move the mouse and type some characters. Press the playback button and watch the cursor move on the target PC and watch characters appear.

Next Step

This article has described a comprehensive example that has used USB host, USB slave, GPIO, UART, SPI Master and Timer drivers. A good next step would be to add more buttons and add routines that allow for multiple individual recordings to be made and played back. This would create a smart device out of a standard keyboard and mouse where multiple repetitive sequences could be recorded and played back to simplify work flow in many applications. This application extension is left as an exercise for the reader.

In the next article we shall look at interconnecting existing USB devices to build interesting subsystems. ●

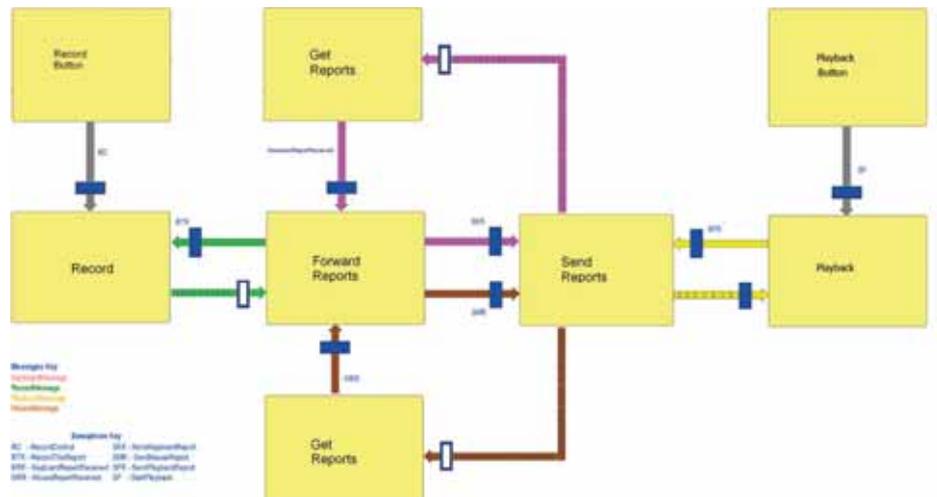


Figure 4: Message flow diagram of Stage 9

Automotive Grade 3-Phase MOSFET Pre-Driver IC for Brushless DC Motor Control

The new A4933 from Allegro MicroSystems Europe is an automotive-grade 3-phase MOSFET



pre-driver IC for the control of brushless DC motors in applications such as electronic power steering systems, engine cooling fans, transmission actuators and hydraulic pumps.

The new device is targeted at extreme applications where high power, high torque and high temperature combine to require a MOSFET pre-driver that is able to deliver large MOSFET gate drive and switching capabilities. It is particularly suited to use in 3-phase systems, especially those which use sinusoidal control of the motor phase currents.

The A4933's key features include an integrated charge pump that provides full gate drive for battery voltages down to 7V and reduced gate drive for battery voltages as low as 5.5V; a top-off charge pump that enables 100% pulse-width modulation; an adjustable dead time that can be regulated by the user; an adjustable drain-to-source monitor; and improved fault diagnostics that enhances the user's ability to decode and identify faults.

www.allegromicro.com

AIM-TTI'S CPX400 EXTENDS SERIES OF POWERFLEX REGULATED LABORATORY POWER SUPPLIES

Aim-TTI has extended its best-selling CPX400 series of PowerFlex regulated laboratory power supplies to include single-output models. The CPX400S is a 420W power-supply unit with extremely compact dimensions, being only 107mm wide (quarter rack width). Maximum output voltage is 60V and maximum current 20A subject to the 420W power limit envelope. Range control buttons allow it to be configured as full PowerFlex, fixed range 60V/7A or 20V/20A, or any user-selected voltage/current combination.

The power supply uses true analogue controls, but incorporates an S-Lock function which transfers control of voltage and current from the analogue controls to internal digital circuitry for stability and safety.

