electronic design

01.10.13
THE AUTHORITY
ON EMERGING
TECHNOLOGIES FOR
DESIGN SOLUTIONS

electronicdesign.com

2013 technology forecast issue

$10.00 A Penton Publication, Periodicals Postage paid, USPS/100 Approved Poly

IT'S NO ACCIDENT...

DIGIKEY.COM

THE BUSIEST WEBSITE IN THE INDUSTRY!

80% MORE UNIQUE VISITORS

— THAN THE NEXT — CLOSEST DISTRIBUTOR

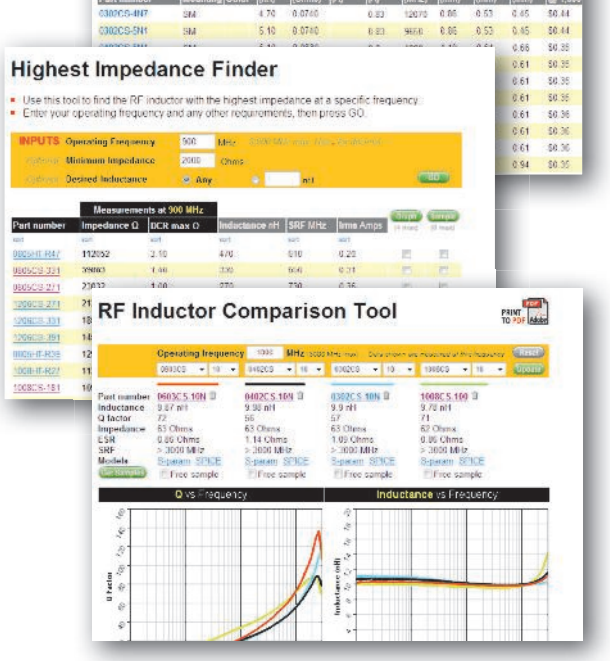
Source: *Unique Visitors, North America, March 2012, Compete.com*

Digi-Key® CORPORATION

World's Largest Selection of Electronic Components Available for Immediate Shipment

2.4 MILLION PARTS ONLINE | 600+ INDUSTRY-LEADING SUPPLIERS | NEW PRODUCTS ADDED DAILY

1.800.344.4539

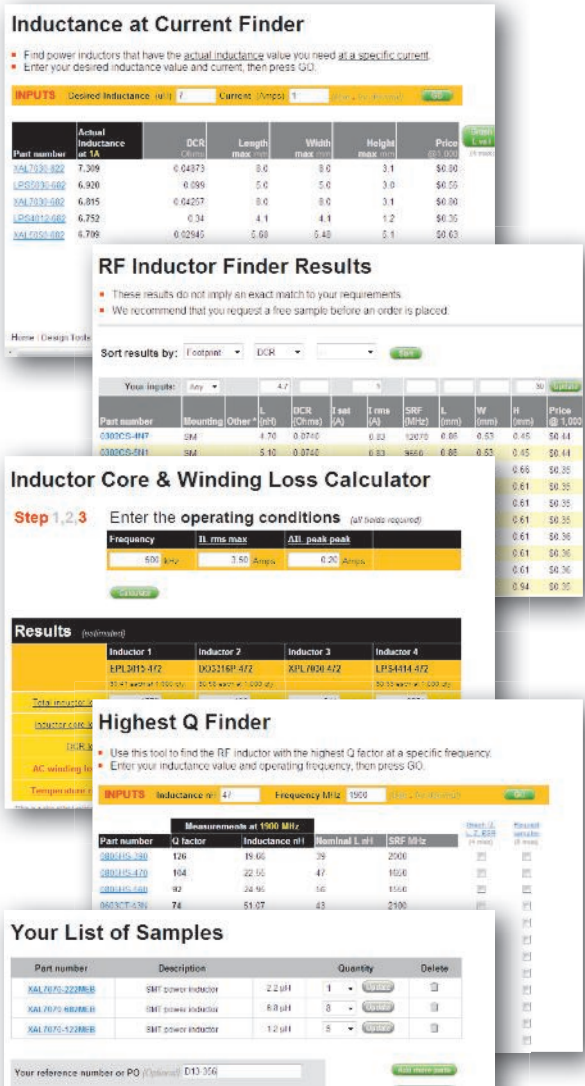


The best inductor selection tools.

coilcraft.com/tools

Now in a handy pocket size.

coilcraft.com/mobile



Coilcraft®

WWW.COILCRAFT.COM

APEC® 2013

March 17–21, 2013

Long Beach Convention Center
Long Beach, CA

The Premier Global Event in Power Electronics™

Visit the APEC 2013 web site for the latest information!

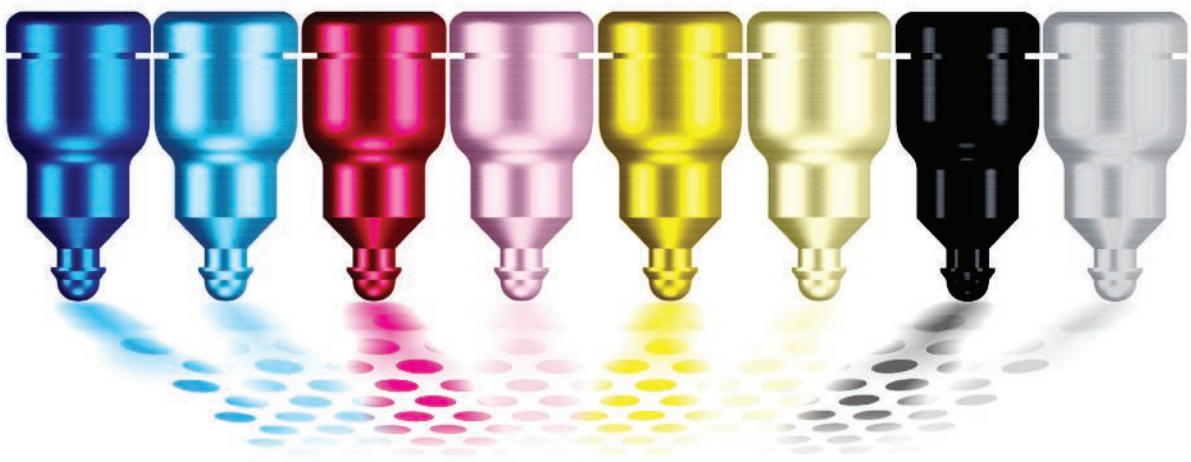
www.apec-conf.org

SPONSORED BY

pels

power sources manufacturers association

IAS IEEE INDUSTRY APPLICATIONS SOCIETY



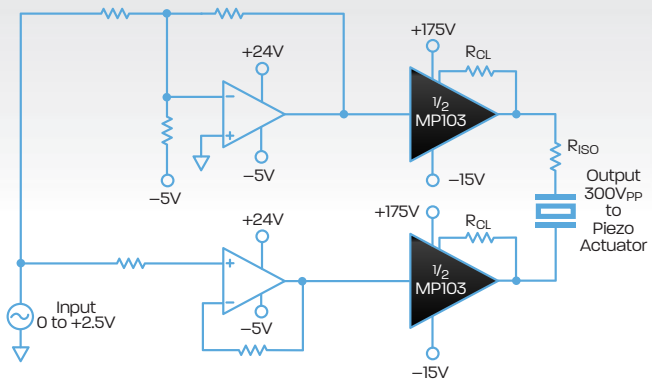
Space Saver. Cost Saver.

MP103FC Power Amplifier: Dual-Channel Design Delivers Space Savings, Cost Savings

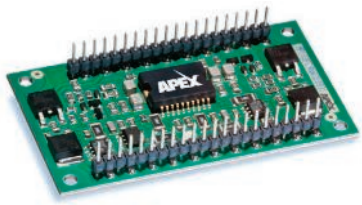
DRIVE MULTIPLE PIEZOELECTRIC LOADS WITH SPEED, CURRENT AND VOLTAGE

The MP103FC from Apex Microtechnology is a dual-channel power amplifier that is designed to drive multiple loads with a single device. With full power bandwidth rated for 230 kHz, the MP103FC is optimized for industrial applications requiring piezoelectric loads with more than one driver. This thermally enhanced module also features output current of up to 15 A PEAK per channel and a 30 V to 200 V power supply. A single MP103FC delivers high current, high voltage and high speed at a per unit cost savings that makes it the option of choice versus single amplifier solutions and discrete designs.

- Print head electronic drives for industrial ink jet printers



BRIDGE MODE PIEZOELECTRIC DRIVER
(For Design Discussion Purposes Only)



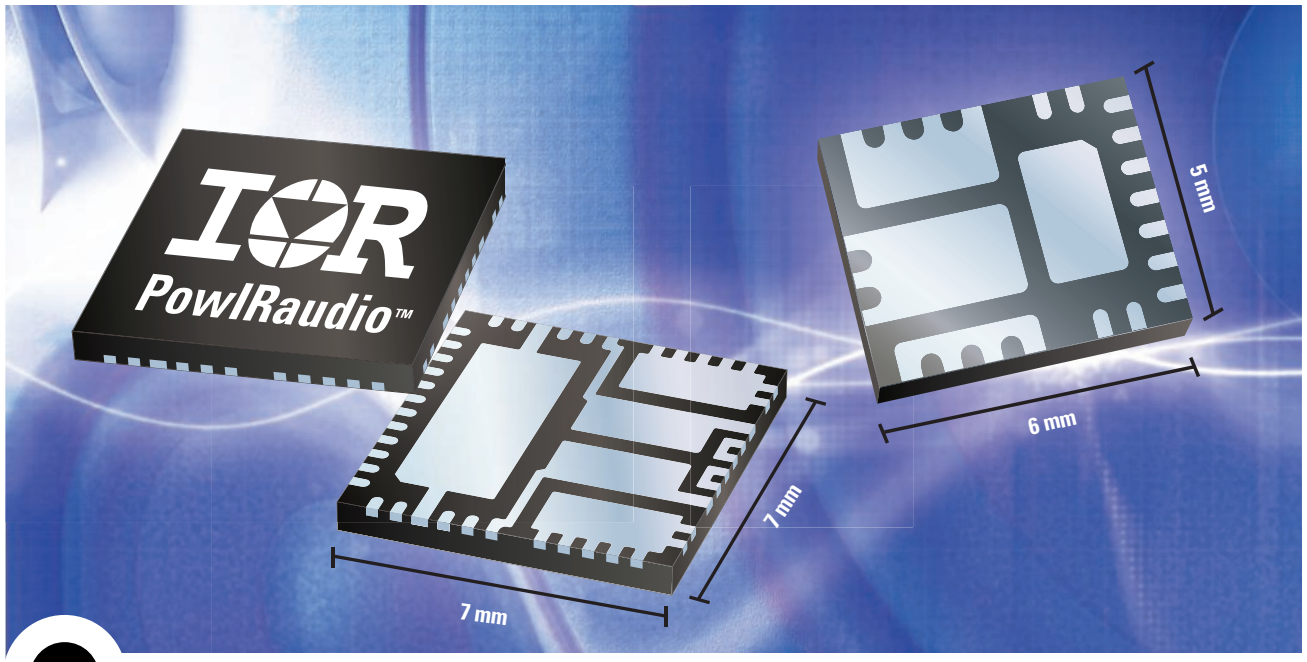
FC MODULAR 42-PIN DIP

Open Frame Product Technology
(actual footprint 65.1mm X 42.5mm)

Power up at www.apexanalog.com/edmp103

apexanalog.com/edmp103

APEX MICROTECHNOLOGY



Compact, Efficient, Class D Audio Solutions

IR's Integrated PowIRaudio™ Class D Amplifier

PowIRaudio™ Integrated Class D Amplifier

IR4301*	4Ω	130W/ch
	3Ω	100W/ch
	2Ω	70W/ch
IR4311	4Ω	35W/ch
	3Ω	45W/ch
	2Ω	60W/ch

PowIRaudio™ Integrated Two-Channel Class D Amplifier

IR4302*	4Ω	70W + 70W
	3Ω	50W + 50W
	2Ω	40W + 40W
IR4312	4Ω	35W + 35W
	3Ω	40W + 40W
	2Ω	30W + 30W

*Higher power capable if heatsink is used

PowIRaudio™ Advantage:

- No heatsink required
- Best-in-class power efficiency and audio performance
- Reduce component count, simplify design
- Compatible with single supply or split rail configuration

Reference Designs Available:

- 20W to 130W per channel
- Single supply or dual supply
- Single channel or dual channel modules

for more information call 1.800.981.8699 or visit us at www.irf.com

International IOR Rectifier
THE POWER MANAGEMENT LEADER

International CES
Jan 8-11, 2013
Audio Suite 30-231, 30th floor
Venetian Tower, Las Vegas

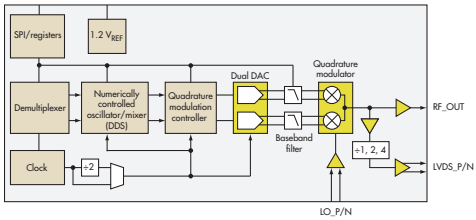
Table of Contents

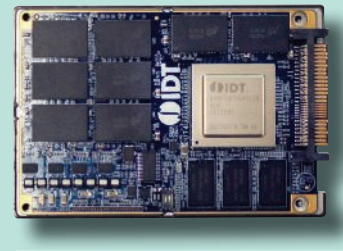
THE AUTHORITY ON EMERGING TECHNOLOGIES FOR DESIGN SOLUTIONS

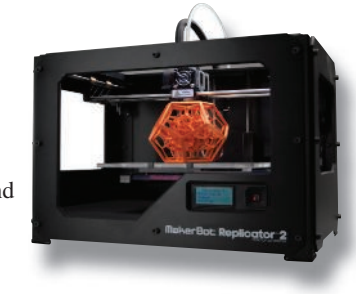
electronic design

Vol. 61 No.1 **01.10.13** | electronicdesign.com

Forecasts







Columns

EDITORIAL MISSION:
To provide the most current, accurate, and in-depth technical coverage of the key emerging technologies that engineers need to design tomorrow's products today.

ELECTRONIC DESIGN (ISSN 0013-4872) is published monthly with an extra issue in June and October by Penton Media Inc., 9800 Metcalf Ave., Overland Park, KS 66212-2216. Paid rates for a one-year subscription are as follows: $120 U.S., $180 Canada, $240 International. Periodicals postage paid at Shawnee Mission, KS, and additional mailing offices. Editorial and advertising addresses: ELECTRONIC DESIGN, 1166 Avenue of the Americas, New York, NY 10036. Telephone (212) 204-4200. Printed in U.S.A. Title registered in U.S. Patent Office. For subscriber services or to order single copies, write to Electronic Design, PO Box 2100, Skokie, IL 60076. POSTMASTER: Send change of address to Electronic Design, PO Box 2100, Skokie, IL 60076. Canadian Post Publications Mail agreement No. 40612608. Canada return address: Pitney Bowes, P.O. Box 25542, London, ON N6C 6B2.

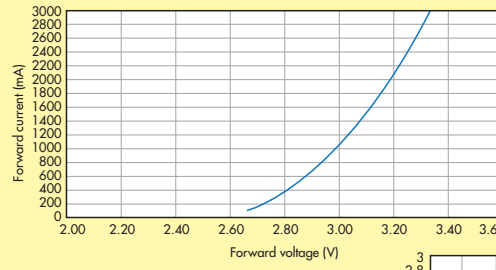
THE AUTHORITY ON EMERGING TECHNOLOGIES FOR DESIGN SOLUTIONS

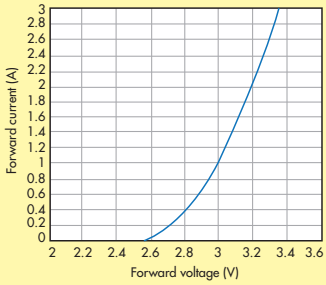
electronic design

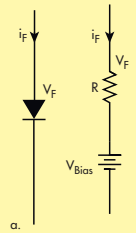
Vol. 61 No.1 **01.10.13** | electronicdesign.com

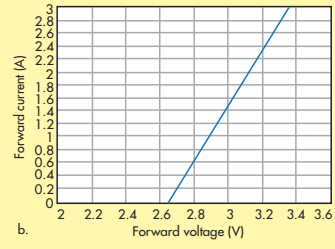
Distribution Resource

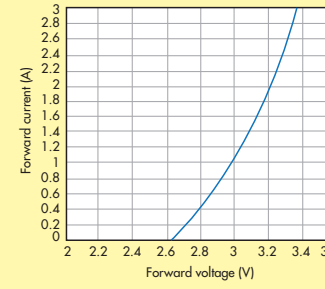
Ideas For Design











Product Features

On the Web @ electronicdesign.com

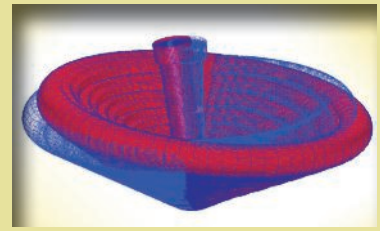
ELECTRONIC DESIGN ON FACEBOOK

Electronic Design is now on Facebook! Check us out for daily updates, exclusive content, and timely discussions. All you have to do is go to *www.facebook.com/ElectronicDesign* and "like" us.

ENGINEERING TV

INFLATABLE RE-ENTRY VEHICLE DESIGN AT NASA

Lee Teschler | *Machine Design*



Anthony Calomino, research aerospace engineer at the NASA Glenn Research Center, discusses an inflatable re-entry vehicle that can withstand the temperatures of dropping through the Earth's atmosphere. See the video at *engineeringTV.com*.

LET'S CONNECT

WI-FI AND CELLULAR GROWTH WILL CONTINUE IN 2013

Mike Fahrion | *Contributing Technical Expert*

As the cost of embedding intelligence and network communications continues to drop, we will keep moving in the direction of the wireless "Internet of Things," a world in which just about anything, anywhere, can be a node on a network.

FROM *ELECTRONIC DESIGN EUROPE*

ARE YOUR MEDICAL RECORDS REALLY SAFE?

Paul Whytock | *Editor in Chief*

Many medical technologies can monitor patients at remote locations. But how secure is the data that these devices send to medical professionals for evaluation?

TESTING THE LIMITS

FIVE TEST PREDICTIONS FOR 2013

Richard McDonell | *Contributing Technical Expert*

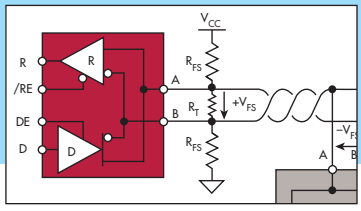
The 2013 National Instruments Automated Test Outlook summarizes five major trends: the role of test economics, big analog data, software-centric ecosystems, test software quality, and Moore's law meeting RF.

THE INTERFACE CONNECTION

RS-485: HOW TO CORRECT THE BUS SIGNAL POLARITY OF CROSS-WIRED DATA LINKS

Thomas Kugelstadt | *Contributing Technical Expert*

RS-485 bus signal polarity correction used to be rare. Now it results from many bad bus design practices in developing countries.



DESIGN SOLUTION

USE ANALOG TECHNIQUES TO MEASURE CAPACITANCE IN CAPACITIVE SENSORS

Martin Tomasz | *Touchstone Semiconductor*

Capacitive sensors are found in a wide range of equipment, from consumer electronics to industrial and process control. Traditional timer circuits may be used in sensors requiring typical capacitance ranges, while integrator-based designs should be considered for applications requiring low capacitance values and higher accuracy.

POWER DESIGN

INDUSTRIAL MOTORS GOT MORE EFFICIENT IN 2012

Paul L. Schimel, PE | *Contributing Technical Expert*

The movement underfoot to build more efficient motors is forcing a look away from squirrel cage and/or dc brush motors and bringing gearing, mechanical power transfer, and hydraulic power transfer into question.

You never thought power supplies could do all of this.

U8000 Series DC Power Supplies

N6705B DC Power Analyzer

Fortunately, we did.

Scan or visit
http://qrs.ly/r623yzf
to view power supply
application videos

Built to the latest standards and technologies, Agilent DC Power Supplies are designed with more than just power in mind. And with over 200 power supply choices, imagine what you could achieve by adding one to your bench.

- Ensure DUT safety with built-in safety features
- Increase throughput with the fastest processing time in the industry
- Gain insights with advanced analytics and scope-like display (N6705B)

Agilent and our Distributor Network
Right Instrument.
Right Expertise.
Delivered Right Now.