The CPX400SP adds a full range of digital control interfaces for remote-control applications, along with duplicate power and sense terminals on the rear panel. RS-232, USB, GPIB and LAN (Ethernet) interfaces are all provided as standard. The LAN interface is compliant with LXI (LAN eXtensions for Instrumentation).

www.aimtti.co.uk



New Flame-Retardant EMC Shielding Gasket from Kemtron

Kemtron, the British manufacturer of RFI/EMI shielding gaskets, materials and components has launched a flame-retardant, low smoke, low toxicity EMC shielding gasket,



that is tested and approved to the international standard UL94V-0 by Underwriters Laboratories for flame retardancy, file number E344902. It is also tested for smoke density

to BS 6853:1999: Annex D.8.3 and oxygen index to BS EN ISO 4589-2:1999 confirming the material meets to requirements for minor internal use on vehicles category 1a such as gaskets for electronic enclosures, making it highly suitable for applications in underground transportation, trains and other safety critical applications.

The material is a nickel-coated graphite loaded into silicone elastomers, product code SNG-FR. The gasket provides a highly electrically conductive path between mating flanges of an electronics equipment enclosure giving a high level of RFI/EMI shielding. The material can be supplied as an extruded strip in various profiles, "O" rings or flat die cut gaskets.

www.kemtron.co.uk

5GS/S DIGITIZER IN CONVENIENT, PORTABLE USB FORMAT

The new PicoScope 6407 USB Digitizer provides high-speed data capture for almost any industrial or scientific application. With four 1GHz 50-ohm analog inputs and a 5GS/s sampling rate, the instrument can handle a wide variety of signals such as high-speed serial data; waveforms from automated test rigs, prototype circuits and high-frequency PCBs; radio, laser and radar IF signals; and many types of experimental data. The 1 gigasample memory buffer on the PicoScope 6407, unsurpassed by any other USB or plug-in digitizer in this price range, allows high-speed capture of very long data records. A USB streaming mode allows continuous capture of unlimited amounts of data at up to 13MS/s.



The software development kit (SDK) supplied allows the digitizer to be integrated into any programming environment that supports C calling conventions. This includes languages such as Visual Basic, C++ and C#, and instrumentation software such as National Instruments LabVIEW.

www.picotech.com

Belden and FMN Cooperate in the Industrial WAN Space

Belden has joined forces with FMN communications GmbH to introduce two Wide Area Networking (WAN) products that combine the WAN expertise of FMN and the LAN expertise of Hirschmann.

The first of the new products is the FMN alpha DSL WTM HS, which is a universal ADSL modem, especially designed for use in industrial environments. The ADSL modem is available in two variants, known as A and B. These cover the Annex A and Annex B standards which are currently in use across Europe. At the time of launch, both variants are only certified for Europe.

The second new product is the FMN alpha UMTS WTM 3 HS. This is a 3G wireless WAN modem and router designed for indoor or outdoor use.

Both models have metal housing, operating temperatures between -25°C and 55°C and support 10 to 60VDC or Power over Ethernet. The ADSL product is a plug and play device.

www.beldensolutions.com



VERY LOW PROFILE ILLUMINATED TACT SWITCH OFFERS HIGH QUALITY USER EXPERIENCE

Foremost Electronics announces the availability of the Marquardt 3006 series of low profile, short-travel, LED illuminated TACT switches.

The 3006 TACT switch series offers users a superb tactile "feel" using Haptic technology. Haptics is a tactile feedback technology that takes advantage of the user's sense of touch to provide reassuring or relevant feedback on operation of the switch. Common uses of Haptics are arcade games and home games consoles and controllers, frequently taking the form of vibration or force-feedback in joysticks and controllers.

The key to the advanced design of the 3006 TACT switch family is a damped snap action disc, a mixture of switching mat and snap action disc, which allows very flat control elements with a fine tactile response and a clear user feedback signal with minimum travel. The design of the LED illumination makes backlit symbols (pictograms) visible even at night.

www.4most.co.uk





INTERCHANGEABLE (RT CURVE-MATCHED) NTC THERMISTORS

ATC Semitec's SP interchangeable series is a range of NTC thermistors that offers very high precision ($\pm 0.2^{\circ}\text{C}$ 0~70C or better) at significantly lower pricing to that of existing interchangeable NTCs.

Readily available from stock, these new high-accuracy NTCs mean that now a wider range of users can cost-effectively achieve more accurate temperature control and thus more energy-efficient and comfortable working environments.

The main features of the SP thermistor range include R25 values from 1k Ω to 100k Ω ; accuracy of $\pm 0.2\text{K}$ from 0 $^{\circ}\text{C}$ ~70 $^{\circ}\text{C}$; temperature range of -40 $^{\circ}\text{C}$ /+150 $^{\circ}\text{C}$; fast response and a 2.6mm bead size among others.