ALLIED ELECTRONICS

800-433-5700
www.alliedelec.com/agilent

To build a more powerful bench, download our power supply catalog at
www.alliedelec.com/lp/agilentpowersupplies/

Anticipate ___Accelerate ___Achieve

Agilent Technologies

electronic design

EDITORIAL

EDITOR-IN-CHIEF: **JOE DESPOSITO** T | 212.204.4368 joe.desposito@penton.com
MANAGING EDITOR: **RICHARD GAWEL** T | 212.204.4381 richard.gawel@penton.com
CREATIVE DIRECTOR: **DIMITRIOS BASTAS** T | 212.204.4372 dimitrios.bastas@penton.com

EDITORS

ANALOG/POWER: **DON TUITE** T | 650.367.6268 don.tuite@penton.com
COMMUNICATIONS: **LOUIS E. FRENZEL** T | 512.243.5173 lou.frenzel@penton.com
DISTRIBUTION: **VICTORIA FRAZA KICKHAM** SourceESBeditor@penton.com
EMBEDDED/SYSTEMS/SOFTWARE: **WILLIAM WONG** T | 215.736.2449 bill.wong@penton.com

ART DEPARTMENT

GROUP DESIGN DIRECTOR: **ANTHONY VITOLO** T | 212.204.4376 tony.vitolo@penton.com
SENIOR ARTIST: **JAMES M. MILLER** T | 212.204.4371 jim.miller@penton.com
INTERN: **KAMIL WIERCISZEWSKI**

PRODUCTION

GROUP PRODUCTION MANAGER: **JUSTIN MARCINIAK** T | 913.967.1730 justin.marciniak@penton.com
PRODUCTION MANAGER: **JULIE GILPIN** T | 913.967.1373 julie.gilpin@penton.com

AUDIENCE MARKETING

AUDIENCE MARKETING MANAGER: **BRENDA ROODE** brenda.roode@penton.com
ONLINE MARKETING SPECIALIST: **RYAN MALEC** ryan.malec@penton.com

ELECTRONIC DESIGN EUROPE

EDITOR: **PAUL WHYTOCK** T | +44.0.208.859.1206 paul.whytock@penton.com

LIST RENTALS & CIRCULATION CUSTOMER SERVICE (LIVE)

LIST RENTALS: **MERIT DIRECT**
FREE SUBSCRIPTION/STATUS OF SUBSCRIPTION/ADDRESS CHANGE/MISSING BACK ISSUES
T | 866.505.7173 F | 847.763.9673 electronicdesign@halldata.com

SALES & MARKETING

BRAND DIRECTOR, e|DESIGN: **TRACY SMITH** T | 913.967.1324 F | 913.514.6881 tracy.smith@penton.com

REGIONAL SALES REPRESENTATIVES
NORTHEAST/EASTERN CANADA: **DAVE MADONIA** T | 212.204.4331 F | 913.514.3966 dave.madonia@penton.com
SOUTH: **BILL YARBOROUGH** T | 713.636.3809 F | 713.380.5318 bill.yarborough@penton.com
NORTHWEST/NORTHERN CALIFORNIA/WESTERN CANADA: **JAMIE ALLEN** T | 415.608.1959 F | 913.514.3667 jamie.allen@penton.com
MIDWEST/MID-ATLANTIC: **STEPHANIE CAMPANA** T | 312.840.8437 F | 913.514.3645 stephanie.campana@penton.com

PLEASE SEND INSERTION ORDERS TO: orders@penton.com
PENTON REPRINTS: **WRIGHT'S MEDIA** T | 877.652.5295 penton@wrightsmedia.com
CIRCULATION: **CUSTOMER SERVICE** T | 866.505.7173 F | 847.763.9673 electronicdesign@halldata.com

INTERNATIONAL SALES
EUROPE: **MARK DURHAM** T | +44 (0)7958 564137 mark.durham@penton.com
JAPAN: **HIROKAZU MORITA** T | +81 3 3261 4591 F | +81 3 3261 6126
TAIWAN: **CHARLES LIU** T | 886 2-2727 7799 F | 886 2 2728-3686

ONLINE

DIRECTOR OF DIGITAL CONTENT: **PETRA ANDRE** petra.andre@penton.com

DESIGN ENGINEERING & SOURCING GROUP

VICE PRESIDENT & MARKET LEADER: **BILL BAUMANN**
GROUP DIRECTOR OF OPERATIONS: **CHRISTINA CAVANO**
GROUP DIRECTOR OF MARKETING: **JANE COOPER**
RESEARCH MANAGER: **JULIE RITCHIE**
MARKETING & EVENTS SPECIALIST: **ADRIAN PIAZZA**
MARKETING COMMUNICATIONS SPECIALIST: **CYNTHIA RODRIGUEZ**

Penton
Design Engineering & Sourcing Group

PENTON MEDIA INC.

Electronic Design | Machine Design | Microwaves & RF | Medical Design | Source ESB | Hydraulics & Pneumatics | Global Purchasing | Distribution Resource | Power Electronics Technology | Mobile Development and Design | Energy Efficiency & Technology | Defense Electronics | Motion System Design | Auto Electronics | Electronic Design Europe | Electronic Design China | Engineering TV | Fluid Power Expo | Medical Silicone | Medical Prototyping | One Powerful Day | Combating Conterfeit Conference

CHIEF EXECUTIVE OFFICER: **DAVID KIESELSTEIN** david.kieselstein
CHIEF FINANCIAL OFFICER: **NICOLA ALLAIS** nicola.allais@penton.com
SENIOR VP, DESIGN ENGINEERING GROUP: **BOB MACARTHUR** bob.macarthur@penton.com

1166 AVENUE OF THE AMERICAS, 10TH FLOOR, NEW YORK, NY 10036 T | 212.204.4200

No other oscilloscope can touch it. But you can.

The oscilloscope experience redefined.

Agilent's next-generation oscilloscopes offer waveform update rates 20 times faster than the competition. With the latest capacitive touchscreen technology and innovative InfiniiScan Zone touch triggering, you haven't really experienced an oscilloscope until now.

Agilent InfiniiVision 4000 X-Series Oscilloscopes

- 200 MHz to 1.5 GHz
- 12.1-inch screen designed for touch
- InfiniiScan Zone touch triggering
- 1M waveforms/sec update rate
- Fully upgradable: bandwidth, MSO, dual-channel WaveGen, DVM, serial analysis including USB

Scan or visit http://qrs.ly/ey263t8 to see a video demo

Agilent and our Distributor Network
Right Instrument.
Right Expertise.
Delivered Right Now.

TESTEQUITY
800-732-3457
www.testequity.com/agilent

Experience the difference.
See demos, app notes and more.
www.testequity.com/Agilent_Scope

Anticipate ___Accelerate ___Achieve

Agilent Technologies

Infinite Designs, One Platform

with the only complete system design environment

NI LabVIEW is the only comprehensive development environment with the unprecedented hardware integration and wide-ranging compatibility you need to meet any measurement and control application challenge. And LabVIEW is at the heart of the graphical system design approach, which uses an open platform of productive software and reconfigurable hardware to accelerate the development of your system.

LabVIEW system design software offers unrivaled hardware integration and helps you program the way you think–graphically.

>> Accelerate your system design productivity at ni.com/labview-platform

800 453 6202

NATIONAL INSTRUMENTS

JOE DESPOSITO | EDITOR-IN-CHIEF joe.desposito@penton.com

The Semiconductor Industry Looks For A Rebound In 2013

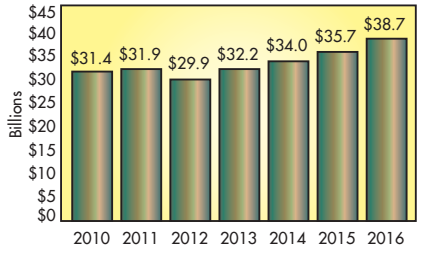
WELCOME TO OUR annual Technology Forecast issue, where our editors prognosticate on the coming year. For this column, I'll be taking a look at some of the projections that analysts are making for the semiconductor industry.

2012 ENDS ON A SOUR NOTE FOR SEMIS

Blaming increasingly weak economic conditions for depressing consumer and business spending, market research company IHS downgraded its forecast for the global semiconductor market, expecting revenue to decline by 2.3% for 2012. This represents a $7 billion decrease compared to 2011, which came in at $310 billion, and marks the first annual decline since 2009.

"An extremely weak global economy resulted in poor demand for electronics. As a result, the semiconductor industry slipped from stagnation in the first half of 2012 to a slump in the second half," said Dale Ford, senior director, electronics and semiconductor research for IHS.

Ford also noted that five of the six major application markets for semiconductors, including the computer segment, were expected to contract in 2012, pulling down the overall performance of the chip market.



Despite a slight tumble in 2012, the worldwide power management semiconductor market will keep growing through 2016. *(courtesy of IHS)*

"Still, one of the few silver linings is that the fourth quarter is expected to bring a mild recovery in year-over-year growth, setting the stage for a market rebound in 2013," Ford said.

In fact, a year ago, IHS didn't expect any meaningful rebound in revenue growth to take place until 2013. The IHS iSuppli preliminary AMFT (Application Market Forecast Tool) predicts semiconductor revenue will expand by 8.2% in 2013 if the small improvement in worldwide GDP growth forecast for 2013 holds up, so that's good news.

NOT SO FAST, SAYS GARTNER

The Gartner numbers for worldwide semiconductor revenue for 2012 and 2013 are not as high as the IHS numbers, with expectations for 2012 at $298 billion. Growth is not as high either, with Gartner predicting a 4.5% increase from 2012 for a projected total of $311 billion in 2013.

"The ongoing European debt crisis, slower emerging market growth, and regional tensions have all played a part in reduced growth projections for semiconductor revenue in both 2012 and 2013," said Peter Middleton, principal analyst at Gartner. "Inventory levels were already high at the start of the second half of 2012, and as PC demand rolled off, supply simply overshot demand."

Gartner says that memory is expected to lead the 2013 recovery with 15.3% growth, while in 2014 total semiconductor revenue is projected to reach $342 billion, an increase of 9.9% from 2013.

BRIGHT SPOTS IN THE MARKET

Also on the rebound for semiconductors in 2013 will be power semis. IHS says the market will return to growth next year at a 7.6% increase to $32.2 billion. A modest rate of expansion will ensue after that for the next three years, with industry revenue reaching an estimated $38.7 billion by 2016 *(see the figure)*.

The need for better power management in most electronics will keep the industry moving forward. Key markets for power management semis will be mobile devices, communications, energy and public infrastructure improvements, and new construction.

IHS thinks a potent market lies in alternative energy, especially in hybrid and electric vehicles, wind and solar energy, and grid upgrades for smart meters and similar devices.

One of the semiconductor areas that did well in 2012 was wireless communications, which IHS expects to generate robust revenue growth, though final figures are not yet available. This growth should continue in 2013 as consumers continue to buy more smart phones and tablets.

An interesting area to watch in the wireless space is the market for small cells. Mobile Experts expects dramatic growth in the semiconductor market supporting small cells, from $90 million in 2012 to more than $650 million in 2017. In particular, semiconductors supporting carrier-grade small cells (excluding consumer and enterprise femtocells) will ramp from practically zero revenue in 2012 to $500 million in 2017.

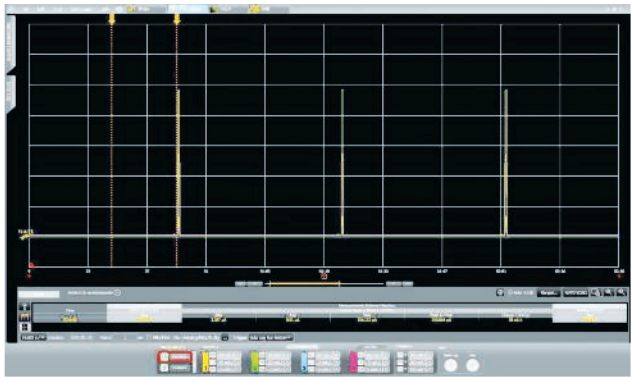
BOB ZOLLO | CONTRIBUTING TECHNICAL EXPERT bob_zollo@agilent.com

Expect Energy Harvesting To Power Wireless Sensors In 2013

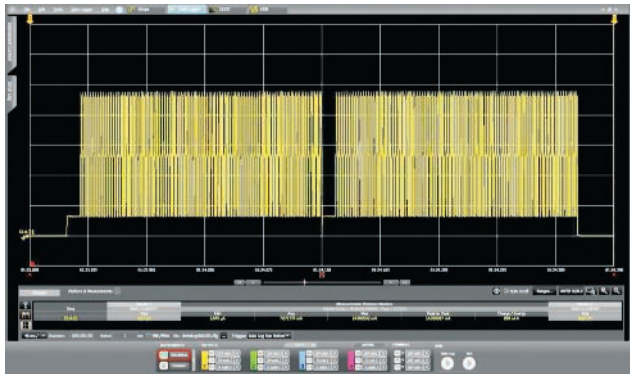
THE TECHNOLOGICAL CHALLENGES of wireless communications are steadily being overcome, permitting sensors to be interconnected into intelligent networks. The increased density of systems-on-a-chip (SoCs) is leading to increased functionality and smaller sizes for wireless sensors. But one key challenge still remains: power.

WIRELESS SENSORS EMERGE

Today, wires for power and communications are one of the limiting factors of widespread sensor deployment. Let's look at an example in building controls. Smart buildings will use wireless sensors to monitor humidity, carbon monoxide, carbon dioxide, fire, and lighting. Wired installations might be not possible in old buildings and too costly in new buildings.



1. The waveform shows the wireless temperature sensor waking up three times and transmitting a pulse each time. The sensor sleeps for approximately 40 seconds between transmissions. The sleep mode current, between the pulses, is about 7.5 μA as shown by the markers.



2. This close-up view of one of the transmit pulses actually is a burst of around 200 ms in duration with a peak current of 14 mA, or 2000 times more current than sleep mode.

Batteries have been an enabling technology for wireless sensors. As the average operating power consumption of the sensor is driven down, it becomes practical to power wireless sensors from long-lived batteries. For example, I have home security sensors that are wirelessly connected to the alarm system. These sensors are running on lithium batteries that will last 10 years, so I will have to go through the trouble to replace them once every decade. This is a workable solution for these wireless sensors.

But for some wireless sensors, battery replacement isn't practical. The sensors could be in remote locations where access isn't easy. Or, the sensors could be so small and in such large numbers that a technician just can't cost-effectively get to all of them to replace their batteries. For these applications, some form of energy harvesting would be ideal.

ENERGY HARVESTING AND POWER MANAGEMENT

Energy harvesting devices can use energy collected from the environment to power wireless sensors. Many energy harvesters use electromagnetic, Peltier cell, piezoelectric, and solar dye cell energy sources. A typical energy harvesting wireless sensor includes an energy harvesting source, an energy management unit, a sensor, a microcontroller, and a transmitter.

The key to a successful wireless sensor is power management. Typically, the energy is collected at some extremely low rate and accumulated in some form of storage device, like a supercapacitor or rechargeable battery. The sensor will then need to very sparingly use its stored energy for its primary task.

Often, the sensor sleeps for a long time consuming almost no power while it is harvesting energy. Current consumption in sleep mode can be as low as hundreds of nano-amperes. Then, the sensor will wake up and perform its task, sending information in a short burst of a few milliseconds *(Fig. 1)*.

The RF transmission is generally in the industrial, scientific, and medical (ISM) frequency bands. This active state power can be 1000 to 1 million times the sleep mode power. This means that 10 ms of activity can drain the same energy as 2.7 hours in sleep mode. Thus, choosing the right communication strategy (interval and transmission scheme) plays an important role in managing energy consumption.

Proprietary communication protocols are often more efficient because they employ short messages so short transmit times can be used *(Fig. 2)*. Finally, after sending its message, the sensor will go back to sleep and collect energy until the next wakeup interval. The resultant power consumption profile is an extremely low-frequency waveform, with perhaps seconds, minutes, or hours of sleep time broken up by a few milliseconds of operation.

10 MHz Distribution Amplifiers

- **Sine wave outputs (+13dbm)**
- **Amplitude leveling**
- **Low additive phase noise**
- **High channel-to-channel isolation**
- **High return loss**

FS730 and FS735 series ... starting at $1250 *(U.S. list)*

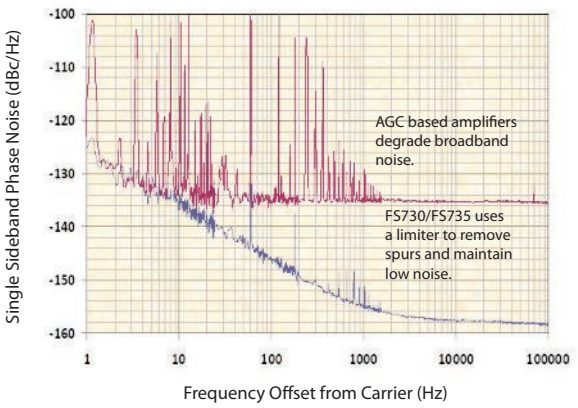
The FS730 and FS735 10 MHz distribution amplifiers from SRS provide state-of-the-art solutions to challenging signal distribution tasks.

These distribution amplifiers use an input limiter design, which removes amplitude modulation from the signal, provides fixed amplitude outputs and blocks input noise. Virtually any 10 MHz waveform with a duty cycle near 50% may be used as an input.

The FS735 model provides fourteen 10 MHz output BNC connectors on the rear panel, with status indicators on the front panel. The half-rack sized FS730 model gives seven 10 MHz outputs and is available in both bench-top and rack-mount forms.

With mix and match capability, the FS735 can also be configured with 10 MHz, 5 MHz, Broadband, and CMOS Logic distribution amplifiers side-by-side for other applications. Multiple units can be daisy-chained for easy expansion.

Please visit www.thinkSRS.com for details.



Additive phase noise in 10 MHz Distribution Amplifiers: Limiter vs. AGC Designs

SRS Stanford Research Systems

(408)744-9040
www.thinkSRS.com

DESIGN AND TEST CHALLENGES

From a test equipment perspective, engineers need tools that can measure micro-amperes or nano-amperes of current flow (during harvesting operations) for long periods of time and accurately accumulate that information to determine the total amount of energy harvested and total amount of energy consumed during the sleep operation. Those same tools will have to be able to accurately measure the brief higher currents consumed during sensor operations.

Normally, an engineer might turn to an accurate ammeter to make these measurements. But ammeters that can accurately measure micro-amperes or nano-amperes have long integration times, making it impossible to measure the short high-current active state while the sensor does its task. If the ammeter is set up to accurately measure the high current (tens to thousands of milli-amperes), it will not be able to accurately measure the sleep mode/harvesting currents.

Oscilloscopes and digitizers can capture the narrow pulses (low duty cycle) of the wireless sensor as it goes in and out of sleep and active modes. However, using an oscilloscope or digitizer requires a current transducer, such as a current shunt. It is nearly impossible to select a current shunt that will allow the oscilloscope or digitizer to accurately measure micro-amperes or nano-amperes and also accurately measure tens to thousands of milli-amperes.

SUMMARY

So the challenges of successfully designing and deploying a wireless sensor that gathers its power from energy harvesting are more than just designing a small, highly functional sensor and wireless communications system. The sensor must also be an extremely energy efficient system.

Testing the designs and validating the operation of these sensors involves specialized tools. Thankfully, a few test and measurement equipment providers have developed a set of tools for sourcing and measuring dynamic current and logging power consumption.

BOB ZOLLO is a product planner with the System Products Division, Electronic Measurements Group, at Agilent Technologies. He holds a degree in electrical engineering from Stevens Institute of Technology in Hoboken, N.J.

DON TUITE | ANALOG/POWER EDITOR don.tuite@penton.com

Analog Chip Makers Switch Focus To Vertical Markets

Discrete performance improvements aren't being ignored, but chip vendors are taking over the trickier aspects of product design from their customers.

TODAY'S EXECUTIVES DON'T expect an imminent return to boom times. They're strategically positioning new products that will help them weather what appear to be doldrums more than hurricanes. Companies are focusing on higher levels of integration, tailoring new products to specific applications—preferably as many as possible with similar needs *(Fig. 1 and 2)*.

OPENING NEW MARKETS

I interviewed Intersil CEO Dave Bell before his surprise resignation on December 10. Perhaps foreshadowing that event, he told me he didn't expect any industry growth in 2013.

"If you look at the last few years, it's been right around $300 billion (U.S.) for the worldwide semiconductor market. It's really down a little bit, and I think just due to hyper-competitive pressures, it's going to stay that way," he said.

With this forecast in mind, the company recently announced specialized products for active cables and picoprojectors and will announce more in 2013. In the short term, Intersil is focused on copper, but fiber cables could be in the equation too considering the need for active cables in terms of the relative properties of USB versus Apple's Thunderbolt.

"With USB 1.0, if you shoved a 10-Mbit signal down a 2-meter cable, you got a pretty decent looking signal out the other end. Today, if you try and do that at Thunderbolt speeds—20 Gbits/s—bidirectionally, on the same sized cable, you get nothing but garbage out the other end. You need the electronics to drive and to recover those signals within the cable connectors," Bell explained.

Also, Bell expects active cabling to be a long-term growth driver because data rates will continue increasing, as they have with USB. He also notes a growing need in the datacenter infrastructure.

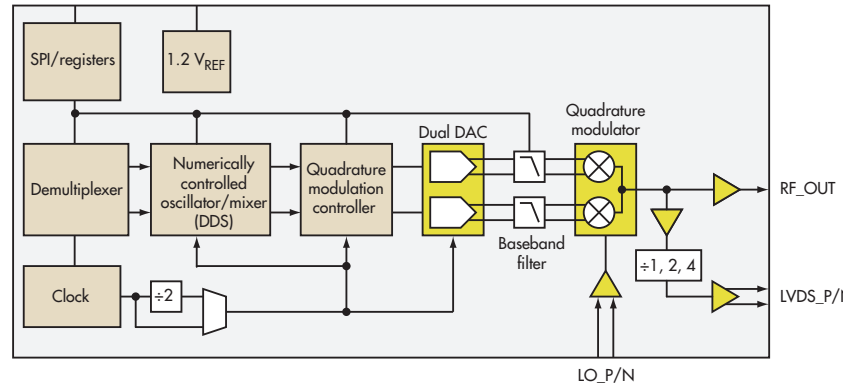
"If you're looking at servers and switches and routers, and network-attached storage, clearly, those are all bandwidth hogs. Today, most of those applications use passive copper cables for connections up to a few meters. Beyond that, they have to go to fiber. Yet active copper cables would allow them to go up to something like 20 meters," Bell said.

Looking further ahead, Bell said that one day, we might see copper and fiber in a hybrid cable, with the copper providing power in a manner similar to today's Power over Ethernet.

Even in today's off-the-shelf Thunderbolt cable, Bell noted, the protocol supports power delivery up to approximately 15 W. He added that it is already possible to deliver 3.3 or 15 V over Thunderbird, so users can get three or four times as much power via a Thunderbolt cable as they could get through a USB cable. Bell said he is familiar with at least one manufacturer that is working on much longer distance optical Thunderbolt cables, and he expects there will be some parallel power wires in those cables as well.

Furthermore, Bell sees continuing Internet growth functioning as a technology driver, relating it to Moore's Law. "People keep saying, 'Well, Moore's Law is just about out of gas.' But they were saying that a decade ago and it keeps finding a way. I think you're going to see the Internet continue to exponentially grow as it's done from its inception," he said.

"I remember an Intel PowerPoint slide that said that, around the world, 24 hours a day, there are 22 new mobile subscribers every second. Those users are going to continue to drive data traffic up and up," he added.



1. Texas Instruments' AFE7071 is a complete radio transmitter that reduces board space by up to 80% compared to discrete implementations. It integrates a dual digital-to-analog converter (DAC), tunable baseband filters, an IQ modulator, and a digital quadrature modulation correction circuit. The AFE7070 adds a direct digital synthesizer (DDS) with a 32-bit numerically controlled oscillator (NCO) and a low-voltage differential signaling (LVDS) output buffer.

In the last two years, Intersil has made a big move into ICs for video applications as well, first with devices for carrying data from security cameras and recently with devices that interface between video sources and the optical systems in picoprojectors. In fact, Intersil has been making laser diode drivers for more than a decade. They were originally used in DVD writers and later in Blu-ray writers. Those technologies have translated well for controlling the color balance and the laser power in picoprojectors.