Evaluation samples and ex-stock pricing are available too.

www.atcsemitec.co.uk

New AVX Connector Sample Kit for Solid State Lighting Applications Available Through TTI, Inc

Now available from TTI, Inc., the global distributor of passive, interconnect, relay & switch and discrete components, is a new sample kit of connectors from AVX for Solid State Lighting (SSL) applications. The kit includes series 9175, 9176, 9177 and 9276 wire-to-board connectors, as well as series 9159 board-to-board devices. It is ideal for design engineers wanting to evaluate AVX's connector solutions for SSL applications in their challenge to find the best suited connector for their PCB designs.

The 917X series of surface mount Insulation Displacement Connectors (IDC) from AVX has been developed for connecting individual wires ranging from 14 AWG to 28 AWG directly to a PCB. The industry proven contact system has been tested to automotive levels of shock, vibration and temperature cycling to prove its reliability and robustness. The simplicity of inserting a wire into the connector with a small tool allows a wide range of devices to be connected to the PCB without soldering.

www.ttieurope.com



Kontron KISS 4U PCI761 with Intel Core i3/i5/i7 Processor And 12 Expansion Slots

Kontron announced another addition to the rugged and extremely quiet KISS industrial server family, the Kontron Industrial Silent Server KISS 4U PCI761. The new, 4U rack-mount server with 64-bit Intel Core i3/i5/i7 processor and long-term availability combines outstanding performance density with extreme flexibility via 12 expansion slots. Application developers will benefit from a flexible platform which can be configured with a wide range of cost-efficient ATX standard components corresponding to the individual application requirements.

The Kontron KISS 4U PCI761 rack-mount server offers broad scalability, from the Intel Core i3 to the Intel Core i7 processor, with up to four 2.8GHz cores and 8GB DDR3-1333 RAM. The industrial server also integrates a PICMG 1.3 backplane, which can be populated with up to 12 full-size PCI and PCI Express expansion cards for customized I/O designs. These features make the Kontron KISS 4U PCI761 the ideal basis for a broad range of applications.

www.kontron.com



NEW CONGA-EAF MODULE FROM CONGATEC PROVIDES BROAD SCALABILITY FOR ETX STANDARD

congatec AG, a manufacturer of embedded computer modules, is guaranteeing a sustainable future and broad scalability for the ETX standard with the launch of the conga-EAF Computer-on-Module (COM). With a choice of seven AMD G-Series processors, the conga-EAF also offers the best price/performance ratio. Ranging from the AMD T56N 1.6

GHz Dual Core (L1 cache 64KB, L2 Cache 512KB x2, 18W) multi-core processor to the AMD G-T40R 1.0 GHz (L1 cache 64KB, L2 cache 512KB, 5.5W) single-core processor with extremely low power consumption, the conga-EAF provides a perfect form-fit function setup for ETX. congatec is thereby granting all ETX applications a life-time extension into a second generation.

A particularly noteworthy benefit of the new COMs is native PCI support. ETX applications are based on this primary data bus and therefore continue to rely on unlimited data transfer for the connection of PCI peripherals. There's also direct native 32-bit PCI support from the chipset.

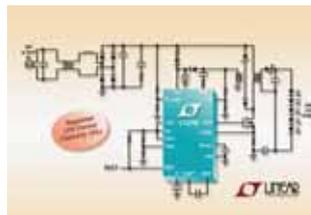
www.congatec.com

TRIAC-DIMMABLE ISOLATED ACTIVE PFC OFF-LINE LED CONTROLLER

Linear Technology has announced the LT3799, an isolated LED controller with active power factor correction (PFC), specifically designed for driving LEDs from a universal input range of 90VAC to 265VAC.

The LT3799 is optimized for LED applications requiring 4W to over 100W of LED power and also compatible with standard TRIAC in-wall dimmers. The LT3799's unique current sensing scheme delivers a well regulated current to the secondary side without using an opto-coupler. This not only reduces cost but also improves reliability. Its single stage PFC regulator design requires minimal external components. Additionally, its thermally enhanced MSOP-16E package ensures a simple and compact solution footprint for off-line LED applications.