CONVERTERS, OP AMPS, AND MORE

Linear Technology's data converters are moving toward more bits and faster speeds. "We're just about ready to release 20 bits at 2 MHz, and that's a very clean 20 bits, in terms of integral and differential nonlinearity and the size of bit-jumps at the transitions," said Linear CTO Robert Dobkin.

The new analog-to-digital converters (ADCs) are intended primarily for instrumentation applications. Steppers would be a typical example. "At 22-nm, steppers need as many bits as fast as they can get it," Dobkin said.

For communications, Linear's latest ADCs are in the 200- to 250-Mbit/s range at 16-bit resolution. "We're going to duals, and we're also going to lower power. I think it's really important that the dual and the quad versions of these 100-plus-MHz A-to-D converters run at low power, because they're going into very dense systems where heat is a problem," Dobkin said.

"We're doing high-speed, high-precision, low-distortion op amps for the 16- and 20-bit converters. Without a good op amp to drive them, they're not 16 bits and they're not 20 bits. We are pushing precision as well as speed, settling time in the op amps as well, specifically mated to the data converters," Dobkin said.

A few years ago, Linear was still relying heavily on its own 0.6-µm technology for the sake of its ability to handle large input-voltage swings. The process technologies for the company's newest parts are foundry-based, 0.18- to 0.25-µm geometries.

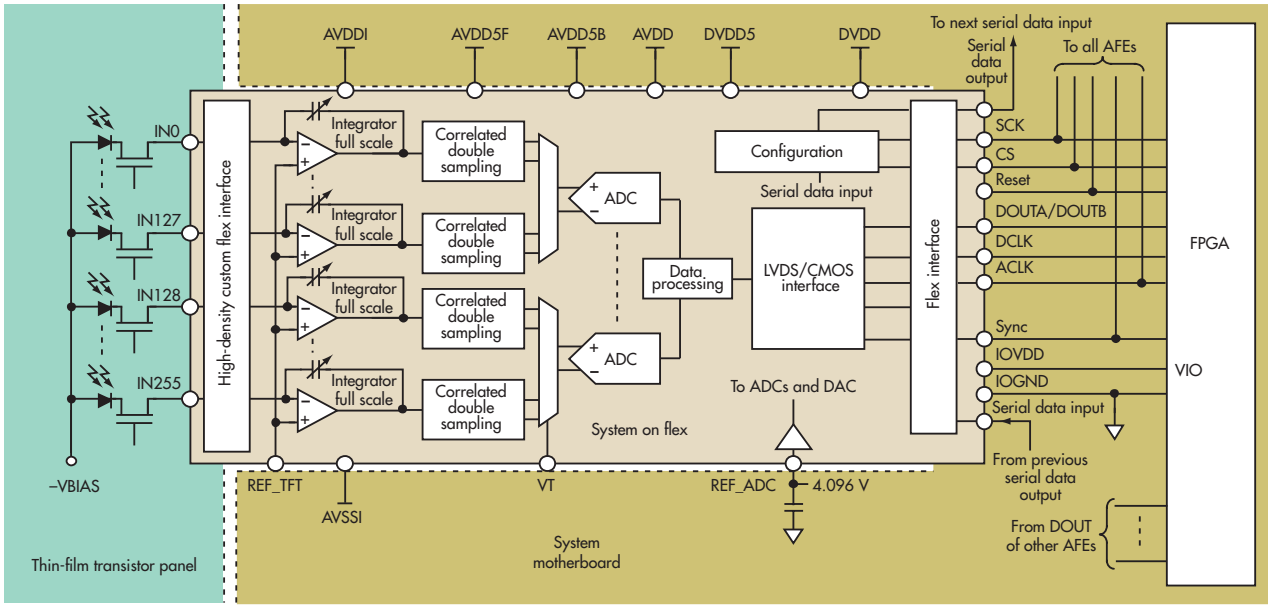
THE FABLESS MARKET

Talk of foundries leads to the analog considerations of fabless companies. Today, independent device makers (IDMs) such as Intersil and Linear Technology aren't the only corporations that are combining their analog and power product lines.

The S3 Group, an engineering services company, is based in Ireland. But semiconductors aren't geographically limited. In fact, S3 typically facilitates design reviews and coordinates with companies a half a world away. Recently, the company has awakened to the value of maintaining its intellectual property (IP).

In terms of what S3 calls its "Silicon Business," the company made a conscious decision to monetize its IP through licensing with a focus on mixed-signal IP, while continuing its traditional engineering services *(see "The Role Of Design Services In Analog Design," p. 20)*. S3's product lines comprise converters along with low-jitter, low-phase-noise phase-locked loops (PLLs) and analog front ends (AFEs) that use both.

Today, IP sales are responsible for a great deal of S3's bottom line. In the present business structure, some 80% of the company's efforts support some communications application, whether



2. The Analog Devices monolithic ADAS1256 digital X-ray analog front end integrates the entire charge-to-digital conversion signal chain, including low-noise programmable-charge amplifiers, correlated double-sampling circuitry, and 16-bit ADCs.

maxim integrated™

ANALOG INTEGRATION ISN'T FOR EVERYONE

www.maximintegrated.com

it's wireless communications like cellular and Wi-Fi or power-line communications. Yet a few customers are using S3 IP in solar applications such as maximum power-point tracking as well.

S3's IP tends to start around 10 Msamples/s and goes up to about 250 Msamples/s for its ADCs and between 500 and 800 Msamples/s for its digital-to-analog converters (DACs). Resolution varies from 8 to 14 bits. The ones that customers are using most are in the 10- to 12-bit range, operating from 60 to 250 Msamples/s. Also, S3's PLLs are designed to complement the company's data converters, emphasizing low phase noise and jitter.

Dermot Barry, vice president of consumer silicon at S3, said that the competition comes from companies such as Synopsys, exploiting the ChipIdea capabilities that came with the MIPS acquisition, and Cosmic Circuits, an Indian company. He also said that S3's designs are generally faster and more precise.

VERTICAL MANAGEMENT

Among the established analog and power IDMs, Maxim Integrated has taken some bold steps in redefining itself for the new business realities. In a way, it is doing what S3 is doing (on a much larger scale) in terms of developing reusable IP and putting it into highly integrated products for specific end uses.

How that affects day-to-day operations depends on what end of the telescope you look through. At the management end, president Tunç Doluca has shortened the company name to Maxim Integrated, with a new logo, a new headquarters, and a team of senior vice presidents whose responsibilities focus on vertical markets, rather than on product lines organized by vertical market segments.

At the dedication of its new headquarters, Doluca said that Maxim Integrated was making the external changes to better reflect the big internal changes that it has made and is making to help customers tackle complex system and architectural issues. Doluca also said that the re-imagined Maxim Integrated would accelerate the development of highly integrated products that complement the company's broad selection of single-function devices.

Distribution channels were strengthened, lead times were cut, and the company has intensified its customer focus. ED

THE ROLE OF DESIGN SERVICES IN ANALOG DESIGN

By adding intellectual property (IP) licensing to its portfolio, engineering services company S3 Group found new "stickiness" in its business relationships, according to Dermot Barry, S3's vice president of consumer silicon. Yet the company continues its chip design business, which will account for 70% of its revenue this year. S3 also is trying to focus on areas where there is a shortage of skills, including the whole mixed-signal space.

"Over the last 10 years, 90% of our customers have been semiconductor companies, whether they'd be the old IBM-type organizations or fabless companies. With the new business model, we're moving away from those guys, not entirely, but to a degree," Barry said.

"They're small to medium-sized system companies that have existing products in the market. Their products contain a reasonable quantity of chips, and discrete components, and usually, their product sales volumes would be in the 100,000 to, maybe, a million, 2 million per annum, not the very high-volume consumer-product companies," he added.

These companies typically don't have any IC design capabilities and don't realize the benefits that integration can deliver. Their product lines, then, use standard parts and discrete components.

"They could achieve significant cost reductions were they to do an integration exercise where they took the functionality of a lot of those components and integrated that into one or two or three chips, even, maybe even in a multi-chip module-type approach or a system-in-package approach," Barry said.

"They don't necessarily need to go to a single chip at 28 or 40 nm. That's probably far too expensive for them and represents a kind of overkill. But doing an integration of, let's say, a whole lot of analog functionality onto an analog chip, and a whole lot of digital functionality onto a digital chip, they could realize product cost savings, of, in some cases, more than $100 per unit," he said.

"Now, of course, there's a large engineering effort to realize that benefit, so you have to do the return on investment analysis over what's the product, what's the remaining product lifetime, and how long is it going to take to actually hit the break-even point. In many cases that can be in less than 18, or up to 24 months once the chip or chips are available," Barry said.

For example, S3 has worked with Iridium, which operates the communications business originally created by Motorola. A separate company purchased those assets and has been operating that system for the last 10 years. Now, Iridium is launching a series of satellites to enable next-generation services. A portion of the business is military, but a larger segment deals with logistics, tracking assets or fleet movements in situations that aren't accessible via standard terrestrial communications systems.

Iridium's existing handset and modem were based on standard components that the company was buying through distributors. That sales relationship meant Iridium didn't have direct relationships with semiconductor vendors that could have helped it with new designs. That's why Iridium deals with a design services company.

"S3 was able to engineer a different partitioning of their system that eliminated roughly 250 components through an integration of analog functions on 0.18-µm CMOS and digital functions on a 0.13-µm process," Barry said.

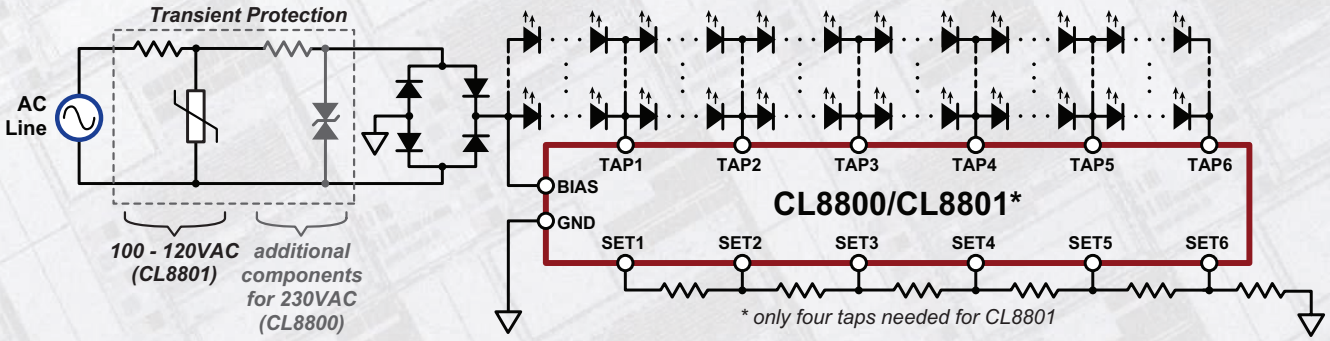
Supertex CL8800 and CL8801:
Sequential Linear LED Driver ICs

Features

- Minimal component count
  (base config: CL8800 + 6 resistors + diode bridge for 230VAC)
  (base config: CL8801 + 4 resistors + diode bridge for 100-120VAC)
- No magnetics, no capacitors
- Up to 7.5W output (13W w/ heat sink)
- >110Lm/W using efficient LEDs
- 85% typical electrical efficiency
- >0.95 power factor
- <20% THD line current
- Low conducted EMI w/o filters
- 85% LED luminous utilization
- Phase dimmer compatible with an RC network

Applications

- Fluorescent tube retrofit
- Incandescent & CFL bulb replacement
- General LED lighting



Device	V_{IN} min (VAC)	V_{IN} max (VAC)	V_{OUT} min (VDC)	V_{OUT} max (VDC)	Output Current (peak mA)	Dimming	Package Option	Features
CL8800	90	275	70	350	115	External Dimmer	33-Lead QFN	6-Stage
CL8801					200			4-Stage

Visit Supertex at Strategies in Light 2013
February 12-14, 2013
Santa Clara Convention Center
Go to http://www.supertex.com/events.html
for a complementary exhibit hall pass.

Supertex inc.

For information about Supertex's complete line of LED Drivers,
visit http://www.supertex.com/feature_LED_general.html

BILL WONG | EMBEDDED/SYSTEMS/SOFTWARE EDITOR bill.wong@penton.com

Memory And Processor Advances Redefine Digital Technology

DDR4, MRAM, 64-bit Arm cores, and more revolutionary technologies will emerge in the coming months.

DESIGNERS ARE IN luck. Many technologies like PCI Express Gen 3 and USB 3.0 are beginning to mature, providing more options to use instead of new specifications to covet. Still, other technologies will emerge and have a significant impact, including DDR4, MRAM DIMMs, and 64-bit Arm cores.

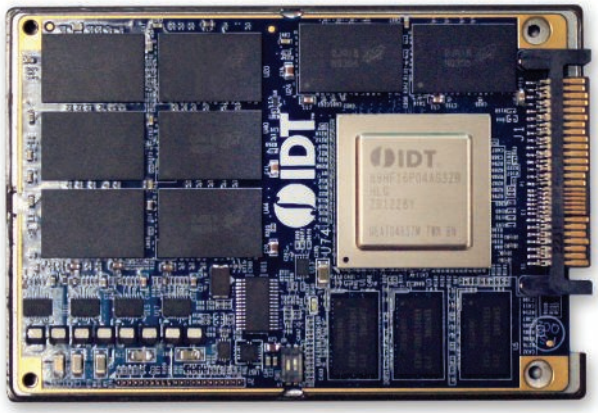
MEMORY AND STORAGE

DDR4 is on the horizon and will see the light of day this year. DDR3 will remain a major factor, especially for embedded applications, while DDR4 takes the high ground.

DDR4 increases throughput starting at 2133 Mtransfers/s. It reduces power consumption starting with a lower voltage range (1.04 to 1.2 V). It also changes from a bus interface to a point-to-point connection with one DIMM per memory channel. Switched systems are supported, although they're likely to be found only on servers requiring a large number of DIMMs. There will still be action in DDR3, though. Nonvolatile DDR3 DIMMs are now available in two forms.

The first was the flash/DRAM pairing, such as Viking Technology's ArxCis-NV. This DIMM requires an external supercap, but it takes advantage of the capacity of the flash and the DRAM to deliver storage comparable to a standard DRAM DDR3 DIMM, albeit a more costly one. Data is copied to and from the flash during power transitions.

The second non-volatile DDR3 storage to watch is based on Everspin's spin-torque MRAM. The chips used in this DIMM are 64 Mbits, but it doesn't require extra power or even refreshing. Non-volatile storage also is changing the way things work. Hybrid disk drives are on the rise as they're more tightly integrated with operating systems like Windows 8. Hard drives continue grow in capacity, but vendor consolidation has reduced competition.



1. IDT's NVMe Enterprise Flash Controller will find a home in a range of form factors including disk drives that employ a PCI Express interface instead of SAS or SATA.

Flash is where the action will be in the disk-drive and related storage market. Nonvolatile Memory Express (NVMe) is going to explode this year. Components like IDT's NVMe controller simplify PCI Express connections to flash chips.

The fast, scalable PCI Express bandwidth will be pushed by flash that has exceeded the bandwidth provided by the SATA and SAS disk interfaces. The lines are blurring as PCI Express is moving to the drive form factor, and comparable functionality is available in PCI Express adapters *(Fig. 1)*. SCSI Express (SCSI on PCI Express), also based on PCI Express, will make a showing this year, but it will be focused on the enterprise.

MICROS BIG AND SMALL

What do you do when you have lots of transistors? At the top end of the spectrum, you put lots of cores on one chip. Intel's Xeon Phi packs in 60 x86 cores with vector support *(Fig. 2)*. It competes with general-purpose on graphics processing unit (GPGPU) platforms like NVidia's Tesla K20X and AMD's high-end FirePro. These platforms target large high-performance computing (HPC) clusters, but a single chip may be needed to make an embedded application practical.

Move down the spectrum a little and you'll find 64-bit Arm Cortex-A50 chips multiplying. The long-awaited platform will target servers, but the chips' low power requirements make them candidates for even mobile devices.

Intel's 22-nm Haswell processors are starting to show up. Initially, they will target tablet and ultrabook platforms. The architecture doubles the graphics performance. The 14-nm Broadwell is on the horizon too.

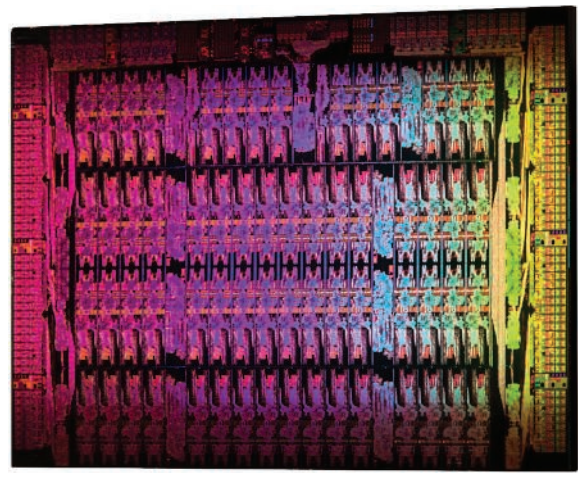
Embedded developers will be looking toward the Atom "Avoton" release later in the year. Targeting the microserver architecture, it will have competition from AMD's Opteron 3300 and 4300 chips as well as the 64-bit Arm processors. Avoton may have up to eight cores.

The accelerated processing unit (APU) approach popularized by AMD will be getting company with Arm platforms mixed with Arm's GPU, Mali. The latest variant is the Arm

CPU's equal when it comes to cache use.

The most action will be in the 32-bit space that Arm cores now dominate. Other 32-bit platforms are still very successful, but the core Arm architecture is found in platforms from the Cortex-M0+ up to the Cortex-A50.

Asymmetric dual-core chips will become more common. The typical CPU/DSP pair will remain the primary configuration, with the CPU usually providing connectivity support. Look for improved tool support for this mixed configuration with better communication and debugging support.



2. Intel's Xeon Phi chip links 60 x86 cores with vector processing support via a high-speed loop that provides cache coherency for a massive SMP programming environment.

Look for more heterogeneous multicore chips going into the cloud as well as more conventional application areas like communications. For example, Texas Instruments' Keystone chip family blends multiple Cortex-A15 CPUs with C66x DSP cores. The challenge is picking the right combination of CPUs and DSPs for an application.

The 32-bit CPUs continue to push into the 8- and 16-bit microcontroller space. NXP's LPC800 targets these form factors, prices, and power envelopes. The programming advantages and the upgrade path are clear. Still, most 8- and 16-bit micro vendors have developed streamlined development tool suites that make migration from 8- to 32-bit platforms painless by providing standard support for common peripherals.

There is still a lot of life in 8- and 16-bit platforms, though, and those extra transistors can be put to use in more, and often better, ways than just increasing register size. Switch matrix connectivity between pins and I/O interfaces is becoming more common. So is intelligent I/O linkage.

With intelligent I/O linkage, programmers can connect a pin or the output of one device to the input of another, possibly with additional logic control in between. Some systems incorporate a basic programmable logic device (PLD) in the mix. The approach reduces external support chips and can enable slower micros to handle chores that require faster response. They also can offload the host, allowing asynchronous operation.

Some systems even extend this support to complex control such as motor control. Reduced power requirements can be achieved with this approach by allowing the host to sleep while the peripherals continue to operate. The host may be awakened as necessary.

Power remains the watchword from tiny to massive processor core collections. It is one reason power debugging continues to grow in importance and availability. Power estimate, power use tracing, and power mode management are turning from nice features into design requirements.

PROGRAMMING FPGAs

Processing cores in FPGAs will continue to be the norm in new designs. The big question is whether they will be hard, soft, or both. Most FPGA vendors offer at least one hard-core option. Xilinx's Zynq-7000 EPP FPGA family with dual, Cortex-A9 cores has been available on platforms like the open-source ZedBoard for a while *(Fig. 3)*.

The lines blur in programming and FGPAs. FPGA logic units (LUTs) are configured or "programmed," but this is a more static process compared to software running on a processing core. The advantages of software and FPGAs are clear and the combination has obvious advantages, including the high-speed connection between the cores and the FPGA fabric. This gets even more interesting when they're combined with OpenCL.

Altera has released a software development kit (SDK) for Altera FPGAs and OpenCL. FPGA fabrics typically are programmed using FPGA design tools and intellectual property (IP) based on languages like SystemC or others that are much different from C or C++. OpenCL is a specialization of C, but it is now commonly used for programming everything from GPUs to clusters of CPUs.

The initial implementation of Altera's SDK targets off-chip hosts using a PCI Express interface, so the result works like GPGPUs where the host provides data and then processes the results. PCI Express is fast but not as fast as the FPGA fabric, and an on-chip core provides faster access. This will be cutting-edge work, but it is a technology to watch since it turns software into hardware without requiring major FPGA expertise.

INTERCONNECTS AND NETWORKING

PCI Express Gen 3 and USB 3.0 have lots in common—particularly stability. Both standards have been around for a long time, at least for the semiconductor industry, and they have growing support. On the PCI Express side, the growth is on host support. There is significant support already on the switch side, though there will be more advances on the enterprise end where virtualization and shared resource access is increasing.

On the USB 3.0 side, switches finally will be showing up. Most clients will be

available as well. USB 3.0 primarily has been used for storage. Connectivity to mobile devices is key when it comes to moving large video files.

MIPI, a high-speed interface that's common on mobile devices, is another area where PCI Express and USB meet. The latest support lets PCI Express and USB ride on MIPI, providing a useful bridge for these protocols. Last year, the standard was finished. This is the year for implementation.

In another area, PCI Express will be picking up a new micro cable connector. The PCI-SIG OCuLink looks to bring 32-Gbit/s bandwidth to external devices. It will compete with USB 3.0 and Thunderbolt in some applications.

The migration from SATA and SAS to PCI Express has already been mentioned. PCI Express will absorb the functionality, but the protocols will still be available in different forms. In the case of SATA, there is SATA Express from SATA-IO. For SAS, there is SCSI Express via the SCSI Trade Association.

SENSORS EVERYWHERE

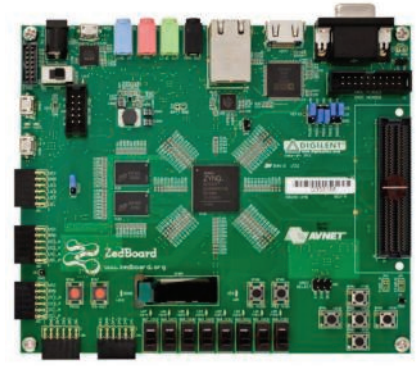
Sensors will appear everywhere and in myriad combinations. Accelerometers, pressure sensors, and other types of sensors are getting smaller and less expensive. They're also being combined into multi-sensor units. Best of all, they're more likely to have smart digital interfaces than analog interfaces, making integration easier.

Sensor integration and virtualization is also rising. Virtual sensors can mimic other sensors by using data from a different type of sensor, typically by using a lower power but less accurate sensor. They might be used during idle periods, with the more power hungry but more accurate sensor awakened when needed.

Another form of virtual sensor combines sensor information to provide more generic information such as whether a user is close to a particular device like a specific display screen. Video cameras fall into this category. Sometimes they provide 3D information, which requires computing and storage resources, but they often can fit on a micro. And although it has yet to be proven a long-term alternative, 3D gesture recognition is on the rise.

DISPLAYS AND TOUCH

3D gestures don't require anything as sophisticated as Microsoft's Kinect. Capacitive-based solutions need computing horsepower but less than what a video solution would use. Microchip's MGC3130 supports basic gesture recognition using an on-chip 32-bit MCU.



3. The open-source ZedBoard, available from Digilent, hosts Xilinx's dual-core, Cortex-A9 FPGA.

3D gestures are fancy, but 2D multitouch is where the volume is, including its use in smart phones and tablets. The news this year is the mass migration to thinner touchscreens because of laminated touch sensor technology. These new displays offer better performance, lower cost, lower power requirements, and thinner packaging.

There will be the usual chaos in the underlying displays, including performance and cost improvements along with availability issues. Demand is high, but display vendors are having a challenging time given the competition.

Flexible displays are likely to see more traction this year. E-Ink has been shipping flexible grayscale displays for years. This year, there will be color displays along with rumors of flexible organic LED (OLED) displays.

GPGPUs primarily will be used to drive displays. At the high end, AMD and NVidia continue to battle with x16 PCI Express cards. Things get much more interesting down the scale where integrated graphics reside and there is a wider variance, even within processor families. For instance, NVidia's popular Tegra 3 quad-core Arm Cortex-A9 uses NVidia's GPU. Arm CPU cores are being combined in this fashion, but Arm's Mali GPU is pushing into the high-performance arena.

There is a definite push toward multiple screen support even on smaller platforms. At the higher end, multidisplay support via standard interfaces like DisplayPort are common.

The link between displays is yet another area where change is occurring. Wireless HDMI technology is readily available now like IOGear's WHDI-based plug-and-play wireless HDMI link. What will be interesting is how WHDI and the alternatives arrive in terms of embedded solutions instead of add-ons. Multiple standards will make choosing products and technology a challenge since they aren't interoperable. Also, the consumer wireless spectrum is already busy, and this adds more to the mix.

ASIC DESIGN TRENDS

Silicon technology is driving from 20 nm down to 16 nm, 14 nm, and even 10-nm design nodes, giving designers access to a tremendous number of transistors. Designers are now building systems using blocks of IP from third parties. Standards like IEEE 1801-2009 for design and verification have helped make this interaction easier.

Look for continued improvements on the verification side of chip designs. The adoption of the Universal Verification Methodology (UVM) has had a major impact and will continue to do so this year. And, there will be more action in yield optimization tools.

BILL WONG | EMBEDDED/SYSTEMS/SOFTWARE EDITOR bill.wong@penton.com

Expect 3D Printers, 3D Vision, And More In 2013

Rapid prototyping and robotics will deliver systems faster, but they will still require reliable and secure software and hardware.

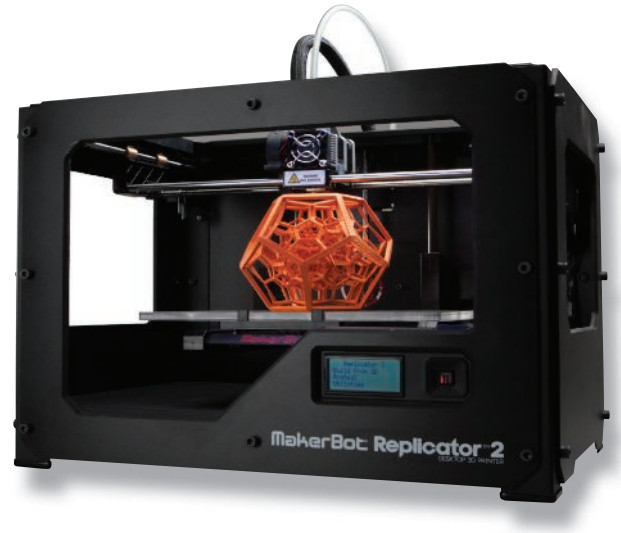
TIME-TO-MARKET HAS NEVER been more important. But getting to market quickly is a challenge because of the myriad chores that must be finished before you can deliver a finished product. The technology required can range from compact modules for mobile devices to 3D imaging systems for robots.

Designers will have more choices about the kinds of technology they can incorporate in their systems, from 3D vision and 3D gesture recognition systems to hybrid disk drives. These systems can be sensor-rich with sensor fusion too, while multifunction digital sensor modules are becoming the norm.

Software is the foundation of almost every embedded device. Many solutions are networked and tied to the Internet, so developers will have to contend with security issues. But on the plus side, many technologies are maturing including PCI Express Gen 3, USB 3, and Gigabit Ethernet. This means more options, from hubs and switches to on-chip support.

PROTOTYPING AND 3D PRINTERS

Whether they're used for prototypes or finished products, 3D printers are changing the way embedded systems are being built. They provide a convenient way to deliver a prototype and enable designers to create solutions that would be challenging using conventional techniques.



1. The Makerbot Replicator 2 Desktop 3D Printer can create an object that fits within a 410-cubic-inch space.

The Makerbot Replicator 2 Desktop 3D Printer is a well known example of the technology *(Fig. 1)*. Priced at only $2199, it can build an object measuring up to 410 cubic inches (11.2 by 6 by 6.1 in) with a 100-µm layer resolution. It also can use renewable bioplastic polylactide (PLA) filament to create almost any object.

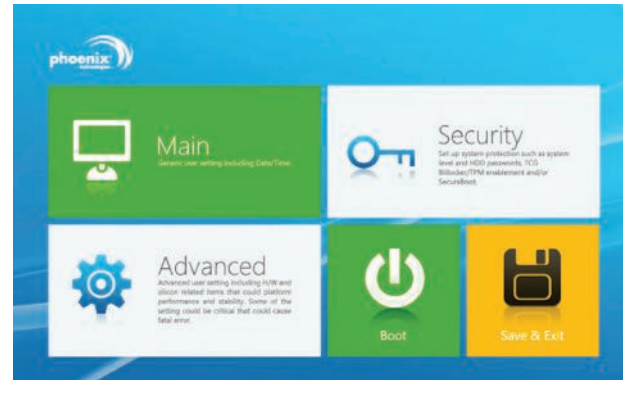
3D printers like the Replicator 2 are becoming as common as laser printers. Small to large commercial 3D printers are available from companies such as 3D Systems, Objet, and EOS. 3D printer technology is available for a range of materials from plastics to powdered metal.

Even printed-circuit boards (PCB) can be made on the desktop these days. The LPKF Laser and Electronics ProtoMat line provides one alternative to creating PCBs using a desktop platform. Also, outsourcing PCB production is easier. Improved Web interfaces provide better upload and tracking capabilities.

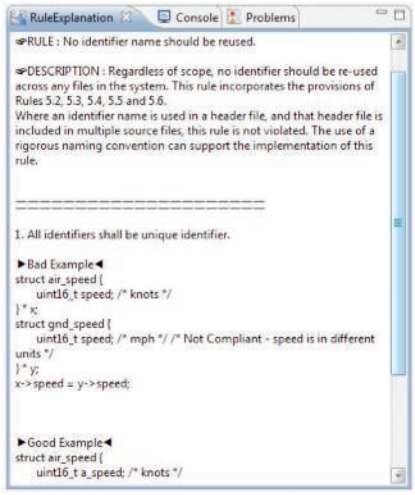
Even setting up a small production is easier. Rethink Robotics' Baxter robot only costs $22,000. Its behavior-based programming allows designers to teach by example. 3D imaging is optional since many pick and place actions don't require it.

THE CHANGING USER INTERFACE

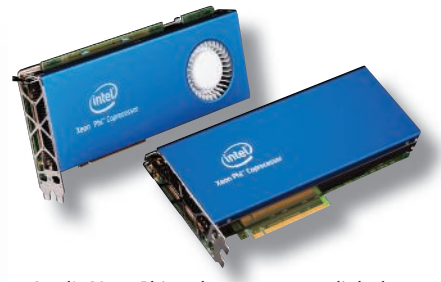
Windows 8 is out and being touched on tablets and desktops. It isn't the first incarnation of Windows with touch support, and there have been plenty of earlier platforms with touch support too. But Windows 8 does highlight the trend and expectation of users who will readily touch any screen looking for a reaction.



2. Phoenix Technologies' UEFI support has a Windows 8 look versus the character-mode BIOS of yore.



3. Atollic's TrueStudio provides MISRA-C support as a standard feature. Highlights for rule violations include both good and bad examples so developers can compare them with their code.



4. Intel's Xeon Phi packs 60 x86 cores linked by a high-speed loop. It plugs into a x16 PCI Express slot.

5. Skyera's Skyhawk packs 44 Tbytes of consumer flash into a 1U rack for the corporate cloud.

Multitouch gestures on a 2D surface are just the beginning. Built on PrimeSense's 3D infrared sensing system, Microsoft's Kinect has popularized 3D gestures. But imaging isn't the only way to handle 3D gestures. Microchip is one of a growing number of companies to deliver capactive-based 3D gesture sensing to developers. Working with electronics is looking more like magic every day.

3D vision and the use of vision in general is on the rise. Increased compute capabilities are allowing a single camera to be employed to generate 3D maps. The use of multiple low-cost digital cameras is increasing because their cost and power requirements are low.

Data from multiple cameras is also being fused into a single, optically correct image. These systems can provide the bird's eye view for high-end automobiles garnered from fixed cameras aimed out from the car.

3D may be the new wave, but 2D multitouch and gestures are the mainstay for smart phones and tablets. They are becoming more common in dedicated embedded applications as well.

SAFE EMBEDDED SOFTWARE

Safety, reliability, and security remain watchwords for embedded developers, but what each of these words means depends upon the application. Systems supporting the Unified Extensible Firmware Interface (UEFI) specification will be in the mainstream. UEFI provides a modular boot system and supports secure boot. It can be used with Arm platforms in addition to x86. Linux and Windows 8 have UEFI secure boot support.

Outfits like Phoenix Technologies and American Megatrends are supporting secure boot, encrypted disk drives, and modular services *(Fig. 2)*. It's surprising how many embedded systems provide little or no security, let alone use secure boot support. This is likely to change as developers begin to use and understand secure systems and the support becomes readily available in the platforms they are targeting.

C and C++ are the primary programming languages for embedded applications, though applications written in these languages are more prone to errors than languages like Ada and Java. Enforced by the compiler, Ada 2012 contracts help programmers create safety-critical applications. Contracts aren't easily replicated without compiler support.

Still, static and dynamic analysis tools can vastly improve the quality of C and C++ programs. Integrated development environments (IDEs) will continue to incorporate more of these features. They have been available as separate tools. For example, MISRA-C support is an option on IAR's tool suite. Atollic's latest TrueStudio IDE includes MISRA-C support as a standard feature *(Fig. 3)*.

Violations are highlighted with examples and counter-examples to help developers correct their code. The Motor Industry Software Reliability Association (MISRA) developed MISRA-C for the automotive industry, but it is useful to any programmer wanting to develop safe and reliable C code. Most tools that support MISRA-C allow it to be selectively applied.

C and C++ may address most embedded projects, but Javascript and HTML5 are the upcoming platforms for browsers and mobile devices. HTML5 use in embedded applications may trail Web site use, but it has the potential to provide a standard presentation platform to developers. Part of the challenge is that tool vendors are targeting the mobile space. Embedded requirements are similar but different enough that some of these tools will not be applicable for embedded developers.

MULTICORE AND MANY CORE COMPUTING

Dual-core and quad-core platforms populate most top-end tablets, smart phones, and PCs. Core creep will continue, but high-performance computing (HPC) platforms are pushing the number of cores past this point by more than an order of magnitude.

Intel's Xeon Phi *(Fig. 4)* takes on NVidia's Tesla K20X and AMD's FirePro in the HPC space. NVidia and AMD deliver hundreds of cores in their general-purpose computation on graphics-processing unit (GPGPU) solutions, but programming is a challenge. Developers

can utilize NVidia's CUDA or the cross-platform OpenCL.

Hundreds of applications map nicely to these programming environments, but many more require more programmable platforms. This is where the Xeon Phi comes into play. It is a symmetrical multiprocessing (SMP) system with 60 x86 cores with single-instruction multiple-data (SIMD) support. The Xeon Phi can run operating systems like Linux, while GPGPUs cannot.

The Xeon Phi, Tesla K20X, and FirePro will be found in supercomputer clusters with hundreds of nodes and thousands of cores. Embedded applications, though, will be able to take advantage of one or two boards to provide a significant performance boost.

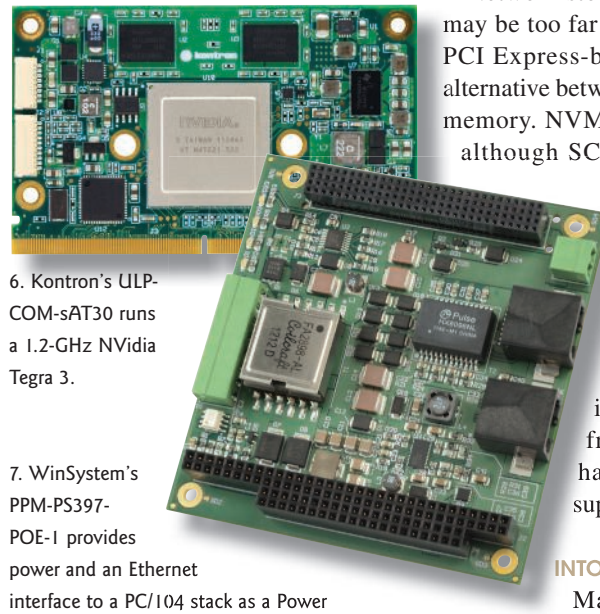
The idea behind these scaled-down supercomputers can be further reduced to a single-chip solution. AMD's APU (accelerated processing unit) will hit its stride this year. It combines a CPU and GPU with hundreds of cores. The APU has targeted desktop and laptop products, but it works equally well for embedded applications. The graphics support can handle display chores or be used for additional computation support as well.

CHANGING STORAGE

DDR4 is on the horizon, but DDR3 DRAM will be the workhorse memory for servers including HPC systems. Nonvolatile memory is migrating to DDR3 dual-inline memory modules (DIMMs) in various forms. For example, flash and DRAM are combined on a single DIMM module from Viking Technology in the form of its ArxCis-NV. A supercap is in the mix as well. RAM contents are saved in flash when power is lost and restored when the system starts up again.

Everspin also provides a non-volatile solution for DDR3 DIMM sockets that uses MRAM instead. The MRAM doesn't require refreshing or a supercap since it is a non-volatile technology. Nonvolatile main memory is a step back into the past where non-volatile core memory was ubiquitous. It allowed a system to be shut down and then restarted almost immediately. This is important in HPC and cloud computing environments where flash drives are in heavy use.

This type of memory is also useful for embedded applications. Fast startup and reliable shutdown are desirable features that are easily included. Systems that don't require mass storage could even forego a disk drive.



6. Kontron's ULP-COM-sAT30 runs a 1.2-GHz NVidia Tegra 3.

7. WinSystem's PPM-PS397-POE-I provides power and an Ethernet interface to a PC/104 stack as a Power over Ethernet Powered Device (PoE-PD).

The challenge from a software perspective is addressing this new feature. It means adjusting the boot process as well as determining whether data structures need to be replicated on mass storage. Not needing to replicate information can improve performance and reliability.

Mass storage will continue to be very important as the trend to flash memory continues. Hard-disk storage remains in the cloud, but it is being replaced by flash solutions in mobile devices.

Hybrid drives that combine flash and rotating magnetic storage are finding homes in laptops and desktops. They also can be found in embedded applications where designers can take advantage of the automatic caching they provide.

While hard disks remain an important for the cloud, flash will make major inroads. Skyera's Skyhawk *(Fig. 5)* packs 44 Tbytes of flash into a 1U rack. It isn't just a matter of putting a lot of flash chips into a box. Flash's inherent write speed and reliability problems are an issue for corporate computing. The secret sauce to this class of storage devices is delivering reliability at a low cost comparable to hard-disk drives.

Network storage units like Skyhawk may be too far from the host for some. PCI Express-based solutions offer an alternative between disk drives and main memory. NVM Express is in the lead, although SCSI Express is likely to emerge this year.

Both put flash memory a PCI Express transfer away from main memory. These platforms actually fit more easily within existing computing frameworks that already have block-oriented disk support.

INTO THE CLOUD

Many core and non-volatile main memories additionally target cloud computing, which continues to be a catchall phrase for a wide range of computing approaches that take advantage of virtualization to provide managed computing platforms. Public clouds give companies access to compute platforms on demand, while private clouds allow organizations to manage their computing requirements.

Companies like Digi and Eurotech already provide cloud-based services linked to embedded devices. More companies are entering this market to provide end-to-end solutions as well as more support for cloud-linked applications. Embedded developers will have to look at that range of solutions to determine what they want to build and what they want to buy.

Cloud-based services will also be a consideration for embedded developers. Many client/server applications have server components, but packaging them to run on the cloud is more than just providing a virtual machine image. Management, security, fail-over support, and other issues need to be addressed if a cloud-based solution is to compete in today's market.

HARDWARE PLATFORMS

Some new board and module level platforms are emerging this year like ULP-COM, a small form-factor standard. Kontron's ULP-COM-sAT30 runs a 1.2-GHz NVidia Tegra 3 *(Fig. 6)*.

ULP-COM is supported by the Standardization Group for Embedded Technologies (SGET). It comes in two sizes: 82 by 80 mm and 82 by 50 mm. Both plug into a 314-pin MXM 3.0 connector that is just 4.3 mm high, allowing 1.5-mm board spacing. The larger COM Express standard remains important, but the smaller modules will allow modular mobile applications.

There will be more movement in the stackable PCI Express space as more peripheral boards are available. Likewise, higher-bandwidth devices are driving the need for high-speed interfaces. Still, ISA remains an important part of this space. The bigger question is whether it will remain an x86 dominated space or whether Arm-based solutions will invade it or target platforms like ULP-COM that are more amenable to the Arm based chips.

There is still room for innovation in the ISA stack. WinSystem's PPM-PS397-POE1 can turn a stack into a Power over Ethernet Powered Device using its PPM-PS397-POE-1 board *(Fig. 7)*.

VME remains important. However, the OpenVPX board form factor will remain the mainstay for rugged applications with the newer, small form-factor version of the standard making some inroads. Likewise, CompactPCI remains a key board platform. It will be complemented by CompactPCI Serial, which will compete with OpenVPX in some markets.

And if you follow military electronics, then sequestration has probably entered your vocabulary—along with the fiscal cliff. The potential reduction of military electronics spending on the order of $500 billion will have an impact on the kinds of technology that will become available in the future as developers try to make best use of existing solutions. ED

DON TUITE | ANALOG/POWER EDITOR don.tuite@penton.com

Power Management Will Take New Forms

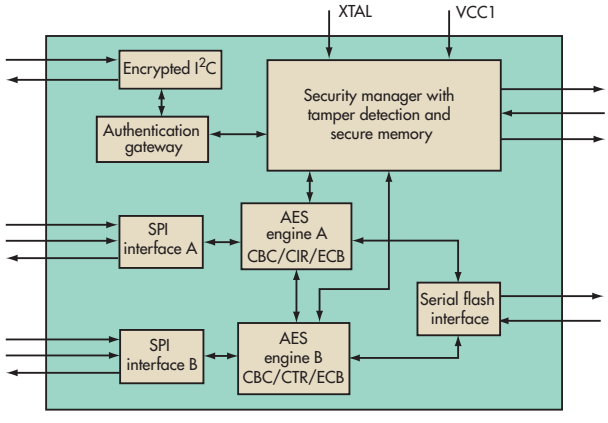
Staying competitive means companies now have to choose the best application arenas for product differentiation.

THIS YEAR PROMISES little growth in the electronics business. Companies hope that by carefully choosing the right evolving technologies, they will gain an edge as those technologies mature. Of course, this leads them to particular strategies in new product development to meet the needs of certain vertical market segments.

For example, Maxim Integrated offers its MAX36025 as a key element for securing elements of the Smart Grid, ranging from backhaul communications from smart-meter concentrators to access to substation controls. Using multiple layers of technology originally developed for secure communications between banks and point-of-sale terminals and ATMs, the MAX3265 employs a tamper-reactive dual AES cryptographic engine architecture for multiple cipher channels across compartmentalized system nodes and storage elements *(Fig. 1)*.

LINEAR STAYS AHEAD OF THE PACK

Linear Technology's experience in LED-driver ICs reflects this trend in developing products that allow differentiation. There are high volumes in incandescent bulb replacement, but poor margins. Dealing with the automotive industry is tougher, but the volumes are just as high and sockets are stickier—that is, product life cycles are longer.



1. Maxim Integrated's business model emphasizes unique IP that can be retargeted for multiple applications in complex products across a range of vertical markets. Addressing security concerns across the Smart Grid, its MAX36025 retargets IP developed for cash machines to secure communications between electric metering equipment and suppliers.

The latest LED segment with high barriers to entry and rich rewards is high-bay lighting, the kind of fixtures illuminating warehouses and factories. There is a strong motivation to switch to LEDs, because of the downtime and service costs for sending qualified electricians out in cherry-pickers to replace or service burned-out conventional gas-discharge bulbs.

"We've had some looks at the guys like Phillips, who are making LED replacement bulbs, and decided that's not where we can get good business. But things like industrial high-bay lighting, factory floor lighting, stadiums, stuff like that, where the cost of maintenance is really high and products need to last forever, were attractive," said Linear Technology vice president Steve Pietkiewicz.