The LT3799 offers over 86% efficiency, eliminating the need for external heat sinking of the LED driver IC in most applications. Special internal circuitry provides active PFC of up to 0.977, easily meeting industrial Department of Energy (DOE) requirements while complying with the IEC 61000-3-2 Class C Lighting Equipment Harmonics requirement.



www.linear.com



OEM PRESSURE SENSORS OFFER EXCELLENT MEDIA COMPATIBILITY

Sensortech's new KMA series measures gage pressures of corrosive and aggressive gases and liquids in ranges from 500 mbar to 100 bar. These pressure sensors utilise internal digital signal conditioning to deliver calibrated and temperature compensated 0.5V to 4.5V output signals. The KMA sensors are based on very accurate and long-term stable ceramic pressure cells with excellent media compatibility. The small stainless steel sensor housing with a G 1/8 (BSP) threaded pressure port is ideally suited for space-saving integration into demanding OEM devices and machines.

www.sensortech.com/kma

New Adaptive Power Supplies VSP Product Range Now at Caltest Instruments



The Adaptive Power Systems VSP Series of Programmable Power Supplies set a new standard for flexible, reliable AC to DC power systems in OEM, industrial and laboratory applications. They have been designed with excellent thermal management and can be conveniently stacked in a 19" rack without the need for any space between them for ventilation.

The zero voltage soft-switching technique employed in the VSP series virtually eliminates the switching transients to derive lower noise, which is closer to levels found in linear supplies. This also helps increasing the overall conversion efficiency which in turn decreases the heat generation, thus reducing the stress on the power components which results in greater reliability.

If you would like any further information or to request a demonstration or quote contact the sales team on 01483 302700 or visit

www.caltest.co.uk

Learn How to Achieve Efficient Power Solutions with Avnet Abacus

Avnet Abacus, one of Europe's leading power, interconnect, passive and electromechanical distributors, is teaming up with some of the world's leading manufacturers of power components to deliver a series of free technical seminars in five locations across Europe focused on the difficult challenges that face power system design engineers.

In the one-day sessions, Avnet Abacus and its franchises Aimtec, Cymbet, Emerson, Enpiron, Excelsys, Murata Power Solutions, Power Integrations and Schaffner will provide an overview of environmental and energy efficient directives impacting power supply design. Explains Cor van Dam, Avnet Abacus' European Marketing Director: "Efficient use of power is a challenge that affects everyone and there are many issues."

The seminars are scheduled for:

- Paris – 4th October, Novotel Charenton
- Milan – 12th October, Avnet Abacus office
- Stuttgart – 20th October, Avnet Abacus office
- Munich – 25th October, Avnet Abacus office
- Newbury – 3rd November, Avnet Abacus office

Design engineers are invited to register for the free seminars by visiting

www.avnet.abacus.eu/power or call +44-1628 512940



FLUKE TOOLS CHOSEN FOR ELECTRONICS SKILL TESTING AT WORLDSKILLS LONDON 2011



Fluke test tools, with rapid troubleshooting capabilities, have been selected by WorldSkills London 2011 to be used by Competitors within the Electronics category at the Competition (www.worldskillslondon2011.com), which will be held over four days at ExCeL London from 5-8 October 2011.

The Fluke 124 ScopeMeter and the high-accuracy Fluke 287 Electronics Logging Digital Multimeter (DMM) have been selected for the participants to use in the 'Electronics' competition. Electronics technicians manufacture and test electronic systems and equipment and are often needed to build prototypes before production because manufacturing processes are highly automated. They are skilled at problem solving but they also manage, monitor and install electronic systems and increasingly replace outdated equipment in organisations like factories and power companies.

The Fluke 124 ScopeMeter, with a CAT III 600V safety rating, is an integrated test tool, combining a dual-input oscilloscope, a true-rms multimeter and a 'paperless' recorder in one easy-to-use instrument.

www.fluke.co.uk

Space-Saving Connector Families From Harwin Featured On Element14 Interconnect Community Group

Harwin is featuring on the Interconnect Community Group within Farnell's Element 14 Electronic Engineering social networking site, <http://www.element14.com/community/groups/interconnect>. Visitors to the microsite will discover a wealth of information on Harwin's space-saving Mix-Tek Datamate and M40 products.