The product differentiator Linear chose was in the architecture it selected for the drivers. Pietkiewicz said customers don't like opto-isolators, and they do like a small external parts count. Linear uses a planar transformer for isolation and a single-stage flyback design with built-in power factor correction.

The large LEDs used in office projectors and theaters represent an even more specialized market. "We've got products that drive those 20-, 40-, 50-A LEDs. They're made by a company called Luminus, using a technology called photonic lattices," Pietkiewicz said.

For Linear's automotive customers, one hot area is buck regulators for the vehicle's many engine control units (ECUs), with a special characteristic—they must turn in 30 ns. The car makers, then, can strip out a voltage-distribution stage. "You can go straight from car battery to engine-control-unit core processor, delivering 1 V at 3 A. That replaces the old two-step approach (12 V down to 5, then 5 V down to 1)," Pietkiewicz said.

Also, automotive dc-dc converters can get complicated. "The car companies like to have the switcher run above 1.6 MHz, so it doesn't interfere with the AM radio band. But if you're running at those kinds of frequencies, let's say you're running at 2 MHz and you want to step from 12 V to 1 V, that means you've got to have a really short 'ON' time in the switcher, which means you've got to have a really high-speed switcher," said Linear CTO Robert Dobkin.

Linear offers switchers that will do that on 2 µA of quiescent current, with efficiencies in the 90s. That's significant, because it means that none of the dc-dc converters ever has to be switched off, except by the ignition key.

How many ECUs does that represent? At Electronica in November, Dobkin met a German auto engineer who told him that there were 100 ECUs, 400 LEDs, and 122 electric motors in one of his vehicles, and they all need silicon to drive them. The fewer times they must be turned on and off, the better, as long as their quiescent requirements are small enough.

Another curious product driver in the automotive market is a response to exactly the opposite problem: the need for line-drop compensation in the dc-dc regulators used to support USB power points. Frequently, the active device is some distance away from the device being powered, and at the same time, that device is drawing significant current.

In 2013, Linear will be putting line-drop compensators in some of its regulators. The first part will be an external device, not a virtual remote sense. It will measure the current and jack the regulator output voltage up, assuming the car maker knows how much the IR drop is going to be at the far end of the internal wiring.

Not everything new in product drivers for small power ICs is automobile-related, though. Linear has been considering thermal energy harvesting as it relates to its recent acquisition of Dust Networks, the "mesh-to-edge wireless" sensor-network company whose technology is distinguished, among other things, by energy efficiency based on its use of deterministic time slots for transmissions.

An upcoming sensor device from Linear will draw less power than its previous generation, even though it includes an ARM core and a lot of memory. It will be built into a module that runs on a lithium-thionyl chloride battery. The energy harvesting becomes valuable when it's necessary to extend battery life or to power the sensor.

There will be more details upon the product's announcement. In the Dust Network scenario, the most common source of energy for harvesting is likely to be thermal, not based on a continuous delta-T but on daily cycling of ambient temperatures.

In electric cars, Linear has had battery charge-balancing chips through four generations. Dobkin is bullish on their potential for being a breakout technology in 2013, and not just in electric vehicles.

"I'm seeing increase in traction in terms of energy storage for averaging peak power demands. Linear will soon have several solutions for balancing very large stacks of batteries that will, depending on what your game is, increase the capacity of the battery, the longevity of the battery, or the cycle life of the battery."

This means balancing currents of 2 A to 10 A or more, in big batteries, in solar farms. "Even today in Asia, you'll find seas of solar farms that need to have large-scale storage systems attached. People want to use wind and solar and other power. They want to harvest that energy when it's available, and they need to store that energy somehow and use it when it's dark," Dobkin said.

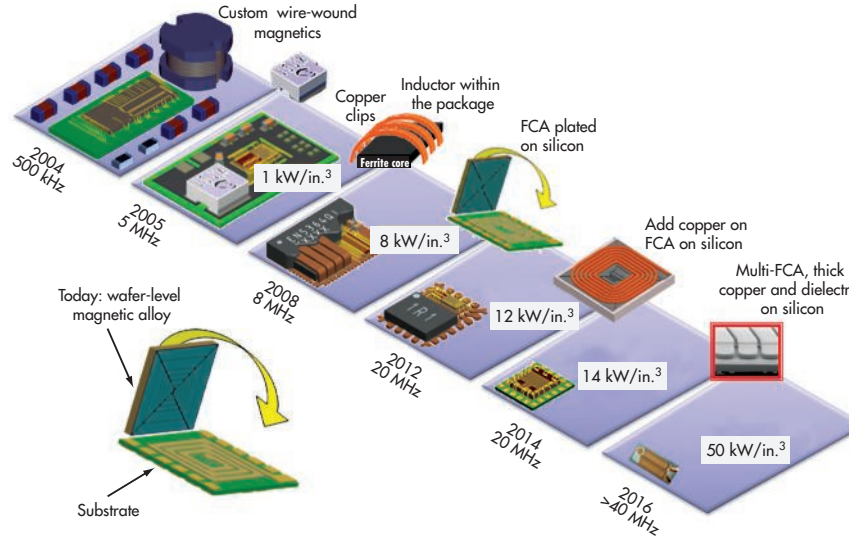
Even when it comes to vehicles, it's wrong to think exclusively in terms of private automobiles. "We've now started to talk about the 'transportation industry' as opposed to 'automotive,' because then you end up with a market that consists of heavy vehicles, and farm equipment, and forklifts, and trains," he said.

The upcoming generation will feature some interesting innovations, such as wireless coupling (through planar coils top and bottom) for communications up and down the battery stack, eliminating noise in the communications link.

There also will be greater precision in measuring battery voltage than ever—a necessity because the extreme flatness of the discharge curves for the latest battery chemistries requires that to determine state-of-charge. So Linear will use its subsurface Zener voltage reference technology, and every time the battery gets a full charge, the system will recalibrate.

INTERSIL SEEKS NEW SOCKETS

Former Intersil CEO Dave Bell is looking for ways to beat what looks like a period of flat growth, which means picking the right market segments to support. For example, total semiconductor content in vehicles continues to grow, particularly in electric cars and hybrids. Semiconductors are now around $250 per car and should increase, in Bell's opinion, to around $400 per car on average in several years.



2. Enperion's roadmap tracks the technologies for magnetics in dc-dc switching regulators, looking ahead to 2016. The latest advance, embodied in products announced late in 2012, are embodied in a 57-cent (in 1000-unit quantities) dc-dc buck regulator that switches at 18 MHz.

Bell was bearish on PCs, especially desktops and traditional notebooks, but bullish on smart phones, tablets, and ultrabooks, although he said that the kinds of ultrabooks and portables he's looking for haven't hit the market yet.

"Today, there really aren't any true ultrabook-like products out there. If you tear apart a MacBook Air and compare it to maybe a clunkier, full-sized notebook computer, there is really not a whole lot of difference from an architectural standpoint," he said. True ultrabooks, he added, will be shipping early in 2013. Companies concentrating on analog and power ICs can focus on integration.

"Today, if you look at a conventional notebook computer, the power system is quite fragmented, with dc-to-dc controllers for core power, additional power controllers for system power, and an external battery charger. As the market starts going to true ultrabooks, that functionality will become more integrated. In particular, as new architectures allow power levels to shrink, it will be possible to integrate on-chip power MOSFETs," he said.

Apple's latest iPad represents the current level of integration in power systems. A single big power-management IC (PMIC) handles almost all of the system-power functions. If there is a cellular interface, another PMIC drives the base and cellular functions.

"Some pretty high levels of integration are already in smart phones and tablets, and the bottom line is, as true ultrabooks emerge, you're probably going to see similar levels of integration in those products as well," Bell said.

Power levels are coming down in ultrabook processors, which may reduce current-demand rise and fall times. However, some quad-core ARM processors can sink currents of 20 A or more.

"If you try to handle that with a very small handheld device, you're going to have to start using architectures that involve maybe two- and three-phase power converters, but with much smaller inductors and capacitors than you find with a full-sized notebook," Bell said.

Product design for such different market segments as automobiles and personal communications and computing can be challenging. To succeed, though, companies need to respond to "the notorious impatience of Wall Street," Bell said.

"When you're talking about things like smart phones, they get all excited because they know that you can get very rapid revenue results from an investment. They like to see revenues growing very rapidly.

But if you start talking about automotive ICs, where you can spend maybe four or five years developing a product before you're going to start seeing early production quantities, Wall Street just doesn't have the patience for that," he said.

"At the same time, you do need to plan on product longevity. In many cases, the automotive companies want assurance that you will be able to provide this same product for 15 years," he said.

POWER IP FOR THE FABLESS AT S3

Engineering service companies such as S3 Group of Dublin, Ireland, provide custom core intellectual property (IP) for ASICs that approach the performance of discrete ICs from the independent device manufacturers (IDMs). For some time, S3 has offered core IP for both low-dropout regulators (LDOs) and digital dc-dc converters in simpler chips. In certain areas, though, there's a trend toward integrating more power-management functionality directly on systems-on-chip (SoCs).

"There are so many power domains now on complex SoCs. Having one or more on-chip dc-dc converters with a fixed set of LDOs would not be a huge challenge," said Dermot Barry, vice president of consumer silicon at S3.

Companies are now taking functionality that used to exist in an external power-management chip and integrating it.

"From the system customer's point of view, if they can remove those power-management chips, it helps, not only from a cost perspective, but from a size and volume perspective as well," Barry said.

Specifically, the advanced work that S3 is involved in focuses on integrated dc-dc converters, using TSMC's 28-nm process. That's a follow-on to a dc-dc converter on an external power-management chip that uses the more mature 0.18-µm CMOS technology.

STILL ROOM FOR INNOVATION

For all the talk of high levels of integration for vertical markets, there is still room for innovation in traditional semiconductor devices, particularly in reducing physical size and external parts count.

In November, Enperion announced its EL700 PowerSoC point-of-load dc-dc converters based on electroplated wafer-level magnetics. The chips in the 42-mm^2 EL700 family integrate MOSFETs, a controller, compensation, and a tiny inductor *(Fig. 2)*. The inductor enables switching rates up to 18 MHz. The 1- and 1.5-A PoLs have an input voltage range of 2.65 to 5.5 V.

LOUIS E. FRENZEL | COMMUNICATIONS EDITOR lou.frenzel@penton.com

Wired Communications Hold Their Own Against Wireless Dominance

You can't have wireless without a wired connection somewhere.

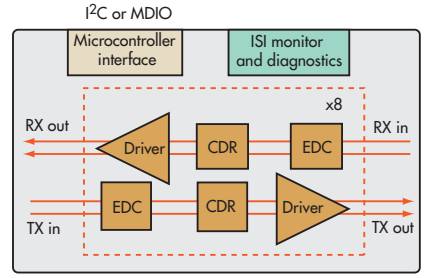
WITH WIRELESS MAKING continuous progress in replacing older wired technology, you might think that wires and cables are approaching obsolescence. Wrong! If anything, there are more wires and cables than ever as we dream up ever more applications that connect devices and exchange information.

Even as speeds have escalated into the upper-gigahertz ranges, cables still hold their own. Fiber-optic cables handle most of that higher-speed data, but even copper cables can deliver gigabit data over reasonable distances. There's a wired infrastructure behind virtually every wireless application, too.

COPPER CABLES CONTINUE TO CONNECT

Who would have thought you could send data at hundred of megabits or even gigabits per second down a copper cable? We knew we could do it with coax if we were willing to put up with the high attenuation and fussy connectors. But how can you do it with twisted-pair cable or other formats?

Thanks to equalization, dispersion compensation, and other techniques implemented with DSP, megabit and gigabit cables are available. Several communications interface standards support the ever-increasing traffic, including Firewire, USB 2.0 and 3.0, HDMI, Ethernet, InfiniBand, HDBase-T, and Thunderbolt.



1. Cortina's CS4343 optical PHY interface incorporates eight full-duplex channels of transceivers capable of up to 15 Gbits/s. It includes CDR and well as electronic dispersion compensation (EDC).

Firewire, the oldest standard, is on its way out now that Apple dropped it as an interface on its Mac PCs and laptops. It was used mainly for external disk drives and video cameras. USB 2.0 is there with its theoretical maximum rate of 480 Mbits/s up to 5 meters, but it can do a couple hundred megabits per second up to about 10 meters. USB 3.0 has a theoretical top rate of 5 Gbits/s up to 3 meters. These rates are great, but the range is too short for many applications.

Then there's HDMI for audio and video media. It supports a bit rate to 10.2 Gbits/s up to about 10 meters, but there are multiple connector types and specifications. Repeaters and active cables support longer distances.

Ethernet has also been doing megabit and gigabit rates for years over unshielded twisted-pair (UTP) cable. It uses multiple pairs and all sorts of electronic modulation and other tricks to extend the range to 100 meters, including 10 Gbits/s—not bad for a cable.

The new interface, Thunderbolt, is a contender in the fast cable interface competition. Created by Intel as Light Peak and now adopted by Apple, Thunderbolt multiplexes both the PCI Express and DisplayPort interfaces on a single cable where both data and video can be carried at speeds up to 10 Gbits/s. Cable lengths up to 3 meters are supported. Up to six devices may be daisy-chained to extend range. Optional fiber-optic cables accommodate longer distances.

Intersil's ISL37231 Thunderbolt transceiver chip boasts two differential 10.3125-Gbit/s full-duplex lanes that make it easy to build active cables where the interface circuitry is inside the cable connectors. The Intersil ISL80083 is a companion power management chip.

FIBER OPTICS CONTINUE TO LEAD

The Internet backbone can't keep up with the continued growth in data traffic thanks to the cloud, tablets, smart phones, the LTE expansion, and video. The continuous improvements in data rate and capacity help but never seem to quite catch up with demand. That's why the push to 100-Mbit/s systems is accelerating.

All sectors including data centers, local-area networks (LANs), storage-area networks (SANs), metro networks, long-haul networks, and even undersea connections are targeting the 100-Gbit/s node. Many data centers wish they could move more quickly to 400 Gbits/s. The ultimate goal, 1000 Gbits/s or one terabit (1 Tbit/s), will require multiple fibers as well as new modulation formats like 16-phase quadrature amplitude modulation (16QAM) or orthogonal frequency division multiplexing (OFDM) on fiber.

The de facto standard for metro and long-haul 100-Gbit/s systems is single-wavelength (λ) polarization division multiplexing quadrature phase-shift keying (PDM-QPSK), or more specifically, dual polarization QPSK or DP-QPSK. It has a high tolerance to both polarization mode distortion (PMD) and chromatic dispersion, which are typical maladies affecting long fiber.

DP-QPSK is the chosen method for OTU4, the 100-Gbit/s version of the Optical Transport Network (OTN). The format

is either four lanes of 32 Gbits/s or four lanes of 28 Gbits/s depending on the protocol. Ethernet over shorter distances uses four lanes of 25.8 Gbits/s or 10 lanes of 10 Gbits/s (CFP).

The fastest growing sector of fiber serves shorter ranges under several kilometers, with growing use in data centers and access networks. Data centers are upgrading to 10-Gbit/s and 40-Gbit/s equipment and cabling. Line cards and switch density are increasing, along with port counts. As usual, requirements for lower power consumption and shorter latency are critical.

Cortina's CS4343 incorporates electronic dispersion compensation (EDC) and clock and data recovery (CDR) plus the related amplifiers and drivers *(Fig. 1)*. Protocol agnostic, the octal 15-Gbit/s physical-layer (PHY) chip works with Gigabit Ethernet (1/10/40G), Fibre Channel, InfiniBand, and Common Public Radio Interface (CPRI). It also provides full-duplex operation on eight independent channels and uses analog techniques for EDC. Dispersion compensation is needed at the higher data rates and long reaches of cables to offset the effect of pulse stretching due to the different rates of travel of different wavelengths of light.

Many data centers are already at the 100-Gbit/s level. Enterprise LAN and SAN installations are continuing their upgrades to 10-Gbit/s systems. Ethernet provides a path to upgrade to 40 Gbits/s and 100 Gbits/s. Only a few 100-Gbit/s metro and long-haul systems are in place. In these networks, the OTN standards leading to 100 Gbits/s are slowly replacing Sonet/SDH.

Fiber-optic cables provide even faster rates, with 40-Gbit/s and 100-Gbit/s rates possible at distances up into the kilometer range. Most of the need is for higher speeds over shorter distances up to 100 meters. Connections to servers, routers, and switches in data centers are a common application.

2. The Avago Technologies AFBR-83DC/PDxxZ active optical cable uses the CXP MSA connector standard and 10 or 12 fibers to achieve data rates to 100 Gbits/s. The cables are available in various lengths to 100 meters.

Avago Technologies offers active optical cables that deliver high-speed data over moderate distances. Copper Ethernet and InfiniBand interconnects dominate now with their large size, heavy weight, and power dissipation. Optical cables can replace them and greatly reduce the size and weight of the cables at no extra cost. And as a side benefit, they minimize electromagnetic interference (EMI).

The Avago AFBR-7CERxxZ uses standard multi-source agreement (MSA) standard small form-factor pluggable (SFP+) transceivers as terminations. This full-duplex cable offers a line rate to 10.3125 Gbits/s. The maximum cable length is 20 meters, but shorter versions are also available. It can be used with 10-Gigabit Ethernet (10GE), 8G Fibre Channel, Fibre Channel over Ethernet (FCoE), or InfiniBand single data rate (SDR), double data rate (DDR), and quad data rate (QDR) versions of 2.5, 5, and 10 Gbits/s. Power consumption is 25 mW per transceiver.

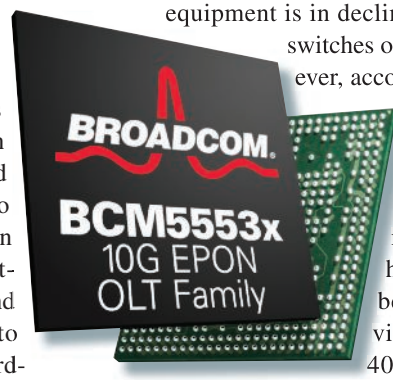
The Avago AFBR-7QERxxZ uses the QSFP+ MSA transceivers that feature four bidirectional links, each with a rate of 10.3125 Gbits/s, making it useful in applications like 40 GE-SR4 as well as the SDR, DDR, and QDR InfiniBand applications. Cable lengths to 20 meters are possible. The power consumption is only 1.5 W (maximum) for all four channels.

The AFBR-83DC/PDxxZ version meets the CXP MSA transceiver standard *(Fig. 2)*. It provides 10 or 12 lanes of bidirectional data at 10.3125 Gbits/s with a reach of up to 100 meters. A 12-lane

version capable of 12.5 Gbits/s is also an option. It's good for use in 100GBASE-SR10 and CPPI or in InfiniBand applications. It also can be used to extend PCI3 Gen3 buses.

All three basic versions specify a 1E-15 bit error rate (BER) and low power consumption. These active optical cables not only are keeping cabling alive, they're also offering some unexpected benefits such as smaller size, lower weight, and EMI reductions at approximately the same cost as passive or active direct attached copper cables.

The growth of passive optical networks (PONs) such as Google's new fiber optical network in Kansas City continues quietly in areas for new homes and in some rural areas with no cable. There are 7.3 million Gigabit PON optical network terminals (ONTs), and that's expected to grow to 18 million by 2016, according to Infonetics Research. The ONTs are the service provider gateways.



3. Broadcom's BCM5553x OLT is designed for new EPON fiber systems at the 1-Gbit/s and 10-Gbit/s rates.

With up to 32 customer premise optical networking units (ONUs) per ONT, their growth represents a huge increase in home or business coverage. GPON has a standard 2.488-Mbit/s downlink speed and 1.244-Mbit/s uplink speed. Already, the faster 10GPON or 10-Gbit/s version is being deployed in the U.S. Broadcom offers the BCM685xx series of GPON systems-on-chip (SoCs) for residential triple-play services including video on demand (VoD), HD-IPTV, voice over IP (VoIP), and high-speed Internet service.

EPON, the Ethernet version of a PON, is growing nicely in the world marketplace. This standard also supports a 10-Gbit/s version. It's widely used in China, Japan, and South Korea. The PON approach is superior to wireless connections for residential access, especially in multi-dwelling units (MDUs) where thick walls and floors block wireless signals. EPON is also showing promise as a basestation backhaul solution because of its low cost.

Broadcom's BCM5553x family of optical line terminal (OLT) chips for EPON supports both 1-Gbit/s and 10-Gbit/s speeds *(Fig. 3)*. They comply with the IEEE 802.3av standard as well as China Telcom 3.0 and CableLabs DOCSIS Provisioning over Ethernet.

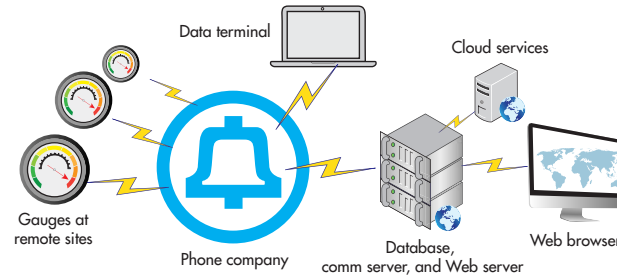
The metro and long-haul optical networking sectors are doing moderately well. Older Sonet/SDH networking equipment is in decline as the industry switches over to OTN. However, according to Dell'Oro Group, wavelength division multiplexing (WDM) equipment sales are healthy as a number of service providers roll out their 40- and 100-Gbit/s services in response to the ongoing demand for more bandwidth. The metro and long-haul WDM sector grew by 14% in 2012 to $8 billion. Growth is expected in 2013.

POTS CONTINUES ITS SERVICE

Plain-old telephone service (POTS) isn't dead yet. All that telephone wiring is still there, and about 50% of the U.S. population still relies upon it for telephone service. Many have given up their POTS lines for cell-phone connections, yet those POTS connections are still present and useful for data services like DSL or over-the-top (OTT) TV and even new applications for machine-to-machine (M2M) communications or industrial monitoring and control.

M2M is growing rapidly as more companies and institutions find they need to monitor or control devices or facilities remotely. Most M2M connections

today are cellular or some other wireless option. But for some cases, there's no reason not to use the installed base of telephone wiring. It exists nearly everywhere, and phone line service is cheap and very reliable. Every traditional landline also supplies dc power, so it can power many devices instead of batteries or local ac power. Furthermore, connectivity is robust, as it typically remains connected even during storms and floods.



4. Global Monitoring's GMU8120 modem uses telephone lines for industrial monitoring and control. Standard interfaces and telephone modem data rates are available.

One company is taking advantage of this medium for both M2M and other industrial control. Global Monitoring's GMU8120 modem offers related interfaces to transmit and receive data over POTS *(Fig. 4)*. It uses traditional telephone dial-up speeds from 1200 bits/s to 53 kbits/s. Interfaces include 4 to 20 mA, 0 to 5 V and dry contacts, ±1 V to ±10 V dc. Analog-to-digital converter (ADC) inputs have 14-bit resolution. Outputs are four relays.

The major telecom companies would love to abandon their wireline business to focus on the more lucrative wireless and broadband markets, but state and federal regulations require them to maintain their existing lines. AT&T, which serves 76 million homes in 22 states, recently indicated a desire to phase out its landline business. The company is trying to get local and federal regulations changed. Verizon, the other largest wireline company, also serves millions but would prefer to move on to more profitable broadband services.

Landlines are here to stay for the time being, though, so take advantage of this low-cost and reliable medium while it lasts. In addition, landlines are still widely used to supply high-speed Internet connections via DSL to a huge population not only in the U.S. but also in Asia and Europe. Cable TV-based Internet connections still dominate in the U.S., but DSL is a close second.

AT&T uses the connection to the home for its U-verse TV service. This OTT Internet TV service is a strong competitor with cable TV services in some parts of the country. U-verse is a hybrid service with fiber to local nodes and existing telephone UTP to the homes. Advanced DSL technology like ADSL2 or VDSL2 is used to achieve the speeds needed for compressed HDTV delivery.

Broadcom's BCM63168 mulitmode ADSL2+/VDSL2 chip further extends the reach and speed of DSL lines. DSL technology uses discrete multitone (DMT) technology, which is a form of OFDM, to achieve high speeds on UTP telephone cable. In VDSL2 format, it uses up to 30 MHz of bandwidth on the line with up to 3479 carriers, each 8.625 MHz wide, to deliver data rates to 200 Mbits/s over limited distances. The speed depends mainly on cable length. Maximum data rate at 0.5 km is about 100 Mbits/s, for example.

This chip also uses vectoring and channel bonding to further improve speed and reliability over longer distances. Vectoring is a technique for reducing crosstalk and noise on adjacent cables using DSP. With a single vectoring connection, VDSL2 can deliver up to 50 Mbits/s up to 1 km. Channel bonding permits the use of two or more pairs of cables to deliver parallel paths, further increasing the data rate up to 100 Mbits/s with some combinations. Such techniques keep DSL competitive speed-wise with cable TV systems. The BCM63168 also includes a full dual-band 802.11n/ac Wi-Fi transceiver.

CABLE TV UPGRADES

U.S. cable TV companies will maintain their dominance in high-speed Internet service over DSL. They offer higher speeds and more channels than ever. This capability comes as a result of the ongoing upgrade of cable modem termination systems (CMTS), the stilted name of the cable head-end system that feeds the network of connected homes and businesses. Cable systems are hybrid fiber coax (HFC) networks that put multiple channels on a fiber that terminates at neighborhood nodes that convert the connection to RG-6/U coax for attachment to the customer's cable STB. Each fiber node serves about 500 homes.

Over the past several years, the cable companies have gradually changed from an all-analog system to an all-digital format. The more recent upgrades are to the latest version of the Data Over Cable Service Interface Specification (DOCSIS), an international standard from CableLabs that specifies how to supply video and Internet service over the HFC system.

DOCSIS 3.0 aims to provide 50- to 100-Mbit/s data service to customers and address the need for more IP identification with IPv6. It also provides stronger encryption and should help reduce the number of HFC node splits needed to cover a given area. In the downstream from the CMTS to the customer, the standard 6-MHz wide channels are still used.

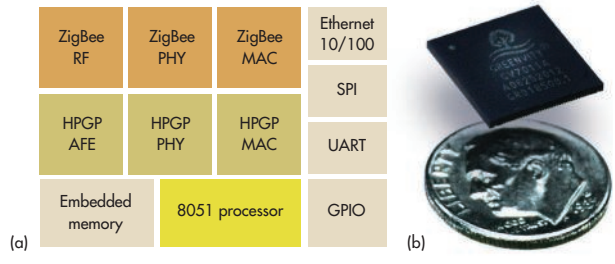
Total cable bandwidth is commonly up to 1 GHz wide, meaning it can accommodate up to about 166 channels, mostly downstream. 64QAM and 256QAM provide 26 to 38 Mbits/s per channel. The upstream data occurs in the 5- to 42-MHz space on the cable and uses QPSK or 16QAM to get rates ranging up to about 30 Mbits/s but averaging 1 to 3 Mbits/s. More than 80% of all U.S. cable systems have upgraded to DOCISS 3.0.

Aiding the DOCSIS 3.0 transition, the Analog Devices ADS9129 14-bit digital-to-analog converter (DAC) supports up to 2.8 Gsamples/s. It's designed for CMTS infrastructure equipment and can handle as many as 158 carriers at a time. The ADS9129 and the 11-bit AD9119 are expected to reduce total systems power consumption, component count, and overall cost.

PLC STILL CONNECTING

Power-line communications (PLC) uses the existing ac power lines to carry data. Sophisticated modulated signals ride on top of the 60-Hz power sine wave along with all the attendant noise to carry data. While the attenuation is significant, whole home coverage is possible at data rates that previously were impossible. Most PLC standards specify OFDM, which provides for high noise tolerance and good spectral efficiency to deliver high speeds at reasonable distances.

Multiple PLC standards have been developed, but only a few have survived. The leading PLC technology, HomePlug, has been around for years and has gradually advanced the state of the PLC art to a new level. Its latest version, HomePlug AV2, extends the signal bandwidth from its usual maximum of 30 MHz to 86 MHz and boosts modulation higher-level QAM to produce near 1-Gbit/s rates over reasonable distances.



5. The Greenvity GV7011 Hybrii-XL integrates a full ZigBee radio and a HomePlug Green PHY transceiver including the full analog front end, RF, baseband, media access controller (MAC), and embedded memory. An 8051 microcontroller implements low-power energy management.

Most home applications involve video distribution between STBs, HDTV sets, and DVD players. HomePlug's lower-speed HomePlug Green PHY is used for home-area networks (HANs).

The main competing standard is the ITU's G.hn. This broader standard uses the power line, but it also can use any existing coax cable or twisted pair to carry the signal. G.hn is designed primarily for home networking, with video transmission being the main use. Speeds to 1 Gbit/s are possible with some configurations.

G.hn has not yet been as widely adopted as HomePlug, but it is fighting for some of the potential consumer market. Lower-speed PLC standards like G3 target applications like industrial communications and smart meter/Smart Grid connections.

PLC's real battle is with wireless, which is so entrenched in the home with Wi-Fi and ZigBee that it's is hard to see PLC as other than a niche technology. There is no questioning its convenience with a connection via any ac plug, but wireless may be even easier and more portable. But PLC does have its place.

In some situations, PLC can be more reliable than wireless. PLC and wireless also can complement each other. Greenvity Communications makes PLC and wireless technologies available on a single chip. Both can be used in smart meters and other HAN equipment, but neither technology fits all possible potential uses.

The Greenvity GV7011 Hybrii-XL integrates a full ZigBee radio and a HomePlug Green PHY transceiver *(Fig. 5)*. This combination reduces the cost of HAN equipment and accelerates product design. Furthermore, this integrated device uses less power than multiple separate chips and boards to support both standards.

The Hybrii chip automatically selects the best medium to transmit data, wirelessly or on the power line. If the power line is too noisy, the wireless nodes will be enabled and vice versa, always ensuring reliable communications under most circumstances.

PLC's greatest potential is probably in the smart meter and Smart Grid space since it is so closely tied to the ac power line. It will also see greater adoption if it gets embedded in STBs and other consumer gear, but it will continue to battle the wireless vendors for those cherished spots.

LOUIS E. FRENZEL | COMMUNICATIONS EDITOR lou.frenzel@penton.com

A Ubiquitous Wireless World Unfolds

A mix of cellular and short-range technologies is blanketing the world.

WIRELESS EVERYTHING—THAT'S THE theme and direction the electronics industry is taking. Practically all new products have some form of wireless component or option. For example, Apple's Hue is a set of three Philips LED light bulbs that can be controlled from an iPhone or iPad.

Hue uses Wi-Fi to talk to a wireless bridge supplied with the bulb set that in turn connects via the home router. The bridge also connects via a ZigBee wireless link to the light bulb to turn it on and off and control its brightness and color.

The smart phone is at the center of all this wireless activity. More than 50% of U.S. cell-phone subscribers have a smart phone, and that percentage is growing in the U.S. and in the rest of the world too. The smart phone has clearly replaced the PC (desktop or laptop) as the top consumer electronics product.

Perhaps we should begin calling the smart phone what it really is: a compact portable PC with communications capability. Those hundreds of thousands of apps that are currently available run on a computer, not a phone. While the smart phone dominates the wireless space, though, other wireless technologies continue to grow and find new applications.

SMART-PHONE GROWTH AND LTE ROLLOUT

Cell-phone growth will continue throughout 2013. A recent report from Ericsson indicates total global mobile penetration of 91% as of the third quarter of 2012. Total mobile subscriptions are now 6.4 billion, and that's expected to grow to 6.6 billion by 2018. China and the U.S. lead in subscriptions.

Furthermore, 40% of the phones sold in 2012 were smart phones. LTE subscriptions grew to 55 million in 2012 with a total of 455 million people with LTE coverage by mid-2012. Subscriptions for LTE are expected to reach 1.6 billion by 2018.

As LTE is rolling out, though, 3G technologies are still growing. HSPA and other 3G networks provide near LTE performance at a lower cost that is suitable for many users in many locations. 3G will be around for many years more, but the older 2G technologies will gradually fade away.

Research firm Gartner says that Samsung is the leading handset manufacturer, including smart phones, with Nokia a close second in the world market. Apple is a distant third followed by ZTE, LG, and others. Sales figures by handset operating system (OS) show Android clearly in the lead followed by Apple iOS, RIM's BlackBerry OS, and others. You also may expect to see some new players in smart phones. Both Amazon and Microsoft are rumored to be working on their own phones for later in 2013.

Screen sizes continue to grow to 4 inches and beyond to a maximum of 5.5 inches for the Samsung Note II. It is doubtful sizes for smart phones will go beyond that size, though. If you want bigger, try a tablet for video and other applications requiring a larger screen.

Most newer smart phones include LTE, the 4G technology now being added to and expanded in most carriers' networks. Verizon is still in the lead in the U.S. with the most LTE sites, but AT&T is not far behind. Other carriers like Sprint will begin to offer LTE, as will T-Mobile and its recent acquisition, MetroPCS. 2013 will see major expansions of all these LTE networks as well as an increasing number of new LTE handsets. More subscribers will opt for LTE despite the growing cost of data plans.

Near-field communications (NFC), the short-range technology designated for mobile commerce, will continue to make inroads as more smart phones incorporate it and as more retailers add terminals and back office systems to accommodate purchases with cell phones instead of credit cards. However, NFC won't be a universal feature like Wi-Fi since Apple has not and probably will not adopt NFC for its iPhones.

While the LTE expansion won't be complete by the end of 2013, there is word of some early deployment of LTE-Advanced (LTE-A), the next version of LTE. LTE is really just a 3.9G technology. LTE-A is the real 4G according to

1. Ceragon's FibAir IP-20C backhaul radio delivers 1 Gbit/s using 2048QAM, 4x4 MIMO, and a unique multiprocessing solution suitable for use in small-cell hetnets.

the Third Generation Partnership Project (3GPP), which develops and sets cellphone standards.

LTE-A's carrier aggregation permits cell sites to assemble up to five 20-MHz LTE channels into a single channel. The channels may be contiguous or non-contiguous as applicable to the carrier's spectrum holdings. Added to that is an 8x8 multiple-input multiple-output (MIMO) option. And, LTE-A offers up to 1-Gbit/s downloads under optimum conditions.

LTE-A is not deployed yet, but formal service is expected to begin in limited areas in late 2014 *(see "Design Trends Address Challenges In Cellular Products" at electronicdesign.com)*. Still, LTE and LTE-A both present multiple design challenges, like Voice over LTE (VoLTE). LTE is an Internet protocol (IP) data network only. The older 2G and 3G GSM and CDMA voice systems carry voice. VoLTE will eventually lead to the phase-out of these older technologies.

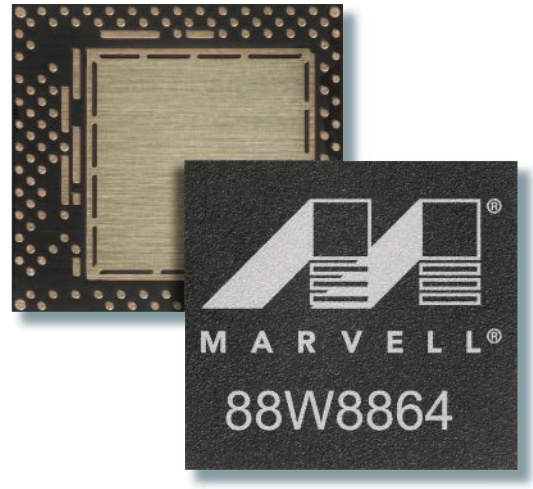
Smart-phone sales by units and revenue have exceeded PCs, according to Barron's. Also, more users access the Internet via their smart phones than their PCs. Smart phones and tablets are causing PC sales to decline, and that decline will continue. PC sales will never go away, but most manufacturers are scrambling to find alternative business models and products.

FORMING THE HETNET

What may become the real 5G standard is the forthcoming adoption of small cells—tiny basestations called picocells, microcells, and femtocells—that can be located anywhere that traffic requires them. Small cells will fill in the gaps between the current standard macrocell basestations to create what is being called the heterogenous network, or hetnet. Wi-Fi offload is part of that solution.

There could be as many as three small cells per macro. Such an arrangement will permit broader and more reliable coverage as well as much higher data speeds to accommodate the growing demand for video, gaming, and other massive data applications. Hetnets don't exist yet, but the number of picocells and home femtocells already has exceeded the total number of existing macrocells.

Look for an even finer grain of small cells moving forward. Small-cell study, development, and trials will continue in 2013 with the earliest deployments in 2014. However, all of these small cells could lead to massive interference. Home femto cells haven't resolved the issue yet, and things could get ugly with a massive small-cell deployment.



2. The Marvell 88W8864 802.11ac chip uses 4x4 MIMO with beamforming to extend range and reliability with a data rate to 1.3 Gbits/s in access points and routers.

Wi-Fi and offloading will be used to fill the data capacity gap until more carriers get LTE or an expanded LTE system. If a subscriber accesses the Internet for some video via the 3G or 4G network but an accessible Wi-Fi hotspot is nearby, the phone will opt for the Wi-Fi connection to avoid loading the cellular system. If no hotspot is nearby, the network will handle the access. IEEE standards 802.11u and 802.21, which have yet to be adopted, address the problem of handing over a connection between the cellular network and the Wi-Fi network.

Offload is not widely implemented yet. The carriers would rather avoid the Wi-Fi unless it is their own local-area network (LAN) to get the income. But the lack of capacity to handle every high-speed request at all times makes other solutions necessary. Until full LTE capability is available, we may see some offload as a stopgap measure.

The use of small cells also leads to the backhaul problem. Home femtocells use the subscriber's home DSL or cable Internet connection for backhaul back to the carrier. But other small cells need a connection to the system as well. Fiber is preferred because it can easily handle the speeds. However, running fiber in cities and dense suburban areas is often just too expensive and impractical.

As a result, microwave backhaul is emerging as the solution of choice. Small, inexpensive 60-GHz (unlicensed) and 80-GHz (licensed) backhaul radios already are being deployed. These radios use Ethernet and can easily achieve the data rates needed to handle LTE small cells over short distances. Market research company Mobile Experts predicts that carriers will invest as much as $1 billion by 2017 in microwave backhaul.

Ceragon's FibeAir IP-20C backhaul unit supports the hetnet movement *(Fig. 1)*. It uses multicore processing and 4x4 MIMO with 2048QAM to achieve a 1-Gbit/s over-the-air data rate. It is available for the most common microwave backhaul bands of 15, 18, and 23 GHz.

Microwave backhaul is replacing some fiber in longer-haul networks as well. Even fiber isn't fast enough for some applications. For example, financial trading between stock exchanges depends on ultrafast transactions. Milliseconds matter. While fiber is fast, the stock exchanges and the traders are finding that microwave backhaul is many milliseconds faster. Many new fast microwave links have been built to replace older fiber.

LINEAR TECHNOLOGY

DESIGN NOTES

System Monitor with Instrumentation-Grade Accuracy Used to Measure Relative Humidity

Design Note 510

Leo Chen

Because much can be deduced about a physical system by measuring temperature, it is by far the most electronically measured physical parameter. Selecting a temperature sensor involves balancing accuracy requirements, durability, cost and compatibility with the measured medium. For instance, because of its low cost, a small-signal transistor such as the MMBT3904 is an attractive choice for high volume or disposable sensing applications. Although such sensors are relatively simple, accurate temperature measurement requires sophisticated circuitry to cancel such effects as series resistance.

The LTC2991 system monitor has this sophisticated circuitry built in—it can turn a small-signal transistor into an accurate temperature sensor. It not only measures remote diode temperature to ±1°C accuracy, but it also measures its own supply voltage, single-ended voltages (0 to V_{CC}) and differential voltages (±325mV). While ostensibly designed for system monitor applications, the top shelf performance of the LTC2991 makes it suitable for instrumentation applications as well, such as the accurate psychrometer described here.

A Psychrometer: Not Nearly as Ominous as It Sounds

A psychrometer is a type of hygrometer, a device that measures relative humidity. A hygrometer uses two thermometers, one dry (dry bulb) and one covered in a fabric saturated with distilled water (wet bulb). Air is passed over both thermometers, either by a fan or by swinging the instrument, as in a sling psychrometer. A psychrometric chart can then be used to calculate humidity by using the dry and wet bulb temperatures. Alternatively, a number of equations exist for this purpose. The following equations are used in testing this circuit.

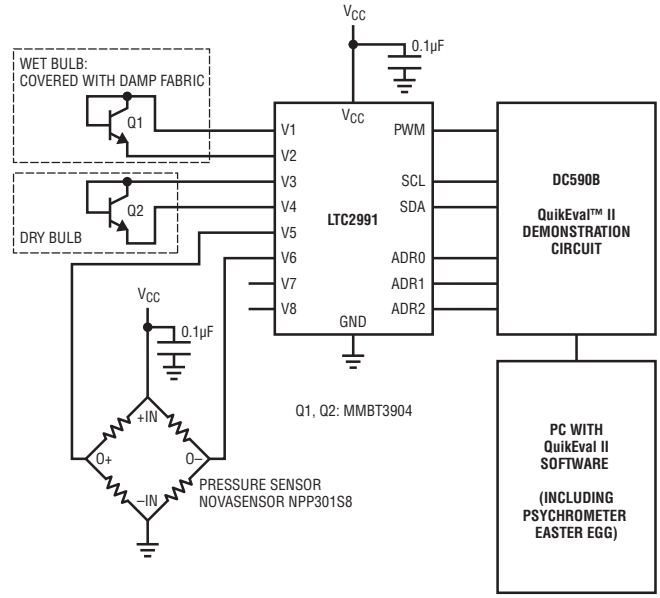


Figure 1. Simple Psychrometer Using the LTC2991

$$A = 6.6 \bullet 10^{-4} \bullet (1 + 1.115 \bullet 10^{-3} \bullet WET)$$

$$ESWB = e^{\left(\frac{16.78 \bullet DRY - 116.9}{WET + 273.3}\right)}$$

Where:

$$ED = ESWB - A \bullet P \bullet (DRY - WET)$$

$$HUMIDITY = \frac{ED}{EDSB}$$

WET = wet bulb temperature in Celsius

DRY = dry bulb temperature in Celsius

P = pressure in kPa

Figure 1 shows a LTC2991-based psychrometer. The two transistors provide the wet bulb and dry bulb temperature readings when connected to the appropriate inputs of the LTC2991.

The equations include atmospheric pressure as a variable, which is determined here via a Novasensor NPP301-100 barometric pressure sensor measured by channels 5 to 6 configured for differential inputs. Full-scale output is 20mV per volt of excitation voltage, at 100kPa barometric pressure (pressure at sea level is approximately 101.325kPa).

The LTC2991 can also measure its own supply voltage, which in our circuit is the same supply rail used to excite the pressure sensor. Thus, it is easy to calculate a ratiometric result from the pressure sensor, removing the error contribution of the excitation voltage.

Error Budget

The LTC2991 remote temperature measurements are guaranteed to be accurate to ±1°C. Figure 2 shows the error in indicated humidity that results from a 0.7°C error in the worst-case direction, and the error in indicated humidity resulting from a 0.7°C error in the worst-case direction combined with worst-case error from the pressure sensor.

Try It Out!

A psychrometer readout is implemented as an Easter egg in the LTC2991 (DC1785A) demonstration software, available as part of the Linear Technology QuikEval software suite.

The demo board should be set up as shown in Figure 1. To access the readout, simply add a file named tester.txt in the install directory of your DC1785A software. The contents of this file do not matter. On software start-up, the message “Test mode enabled” should be shown in the status bar, and a Humidity option will appear in the Tools menu. Relative humidity readings can then be compared to sensors of similar accuracy grade, such as resistive and capacitive film.

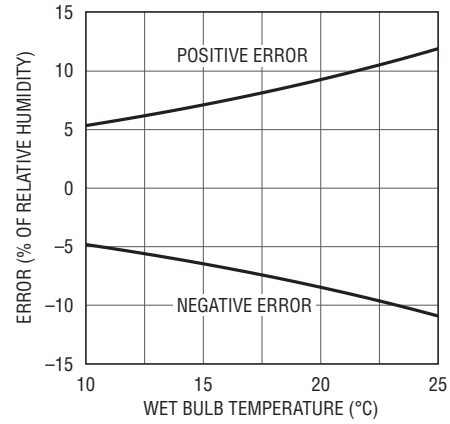


Figure 2. Worst-Case Error

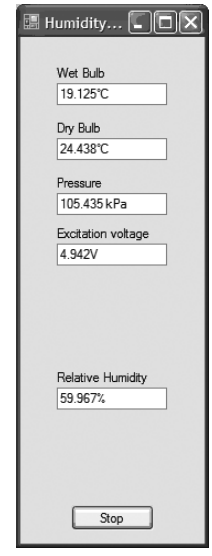


Figure 3. A Psychrometer Readout Is Implemented as an Easter Egg in the LTC2991 (DC1785A) Demonstration Software, Available as Part of Linear’s QuikEval Software Suite

Data Sheet Download

www.linear.com/2991

For applications help,
call (408) 432-1900

SPECTRUM SHORTAGES LINGER

The demand for more speed to handle video, Internet access, and other high-data-rate applications has led carriers to adopt the faster LTE systems. Yet LTE needs more bandwidth than older 3G technologies, forcing network operators to find and buy spectrum.