Andy Waller, Product Manager, Electronic Connectors at Farnell, said: "Our Interconnect community showcases new product launches using materials produced by the manufacturers – such as white papers, tutorials, datasheets and YouTube demonstration videos. We link this fantastic technical resource with our eCommerce capability, so on the same page as all the information, designers and buyers can also dig deeper and view the products, their technical attributes and datasheets, as well as having the option to buy. Members of the group receive updates when they happen saving a lot of time and website surfing."

Ben Green, Harwin's Technical & Marketing Communications Manager added: "Already our connectors, M40 headers and sockets are featured with their own live microsites:

Datamate Mix-Tek @<http://www.element14.com/community/docs/DOC-36519>;

M40 @ <http://www.element14.com/community/docs/DOC-36474>."

www.harwin.com

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FUJITSU AND THE AUSTRALIAN NATIONAL UNIVERSITY COLLABORATE ON SUPERCOMPUTER RESEARCH

Fujitsu Laboratories of Europe Limited was awarded AUD 446,000 (US\$ 474,000) by the Australian Research Council for a three-year Linkage Project on supercomputing with The Australian National University.

The project, entitled “*Robust Numerical Solution of Partial Differential Equations on Petascale Computer Systems with Applications to Tsunami Modeling and Plasma Physics*”, is aimed at applying new mathematical ideas to exploit the unprecedented computational power of the next generation of supercomputers. The objective is to develop new techniques and software that will be key enablers for the science needed to understand the workings of complex dynamical systems.

Commenting on behalf of Fujitsu Laboratories of Europe, team leader and Partner Investigator for Fujitsu, Dr Ross Nobes, explained the importance of the project:

“The project will cover some important new ground – tackling the challenge of scalable, robust, fault-tolerant computer simulation, which will be of increasing importance as we head towards exascale computing,” he said. “We plan to build on ANU’s expertise in advanced mathematical techniques, including wavelets and high-dimensional approximations, to deliver advanced mathematical software for petascale and future advanced supercomputers. As part of the project, we will be undertaking specific optimisations on state-of-the-art supercomputers with multi-core nodes and complex communication networks.”

BURKHARD VOGEL, Managing Director, Germany:

Congratulations to Australia! With that engagement in petascale computing any university in the world could gain a huge amount of additional super-computing knowledge – up to the top of the existing range. Fujitsu recently re-conquered the top. But, where are the Europeans?

PROFESSOR DR DOGAN IBRAHIM, Near East University in Nicosia, Cyprus:

This is an exciting project, showing once again how the collaboration between the industry and universities can result in advanced research and possible solutions to complex environmental problems. Tsunami is one of the greatest environmental disasters facing the mankind today. The collaboration between the ANU and Fujitsu Laboratories of Europe will gather the experts in mathematical modeling and supercomputer manufacturing. I have no doubt that this new joint project will give us some exciting results and an insight to the highly complex nature of the Tsunamis and plasma physics, and will also lead to the design of computers with unprecedented powers.

BARRY MCKEOWN, RF and Microwave Engineer in the Defence Industry, and Director of Datod Ltd, UK:

Last May, D-Wave Systems of Canada sold the first commercial supercomputer to Lockheed Martin. Thus the age of grand-challenge supercomputers, so beloved of mathematicians, is entering a new phase. As well as the defence aspects and stated goals of this project, the issue that shall drive the wide scale adoption of supercomputers is the Cloud, especially as current signal processing algorithms for real-time computation of data-intensive 3D imaging for medical and other purposes, from 4G smart device sensors to smart device enabled displays, is beyond the current standards of processor on this and the next generations of smartphones.

The issue that shall drive the wide scale adoption of supercomputers is the Cloud

HAFIDH MECHERGUI, Associate Professor in Electrical Engineering and Instrumentation, University of Tunisia:

French biologist Louis Pasteur has told that science has no homeland. In this context, the international collaboration between researchers in the world has grown steadily in most countries in the world. The intensity of the collaborative international research varies between disciplines.

The project funding by Australian Research Council comes within the framework of effective cooperation to develop and advance the science of computing. This is a crucial niche for the future. Indeed, the collaboration between Fujitsu Laboratories of Europe and Australian National University can be as a keystone for the computing development of a future supercomputer.

The proposed funding program can only support this strategic initiative of collaborative environments for research and innovation.

I think that institutional collaboration can accelerate the development of science and technology.

If you are interested in becoming a member of our panel and comment on new developments and technologies within the electronics sector please register your interest with the editor by writing to Svetlana.josifovska@stjohnpatrick.com

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