Mergers and acquisitions in the wireless field are often based on one carrier acquiring not only the business but also the valuable spectrum holdings of the acquired company. Yet there is only so much relevant spectrum, and most of it has already been licensed not just to cellular operators but also to satellite and other wireless services.

The Federal Communications Commission (FCC) will have to find and reallocate spectrum to meet these cellular needs. The FCC has promised more spectrum for cellular and broadband wireless, but little has come of that promise. Hopefully the FCC will find usable spectrum and provide an auction in the near future to keep the wireless industry on track for growth.

White spaces can assist in the growth of fixed broadband wireless for Internet access. These unused 6-MHz television channels vary in different localities, so frequency-agile radios are needed to take advantage of them. The spectrum extends from 54 MHz to 698 MHz, but the channels above 470 MHz are the most useful.

The FCC has declared white space to be license-free if approved equipment meets specific technical restrictions. Several companies are making white space radios to provide wireless services in rural areas and small towns that lack cable or other broadband capabilities.

While more spectrum is the answer to the problem, what happens if the current "good" spectrum from 700 MHz to 2700 MHz is fully used? One solution is to find ways to use the higher frequencies where more space is available. Wi-Fi uses the 5-GHz range, but there is room for additional services.

Transmission range is inherently limited at the higher frequencies thanks to physics, but that may be a blessing as this disadvantage could be the solution to the interference problem afflicting small cells. As cells become smaller and more numerous, it may be possible to use even higher frequencies like the millimeter-wave bands above 30 GHz.

Already, Wi-Fi 802.11ad radios and backhaul for cell sites are using the 60-GHz unlicensed band. Plenty of room is available if the short-range limi-

tation can be accommodated. Shorter range means more radios to provide coverage. In any case, that's the direction right now.

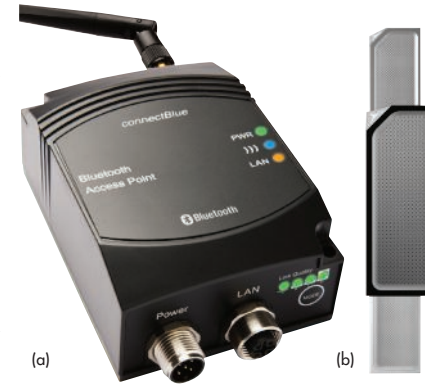
Furthermore, time division duplexing (TDD) could be used instead of frequency division duplexing (FDD). As used in the U.S. and most other countries, LTE uses FDD, which requires matched and paired spectrum segments: one for uplink and the other for downlink. However, the LTE standard offers a TDD option that time multiplexes up and down links in a single band.

China and other countries already use the TDD option, and more plan to use it. U.S. companies like Sprint and Clearwire plan on using it as well. TDD requires precise timing methods, but they're well within the reach of most companies. TD-LTE effectively doubles the amount of useful spectrum. This may be a future option for other carriers as their spectrum runs out or as available spectrum becomes more fragmented.

SHORT-RANGE WIRELESS EXPANDS

Short-range wireless includes Wi-Fi, Bluetooth, ZigBee, and other standards as well as the many proprietary industrial, scientific, and medical (ISM) band technologies. The chips are smaller and cheaper than ever, and the standards are rolling out new applications annually.

Wi-Fi continues its seemingly perpetual growth with the new 802.11ac standard, which uses the 5-GHz unlicensed band now used for 11a and 11n. Along with MIMO, it can produce data rates to 1 Gbit/s over the traditional maximum range of 100 meters associated with Wi-Fi.



3. New Bluetooth products show the technology's continued versatility. For example, this wireless router from connectBlue handles up to seven devices and should see service in the health and medical fields (a). Also, this battery-powered portable speaker from CUBEDGE uses Bluetooth 3.0 and is designed for use with smart phones and tablets (b).

Chips are now available, and 11ac already is beginning to appear in some products. Some 11ac access points and routers are available now, but there are few 11ac clients. Eventually, more laptops and ultrabooks will incorporate this technology, but it may be a while before cell phones use it.

Marvell's 4x4 MIMO 88W8864 11ac chip includes beamforming *(Fig. 2)*. Designed for all manner of access points, hotspots, routers, gateways, and bridges, it can achieve a peak data rate of 1.3 Gbits/s under the best of conditions. The 4x4 MIMO really improves the range and reliability of the connection, and the high data rate makes it suitable for TV connectivity in HDTV sets, DVD players, set-top boxes, and over the top (OTT) Internet TV devices. The device is backwards compatible with 11a/b/g/n devices and features a host CPU offload feature as well.

The future for Wi-Fi is the full deployment of 11ac, but what lies beyond it is difficult to see. Gigabit speeds fulfill most needs, so it's not clear that more speed is needed for now. Plus, the 1-Gbit/s Ethernet port accompanies most 802.11 routers and access points. In the meantime, 802.11ad is emerging.

Chips for the 802.11ad standard are now available. It uses the 60-GHz band to provide even faster data rates of 1 Gbit/s to 7 Gbits/s over shorter distances in the 10-meter range. Known as WiGig in its commercial form, it targets HDTV sets, video monitors, and laptop docking stations. A combination of 11n and 11ad is available in a modular form for laptops from Qualcomm Atheros and Wilocity. WirelessHD, another 60-GHz standard, addresses various TV and video applications as well.

Wi-Fi is also a good candidate for some machine-to-machine (M2M) applications, including automobiles and cellular offload. This flexible standard shows no signs of fading in the foreseeable future. In fact, because of the ubiquity of smart phones and tablets with Wi-Fi, companies are expanding their deployment of Wi-Fi in the enterprise and in public places. Many new uses are being discovered.

While Wi-Fi may be a mature technology, it is still growing. Research firm International Data Corporation expects the Wi-Fi networking equipment market to total $4.29 billion in 2013 and increase between 10% and 15% per year over the next few years.

Bluetooth continues its reign as the most widely adopted short-range tech-

nology, and its increased incorporation continues. With Bluetooth in virtually every cell phone, wireless headset, and tablet, no other wireless technology is so widely embedded. Now with Bluetooth SIG 4.0, the potential is expanding. Most of this potential is the result of a revised version called Bluetooth Low Energy, or BLE *(see "What's The Difference Between Bluetooth Low Energy And ANT?" at electronicdesign.com).*

This very low-power version has a slower data speed for sensor applications. Its most likely uses are in the medical market, such as wireless blood pressure monitoring. Sports and fitness applications are also target applications. For example, a chest strap sensor could send data to a Bluetooth watch display to monitor heart rate. BLE could be big since it can easily be incorporated into existing Bluetooth chips in smart phones. Both Apple iOS and Android support BLE connections now. Look for other new uses thanks to this capability *(Fig. 3).*

ZigBee also continues its slow but steady growth. ZigBee IEEE 802.15.4 radios operate in the 2.4-GHz band with a data rate of 250 kbits/s. With the ZigBee protocol and applications stacks, they have found several key niches including smart electric metering, Smart Grid links, home networking, lighting control, thermostat control, alarm and security systems, and even some special industrial applications involving ZigBee mesh networking applications.

One of the biggest adoptions is RF4CE, or radio frequency for consumer

4. Forthcoming remote controls for TV sets, DVD players, audio equipment, and other consumer products look typical but incorporate RF4CE radio technology based on ZigBee. This one uses Texas Instruments' RF4CE chip.

electronics. This standard is designed for the latest remote controls for TV sets, DVD players, audio systems, and other consumer gear. Slowly but surely, consumer equipment companies are abandoning infrared (IR) remotes in favor of the longer range, less directional radio approach. Most new CE equipment will have an RF4CE remote or one that also incorporates IR for backup and compatibility with older equipment *(Fig. 4)*.

Even the sub-1-GHz radio sector is seeing growth in the huge variety of applications, such as wireless shelf labels in grocery stores and other retail establishments. Shelf labels display pricing and other information. The wireless connectivity allows store management to change prices remotely, saving time and labor. Proprietary protocols on 900-MHz unlicensed radios provide maximum range at the lowest of power levels. This is already happening in Europe and will soon emerge in many U.S. stores.

M2M LEADS TO IOT

Machine to machine (M2M) communications continues to gain ground. M2M technologies remotely monitor and control machines and computers, mostly via cellular connections. Most cellular carriers now offer M2M connection subscriptions for any kind of device or service.

M2M relies on embedded cell-phone modules in vehicles, vending machines, e-book readers, video surveillance cameras, and hundreds of other devices. Most use low-speed 2G digital services, but 3G modules can be deployed where higher speeds are needed. LTE modules are now available from multiple vendors for high-end applications like video.

IMS Research predicts M2M connections to grow from 107 million in 2011 to as many as 326 million by 2016. M2M is the heart of the so-called Internet of Things (IoT) movement, which is expected to see the massive connection of all sorts of devices to the Internet.

MASSIVE INTERFERENCE DISRUPTIONS

With billions of devices transmitting simultaneously in the most popular part of the spectrum (400 MHz to 2700 MHz), look for growing interference problems. Such problems already exist in the almost overused 2.4-GHz ISM band where Bluetooth, Wi-Fi, ZigBee, cordless phones, microwave ovens, and other devices compete. While most new designs provide avoidance or coexistence features to mitigate electromagnetic interference (EMI), it's only going to get worse as the number of wireless devices continues to increase.

New cognitive radios offer listen-before-transmit and frequency-agile features that further limit most potential interference, though most radios don't use them. If the EMI problem begins to seriously limit wireless connectivity, look for massive changes in rules and regulations as well as a transition to cognitive radio capabilities. 3d

VICTORIA FRAZA KICKHAM | DISTRIBUTION EDITOR victoria.kickham@penton.com

DISTRIBUTORS FOCUS ON CORE COMPETENCIES AND WAIT FOR NEW GROWTH

As the economy trudges along, supply chain companies are hunkered down and hoping for a return to growth mode by midyear.

When asked about the business climate for the electronics supply chain this year, Mouser's Glenn Smith says he is optimistic. Mouser recorded strong growth in 2012 as it capitalized on new opportunities in Europe and Asia, and Smith says a focus on more of the same in 2013 should help deliver more growth. In an environment where the trend has been toward slow or no growth, Mouser's strength stands out, especially when you look at the double-digit growth the company had seen in Europe through November. Smith said the company was on track to grow around 6% overall for the year, with the lowest increases coming from North America.

"For us it's going to be more of the same [in 2013]. We're going to continue to focus on the design engineer and focus on bringing new products to market," says Smith, Mouser's president and CEO. "I don't see any reason to change that strategy or target."

Other distributors have similar sentiments, and many indicate their intention to stay focused on core competencies in 2013 in the hope that a return to higher growth rates is on tap for the second half of the year. An air of uncertainty still hung in the balance as 2012 came to a close, with global economic and political climates leaving little certainty about where markets were headed.

A December report from industry analyst firm IHS iSuppli predicted a 2% decline in the global semiconductor market in 2012, the sector's first decline in three years. IHS pointed to deteriorating conditions in end markets such as data processing, consumer electronics, industrial, wired communications, and automotive segments as key reasons for the weak semiconductor market, but called for a rebound in 2013 if worldwide gross domestic product growth forecasts hold up.

The climate left distributors focused on executing existing market strategies, with many keeping an eye on the strong wireless communications market that continued to fuel growth in smart phones, tablets, and elsewhere. Despite the tough conditions, distributors agree the industry's long-term outlook is rosy largely due to the steady pace of research, development, and design and the overall increase in the electronic content in all aspects of our lives.

"Just look at a 15-year-old car versus a new car today," says Future Electronics' Lindsely Ruth, pointing to the proliferation of electronic content in everything from consumer electronics to medical devices. "I think it's pretty exciting. I was in New York City recently and as we were driving around we decided to count the number of people who were walking and talking on their cell phones or smart phones. We just stopped counting at one point because there were so many. You wouldn't have seen that 20 years ago."

Ruth is executive vice president, office of the president for Future Electronics, and he also points to advances in wireless

technology and its application in medical equipment, energy systems, and the "smart" or "connected" home as examples of the electronics evolution. "There will be a lot of exciting things happening just over the next five years, things we're not even thinking about now," he says.

CAPITALIZING ON GLOBAL GROWTH

For large catalog houses like Mouser, growth in Europe and Asia helped boost sales in 2012. Mouser made headway on both continents in 2012, but especially in Asia where it hit major business milestones in China. The distributor incorporated in the country during the year, allowing it to begin accepting local currency transactions, which helped grow sales.

Mouser also installed a local marketing team in Hong Kong, expanded its Chinese-language Web offerings, and continues to add people in the region to build its technical and customer support network. Those actions follow similar moves in Europe, where the company built on its momentum throughout the region by adding people and locations, in particular establishing nine European customer support centers in the last few years.

"The design business there has been underpenetrated, and I think that that's going to continue to be what we keep focused on," Smith says of both regions. "We don't view [that business] as just being a Web business. We've got to be there to help with whatever customer service or technical issues are needed to support the design. For us, it's [about] continuing to grow the scale and the locations."

Ruth agrees with the importance of continuous investment in company resources, both human and material. He says Future is in "investment mode" worldwide despite tough market conditions everywhere, adding salespeople in particular and focusing on training them to identify, qualify, and capitalize on the best customer opportunities. At the end of the day, he says, distribution is still a relationship business.

"There is still so much opportunity to expand our customer base worldwide," Ruth says, emphasizing the need for salespeople and customer service representatives who can "touch" those customers. "There isn't one particular region where we're focusing our investment. The two countries that have the greatest share in Europe are Italy and Germany, but we're not limiting our investment there. We're also investing in the Americas as well as China and elsewhere in Asia.

"Our number one priority as a company is the customer. Regardless of the market segment, we have to carefully select the right customers for the long run."

Ruth says Future will remain focused on that goal despite the uncertain economic outlook, though he remains concerned about the business climate worldwide.

"Everyone has a different opinion on what's going to happen in 2013. A general consensus is that Q2 will be a turning point, but I have to question what that's based on. I think it's a feel-good statement. People feel good when they say it. There's so much global uncertainty and political uncertainty that it's tough to predict," he says. "But we're in an investment mode right now on a worldwide basis. Regardless of what happens in the market, we believe we can grow. It's a beautiful thing to be privately held right now."

"A general consensus is that Q2 will be a turning point, but I have to question what that's based on. I think it's a feel-good statement. People feel good when they say it. There's so much global uncertainty and political uncertainty that it's tough to predict," says ***Lindsely Ruth,*** *executive vice president, office of the president for Future Electronics.*

"We're looking for slow, steady marginal increases in demand. We've seen that in the last 90 days, so that's what we're watching. If we remain up and to the right, and the other things we talked about come in line in the first half of 2013, we'll see some growth in 2013," ***Brian Ellison,*** *president of America II Electronics, said in November.*

"I think we're going to continue to see growth in our model in 2013, because we're seeing so much engineering activity," says ***Glenn Smith,*** *president and CEO of Mouser. "That tells me there's a lot of work out there."*

SLOW, STEADY INCREASES

Brian Ellison, president of large independent distributor America II Electronics, emphasized the uncertain economic outlook in late 2012 as well, and in mid-November he pointed to slow and steady demand increases for 2013. Ellison says he is keeping a close eye on key indicators such as fab utilization and inventory levels industry-wide.

"One of the key indicators is the inventory correction," he says. "Based on the level of activity we see at this time of year, I'm confident in saying that the inventory correction is not finished. Toward the end of Q1 we will have a better vision."

Ellison also points to wafer fab utilization rates, which were expected to hit the low 80% range by the end of 2012 before creeping back up to about 87% toward the end of this year. Hitting those higher numbers will help put conditions back in balance and set the industry on a better path to growth, he says.

"We're looking for slow, steady marginal increases in demand. We've seen that in the last 90 days, so that's what we're watching," Ellison says. "If we remain up and to the right, and the other things we talked about come in line in the first half of 2013, we'll see some growth in 2013. I think we'll get back into whatever normal is."

Ellison also notes key end markets such as medical and automotive as bright spots on the horizon and emphasizes the strength in certain pockets of the consumer electronics segments as important drivers for the industry overall. ■

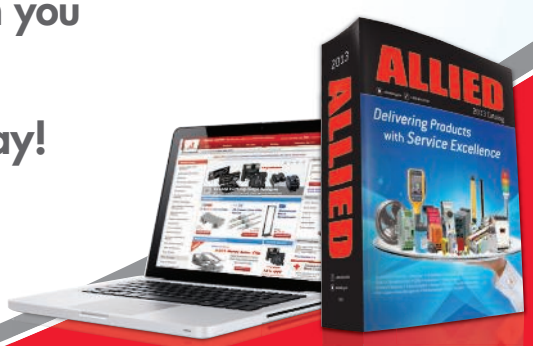
ALLIED ELECTRONICS®

Get It Faster

Don't wait for these brands to be shipped from outside the U.S.

We stock these brands in our U.S. warehouse, so you get the products you want when you need them.

Order by 10 p.m. ET, it ships today!



alliedelec.com

1.800.433.5700

QUAD-CORE PROCESSORS DRIVE NOTEBOOK PC DEMAND

PC makers are adopting more powerful quad-core microprocessors for notebook computers to compete with ongoing consumer demand for tablets and smart phones.

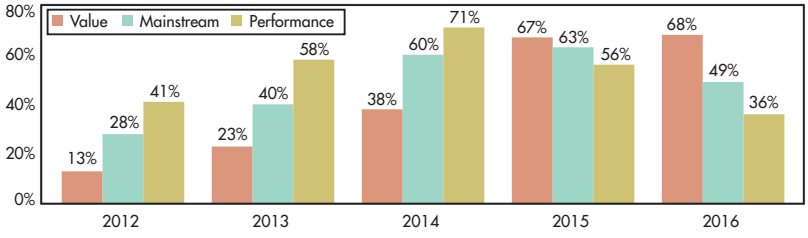
Shipments of notebook computers powered by quad-core microprocessors are set to nearly quadruple by 2016, according to industry analyst IHS iSuppli. The increase is an industry response to the competitive challenges posed by media tablets and smart phones as PC makers adopt the faster, more powerful processors to give their products an edge in the consumer marketplace.

"The increase in notebooks' computational capabilities through the use of quad-core microprocessors will play a critical role in PC makers' efforts to remain competitive amid the onslaught of media tablets and smart phones," Peter Lin, senior analyst for compute platforms at IHS, said late last year. "While notebooks have greater computing power than either tablets or smart phones, they have lost considerable clout as consumers flock to the flashier gadgets, especially products like the iPad from Apple. Notebook sales have suffered as a result, alarming companies throughout the PC supply chain."

IHS says shipments of notebook PCs configured with quad-core microprocessors will reach 179 million units by 2016, making up 59% of all notebooks. That compares to the 48 million units shipped in 2012, when quad-core-equipped notebooks represented 22% of notebook PC shipments.

IHS adds that increasing penetration among value and mainstream notebooks, defined as those priced less than $700 and $1200, respectively, will drive much of the growth in notebook quad-core microprocessors. The quad-core technology will replace the prevailing dual-core technology *(see the figure)*.

Demand for more detailed, high-definition media and increased speed will fuel accelerated growth in quad-core processor technology as early as 2014, IHS said. The trend is likely to have the greatest effect on value notebooks, where quad-core technology is expected to represent 68% of the market by 2016 compared to just 13% last year. Quad-core processor penetration is expected to climb from 28% last year to 49% in 2016 among mainstream notebooks.



Quad-core technology penetration in value notebook PCs will grow, eclipsing mainstream and performance notebook penetration percentages in 2015. (courtesy of IHS iSuppli Research)

Though the IHS data is welcome news to makers and distributors of the latest quad-core technology, the overall PC market outlook remained weak at the end of 2012. The market, which has suffered amid burgeoning demand for tablets and other high-tech gadgets, was set to decline for the first time in 11 years in 2012, according to a separate report from IHS earlier last fall. The total PC market was expected to contract about 1% to 349 million units, down from 353 million units in 2011.

TOP EMBEDDED DISTRIBUTORS LAUNCH NEW OFFERINGS

The industry's top two distributors make headlines with new tools for embedded design customers.

As 2012 came to a close, Arrow Electronics and Avnet Electronics Marketing were busy adding to their growing lines of embedded design products and solutions. The industry's top two distributors announced new partnerships and the launch of enhanced online design tools to help embedded customers find the best solutions to their design challenges even faster.

ARROW AIMS AT ALTIA

In a move to broaden its software tool offering, Arrow signed a new agreement with Altia Inc. to distribute the company's suite of user interface development tools to customers throughout North America.

Altia offers a concept-to-code tool suite that allows designers to create custom graphical user interfaces (GUIs) without hand coding and generate graphics code for a wide range of

industry-leading hardware targets. The company says its mission is to help customers get the best user interface on the right fit, right priced hardware.

"This necessitates the support of a wide range of MCU and MPU platforms from all the different silicon providers. Our approach helps manufacturers save significant BOM [bill of materials] costs while offering a competitive advantage on the user experience," says Mike Juran, Altia's CEO, adding that Arrow's broad silicon vendor base is critical to helping the company reach that goal.

"An increasing percentage of embedded systems now have a display and it is growing, propelled by systems for medical, building control, automation and industrial control, and retail and information kiosks. Our customers need simple, intuitive, yet stylized graphical interfaces for these products," adds Aiden Mitchell, Arrow's director of supplier marketing. "Altia provides our customers a single tool suite that spans our major processor and FPGA lines for the deployment of a great GUI experience."

Arrow also launched Arrow Cloud Connect, a tool for developing designs based on the ARM Cortex-MO+ designs and machine-to-machine (M2M) solutions. Featuring technology from Freescale Semiconductor and Digi International, the free development environment helps designers "realize the potential of adding connectivity to their products," according to the distributor.

The tool provides an online integrated development environment for users to write, compile, and program code to Freescale's development platform for Kinetis L series microcontroller units (MCUs). Engineers can also connect to Digi's iDigi Device Cloud through a software gateway, providing instant cloud connectivity to devices and making it easier to develop applications using remote connected devices, remotely update firmware, and troubleshoot problems during development.

AVNET TRIES ON RED HAT

Avnet EM added to its embedded software and services portfolio through a new agreement with Red Hat Inc. to provide a range of products to customers in the Americas. Through its Avnet Embedded business, the distributor will provide Red Hat's Embedded Linux, JBoss Middleware solutions, Red Hat Developer Support, and JBoss Developer Support.

"Red Hat is a recognized leader in open-source enterprise software and embedded Linux," says Chuck Kostalnick, senior vice president for Avnet Embedded. "The addition of Red Hat to Avnet's embedded software and service portfolio substantially enhances our value proposition for providing comprehensive support across our customers' entire solution stack."

Avnet also marked a key milestone during the fall, as its Embedded Software Store (ESS) celebrated its first anniversary. A partnership with semiconductor IP provider ARM, ESS is an e-commerce Web site and online information center for the embedded community featuring nearly 1000 products from 24 vendors including DSP Concepts, InterNiche Technologies, Motomic Software, RoweBots, and Timesys.

"The ESS allows embedded software developers to leverage the ARM and Avnet ecosystems to quickly acquire industry-proven software IP blocks, decreasing their time-to market," says Tim Barber, senior vice president, design chain global business development for Avnet EM. "Having a variety of reliable off-the-shelf solutions complements any in-house designs teams' efforts."

More From Global Purchasing

BUYERS AND MANAGERS turn to Global Purchasing for up-to-date news, trends, market insights, product updates, and global supply chain solutions. For more, go to globalpurchasing.com and see:

- "Avnet To Acquire USI Electronics"
- "Saas Adoption Continues To Grow"
- "Counterfeit Mitigation Sparks Business Opportunities"
- "The Real Value Of Purchasing Management"

KENG C. WU | SWITCHING POWER INC., kengchi.goah@ieee.org

Generate Realistic Models For LED Current Versus Voltage

LEDs ARE NONLINEAR devices with I/V curves that resemble the curves of rectifier diodes. Designers of lighting drivers require a good approach to modeling the LED device performance in the first quadrant of the I/V plane.

For engineering applications, there are three approaches to consider: the linear, bias-voltage plus resistor equivalent; a quadratic equation; and an exponential equation. Let's use the three techniques with Cree's XLamp XM-L LED as the LED to be modeled *(Fig. 1)*.

THE LINEAR MODEL

This model is the simplest, but the most inaccurate. It consists of a dc bias voltage plus a resistor *(Fig. 2a)*. The equivalent mathematical form is given by:

$$i_F(v_F) = a + \frac{1}{R}(v_F - b) = \frac{v_F - v_{bias}}{R}, \quad v_F \geq v_{bias} = b - a \cdot R \qquad (1)$$

You select two data points (v_F, i_F) in coordinate form (i.e., 3.28 V, 2.6 A and 2.71 V, 0.2 A). Then, R is evaluated and yields 0.2375. The selection also implies a = 0.2 and b = 2.71. With all three parameters (a, b, R) properly assigned, the linear model yields Figure 2b. Evidently, the linear model offers the advantage of simplicity, but suffers in accuracy.

THE QUADRATIC MODEL

The curve of Figure 1 has a concave portion that resembles one arm of a parabolic curve. It can be expressed with a quadratic equation of the form $a_2 v_F^2 + a_1 v_F + a_0$. The key is the determination of three coefficients: a_2, a_1, and a_0.

To determine these coefficients, you can use the well-known Least Square Polynomial Curve-fitting algorithm of linear algebra. To do this, select more than a dozen data points from Figure 1 (15 in this case) and place them in two matrixes.

One is a 3x15 rectangular matrix C *(Equation 2)*. The other is a 1x15 column vector i_F *(Equation 3)* where vF_j , for j = 0 to 14, are the corresponding LED forward voltages at the selected forward currents given in vector i_F. The three coefficients are then given by a column vector of:

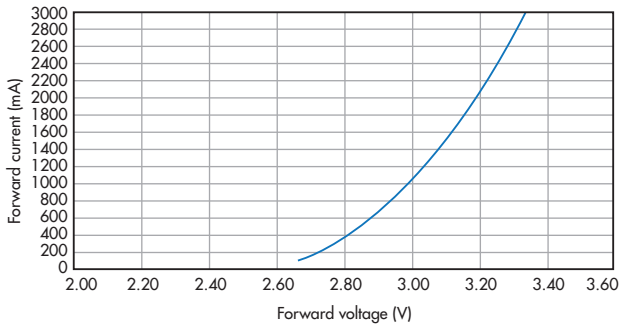
$$a = (C \cdot C^T)^{-1} C \cdot i_F{}^T \qquad (4)$$

Using software tools such as Matlab from the Mathworks or MathCAD from Mathsoft, you can easily compute Equation 4. For this example, we obtain:

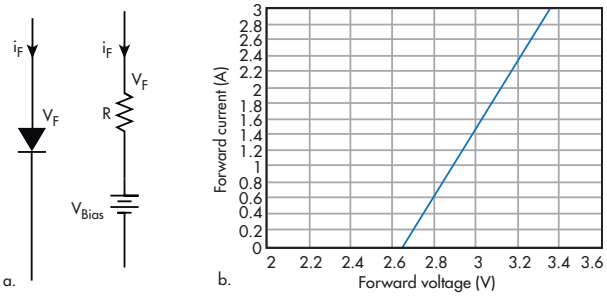
$$a = \begin{pmatrix} 24.849 \\ -20.093 \\ 4.058 \end{pmatrix} \qquad (5)$$

$$C := \begin{bmatrix} 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 \\ vF_0 & vF_1 & vF_2 & vF_3 & vF_4 & vF_5 & vF_6 & vF_7 & vF_8 & vF_9 & vF_{10} & vF_{11} & vF_{12} & vF_{13} & vF_{14} \\ (vF_0)^2 & (vF_1)^2 & (vF_2)^2 & (vF_3)^2 & (vF_4)^2 & (vF_5)^2 & (vF_6)^2 & (vF_7)^2 & (vF_8)^2 & (vF_9)^2 & (vF_{10})^2 & (vF_{11})^2 & (vF_{12})^2 & (vF_{13})^2 & (vF_{14})^2 \end{bmatrix} \qquad (2)$$

$$iF := \left(200\,m \;\; 400\,m \;\; 600\,m \;\; 800\,m \;\; 1000\,m \;\; 1200\,m \;\; 1400\,m \;\; 1600\,m \;\; 1800\,m \;\; 2000\,m \;\; 2200\,m \;\; 2400\,m \;\; 2600\,m \;\; 2800\,m \;\; 3000\,m\right) \qquad (3)$$



1. Modeling the I/V curve of the Cree XLamp XM-L LED with increasing accuracy is the objective of this analysis.



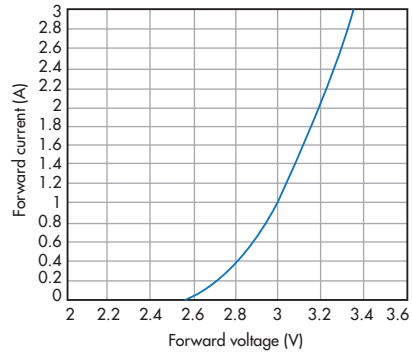
2. The linear model (terminal view) is simplest and easiest to understand, but also the least accurate (a). The linear model results in this "curve," which clearly has some shortcomings (b)

Note that the first element of vector a is coefficient a_0, etc., which leads to the quadratic model of Figure 3. This approach yields significant improvements in the model across the whole operating range of the LED.

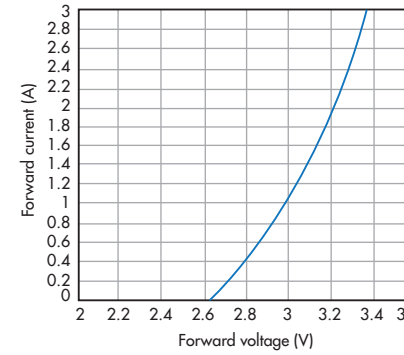
THE EXPONENTIAL MODEL

Figure 3 appears to bend more near the low current, which is where the exponential model may offer further improvement. This model comes in the form of $ae^{b \cdot vF} + c$ with three unknown parameters a, b, and c to be determined. Again, software tools such as MathCAD help you find those parameters numerically.

Under the specialized regression section, an exponential regression statement expfit (v_F, i_F, vg) can find all three parameters, given a data set in vectors and initial guess value vg, also a column vector. For this example, $a = 9.66 \cdot 10^{-3}$, b = 1.818, and c = –1.157 are obtained. This results in the exponential model of Figure 4.



3. The curve based on a quadratic curve is much closer to the reality of the I/V curve for this LED.

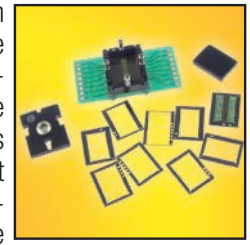


4. The exponential model further refines the quadratic model and provides a better approximation in the low-current region of the LED.

Overall, the best fit near the low-current region may be found between the quadratic and the exponential models. It is unrealistic to expect a single, perfect prediction from any given model, since almost all such analytical efforts are an attempt to represent the complexities of nature.

KENG C. WU has a BS from Chiaotung University, Taiwan, and an MS from Northwestern University, Evanston, Ill. He has published four books and holds seven U.S. patents.

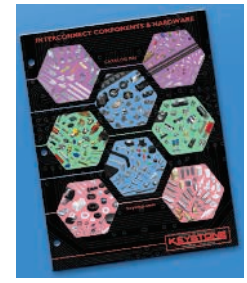
Multi GHz Bandwidth Universal Socket for DDR



Universal BGA socket for 0.8mm pitch DDR2 & DDR3 packages. The sockets are designed with replaceable IC guide for each package sizes. The contact resistance is typically 20 milliohms. The socket bandwidth is 8GHz. The temperature range is -35 C to +100 C. The pin self inductance is 0.11 nH and mutual inductance of 0.028 nH. Capacitance to ground is 0.028 pF. Current capacity is 2 amps per pin.

Ironwood Electronics, Inc.
1335 Eagandale Court
Eagan, MN 55121
T: 800-404-0204 • F: 952-229-8201
Email: info@ironwoodelectronics.com
Web Site: www.ironwoodelectronics.com

KEYSTONE'S M60 CATALOG - OVER 1,000 NEW PRODUCTS!

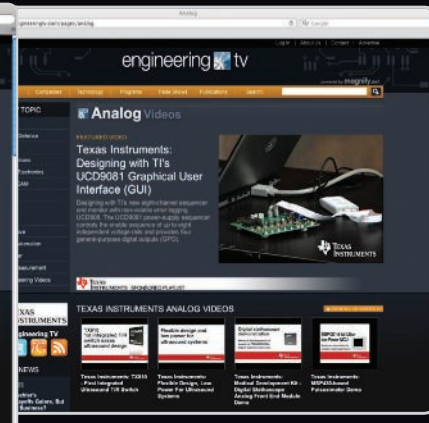


- Battery Clips, Contacts & Holders
- Fuse Clips and Holders
- Terminals and Test Points
- Spacers and Standoffs
- Panel Hardware
- Pins, Plugs, Jacks and Sockets
- PC Board & Multi-Purpose Hardware...MORE!

Keystone Electronics Corp.
Astoria, NY · (800)221-5510
Request your copy www.keyelco.com

The NEW engineering tv The place where engineering videos gather

Recent Videos



Engineering Channels

Trade Show Coverage

THE SAME GREAT VIDEO CONTENT, IN AN EASY-TO-BROWSE FORMAT

In the past, we've been told by our design engineers that **Engineering TV** is their favorite place to "geek out". Well get your computers ready, because **Engineering TV** is all new and completely redesigned!

Browsing the most compelling videos is easier than ever. Our new engineering channels let you explore the technologies that are of interest to you – everything from Aerospace to Embedded to Robotics. Plus, we film at all the key electronics and design engineering trade shows, so even if you can't attend, you can find out everything that is happening at these important events.

CHECK US OUT TODAY:
www.engineeringtv.com

For more information on products or services visit our website www.electronicdesign.com, menu item Reader Service. The advertisers index is prepared as an extra service. *Electronic Design* does not assume any liability for omissions or errors.

BILL WONG | EMBEDDED/SYSTEMS/SOFTWARE EDITOR bill.wong@penton.com

The Tablet's Evolution Will Continue Into 2013

JANUARY TENDS TO be the time for forecasts. Sometimes, they're paired with a look back to provide context for what lies ahead. This year is no different, as many pundits will have lots to say about the hot tablet market—including me *(see "Tablets Eclipse The PC Market" at electronicdesign.com)*.

THE FIRST TABLETS

I've been involved in the computer and electronics industry for decades and have some of the relics to prove it, like Epson's HX-20, circa 1981 *(Fig. 1)*. I would consider it one of the first tablets given its portability and form factor. I had it when I was working with Rising Star Industries (RSI), which delivered Valdocs on another Epson platform, the QX-10.

The HX-20 had two 614-kHz Hitachi 6301 CPUs and a 120- by 32-pixel display. Its removable printer and microcasette storage system could accommodate other modules. At the time it was a remarkable system, although it was years before there was something else in the same form factor.

Skip forward to 2007, almost 30 years later, when I got my hands on a Samsung Q1B UMPC *(Fig. 2)*. It ran a 1-GHz x86 processor and had a 7-in. 800- by 480-pixel touch LCD that used a stylus *(see "A Long Look At Samsung's Q1B" at electronicdesign.com)*. The unit also had a 40-Gbyte hard disk, and wireless support included Wi-Fi and Bluetooth. I used a Bluetooth keyboard with it.

I thought the Q1B was as great as the HX-20 when it arrived. I used both for years before the lack of new batteries moved them to my shelves. The HX-20's sub-C nickel-cadmium (NiCd) pack would be the easiest to replace.

These platforms were the result of what was possible at the time rather than what the designers wanted to build. There has been some change in battery technology but nowhere near the magnitude of the changes in processing performance and storage. The processing improvements were forecast, but flash memory was more of a glimmer even in 2007.

It has only been about five years since the Q1B appeared, but the difference between it and even today's lowliest tablet is amazing. Other major differences include motion sensors, cameras, and GPS. Even more remarkable is that all of this technology can fit into a handheld smart phone as well.

TABLETS GOING FORWARD

Tablets have taken over the PC revolution. They can be had for under $50, and the Pro version of Microsoft's Surface starts at $899. Tablets will operate for a day with average use and a week with light use. They can play 1080p HD videos and even stream them via 4G or Wi-Fi. These days, there are fewer than four physical buttons on a tablet.

There is still a lot of variety, too. Tablets are available with covers that turn into keyboards *(Fig. 3)*. Some tablets are even going back to styluses because some users find them easier for input than their fingers.

The big question is where tablets go from here. Display resolutions are starting to reach the limits of human eyesight. Processing cores are showing up like weeds, and we have almost hit the limits on the types of sensors that they can accommodate. Qualcomm's Tricorder X Prize may eventually turn our tablets into Star Trek technology. For now, though, I'll be using my Google Nexus 7 *(see "Hands On Google's Nexus 7 Tablet" at electronicdesign.com)*. ed

1. I got my Epson HX-20 in 1981. It ran Microsoft Basic and used a microcassette to store programs and data.

2. The Samsung Q1B was one of a group of ultra-mobile PCs that were available back in 2007.

3. Microsoft's Surface uses a keyboard to replicate the laptop feel without sacrificing form factor.

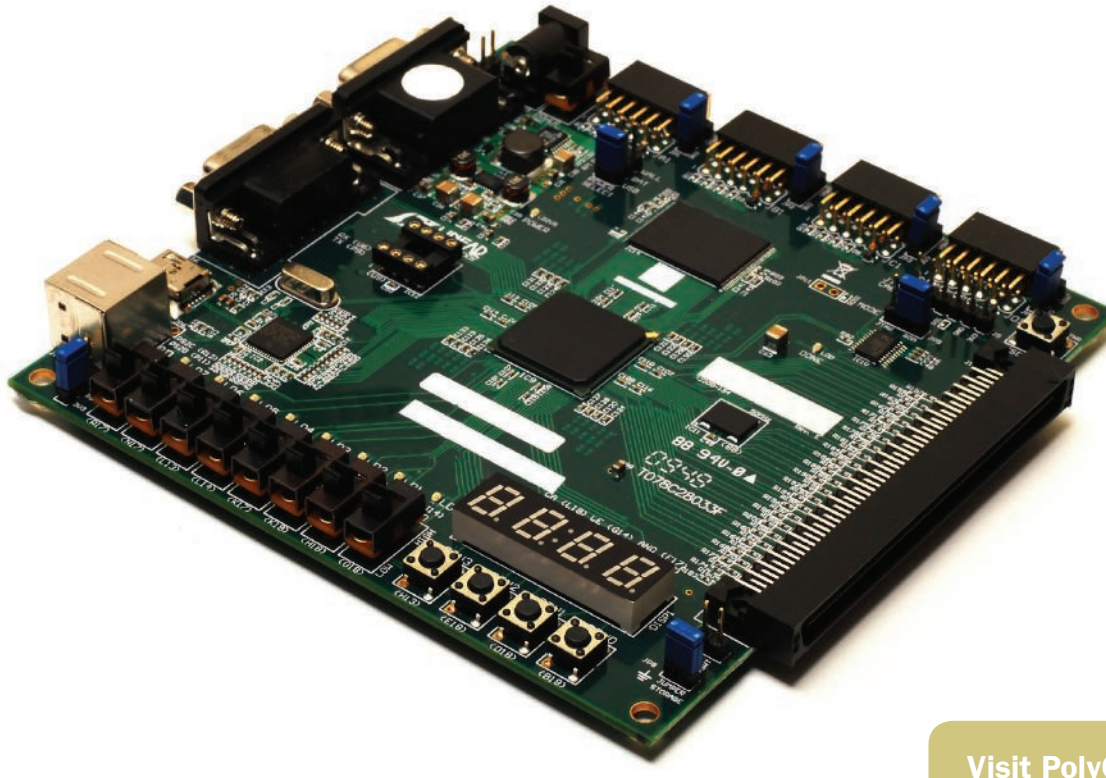
What if:

choosing the right high speed connector polymer was quick and easy,

moving you from design to commercialization in record time?

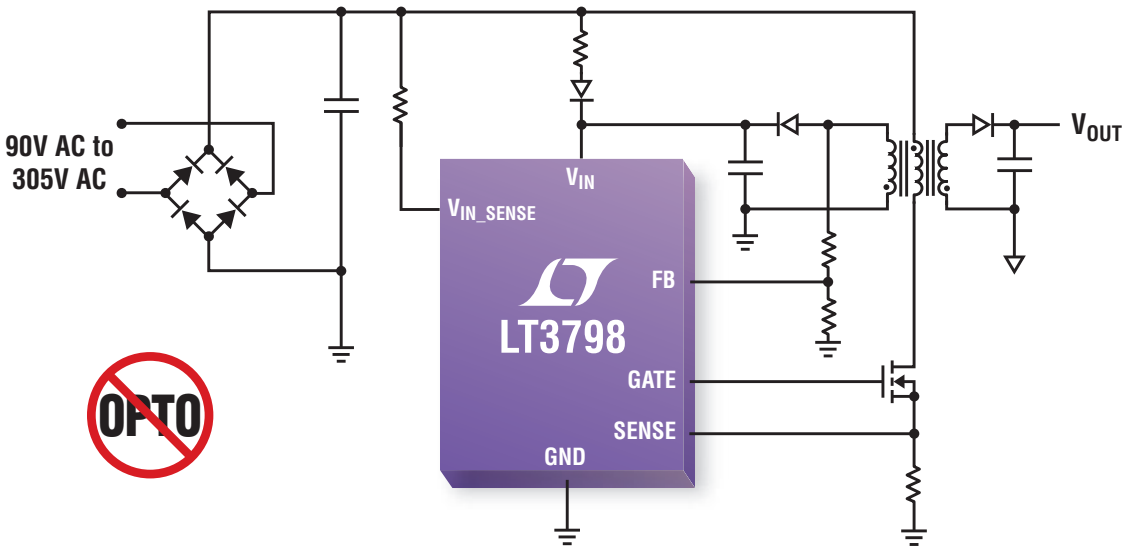
It is – when you work with PolyOne. We understand that when it comes to connectors, polymer choice is important, impacting cross-talk and signal integrity. Our Stat-Tech™ EMI/RFI formulations are customized to meet your specific challenges. We provide focused design assistance and formulating expertise to speed your development cycle and get to you to market fast. For answers to the biggest questions facing your business, visit www.polyone.com/whatif. Make it possible.

PolyOne™



Visit PolyOne at DesignCon 2013 Booth #740

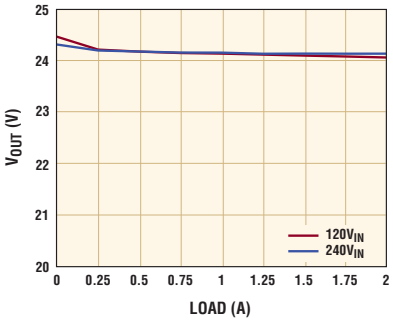
You Can Do Offline Power



Simple AC/DC Conversion with Active Power Factor Correction

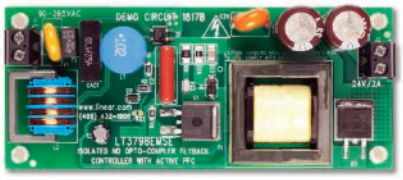
The LT®3798 is a general purpose isolated offline flyback controller that combines active power factor correction (PFC) with no optocoupler required for output voltage feedback into a single-stage converter. The device modulates input current in phase with line voltage to attain a PF greater than 0.97. It has both a voltage and current loop so it can provide a constant current or constant voltage (CCCV) output. Its internal architecture provides low harmonic distortion and delivers efficiencies as high as 90%.

Output Regulation



LT3798 Demo Board

(4.45" x 1.75" x 1.25")



V_{IN} = 90V AC to 265V AC
V_{OUT} = 24V, I_{OUT} = 2A

Info & Free Samples

www.linear.com/product/LT3798

1-800-4-LINEAR

video.linear.com/99

LINEAR TECHNOLOGY