ALLER ALLER

30E10K0F •

BRIDGELUX

H

KEY.CO

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



THE WORLD'S LARGEST SELECTION OF ELECTRONIC COMPONENTS AVAILABLE FOR IMMEDIATE SHIPMENT!"



Digi-Key is an authorized distributor for all supplier partners. New product added daily. © 2013 Digi-Key Corporation, 701 Brooks Ave. South, Thief River Falls, MN 56701, USA



The best inductor selection tools.

coilcraft.com/tools

	DCR C 64373 0 699 0 64257	Long max	th W	and an a second second	in the second	-	and and			
effective Description Description With the highest Q factors at a specific frequency. effective Experimental to the highest Q factors at a specific frequency. Experimental to the highest Q factors at a specific frequency. Experimental to the highest Q factors at a specific frequency. Experimental to the highest Q factors at a specific frequency. Experimental to the highest Q factors at a specific frequency. Experimental to the highest Q factors at a specific frequency. Experimental to the highest Q factors at a specific frequency. Experimental to the highest Q factors at a specific frequency. Experimental to the highest Q factors at a specific frequency. Experimental to the highest Q factors at a specific frequency. Experimental to the highest Q factors at a specific frequency. Experimental to the highest Q factors at a specific frequency. Experimental to the highest Q factors at a specific frequency. Experimental to the highest Q factors at a specific frequency. Experimental to the highest Q factors at a specific frequency. Experimental to the highest Q factors at a specific frequency. Experimental to the highest Q factors at a specific frequency. Experimental to the highest Q factors at a specific frequency. Experimental to the highest Q factors at a specific frequency. Experimental to the highest Q factors at a specific frequency. Experimental to the highest Q factors at a specific frequency. Experimental to the highest Q factors at a speci	DCR Chirth 0.04373 0.099 0.04257	Leng mox	th W							
Interview 14.0 Color Interview Interview <th< th=""><th>0.04373 0.099 0.04257</th><th>max</th><th>max</th><th>lidth I</th><th>Height</th><th>-</th><th>Price</th><th>See.</th><th></th><th></th></th<>	0.04373 0.099 0.04257	max	max	lidth I	Height	-	Price	See.		
Number Number Operating of the second seco	0.04373 0.099 0.04257	0 1			ax mm	6	10:00	26 (1983)		
Name Note Note <t< td=""><td>0.04257</td><td></td><td>0</td><td>50</td><td>3.1</td><td></td><td>50.00</td><td></td><td></td><td></td></t<>	0.04257		0	50	3.1		50.00			
202302000 6.739 0.31 4.1 4.1 1.2 6.03 4.700 0.235 0.03 4.1 4.1 1.2 6.03 FE Inductor Finder Results • "The matched to not may an ease in match to your requirements. • We recommend that your require a free sample before an order is placed. • We recommend that your require a free sample before an order is placed. • We recommend that your require a free sample before an order is placed. • We recommend that your require a free sample before an order is placed. • We recommend that your require a free sample before an order is placed. • We recommend that your require a free sample before an order is placed. • We recommend that your require a free sample before an order is placed. • We recommend that your require a free sample before an order is placed. • We recommend that your require a free sample before an order is placed. • Order of the weak placed to place before an order is placed. • Weighter the operating conditions (at news required) • Weighter the operating conditions (at news required) • Weighter the operating conditinon weak placed do tone t			0	0.0	3.1		\$0.00			
Action 2000 0.4799 0.02540 0.60 0.48 0.1 0.03 Image: Contract of Contract of Image: Contract of Contrac	0.34	4	1	4.1	1.2		\$0.35			
PC Inductor Finder Results • These results do not imply an exact match to your requirements. • We recommend that your equired a free sample before an order is placed. • We recommend that your equired a free sample before an order is placed. • We recommend that your equired a free sample before an order is placed. • We recommend that your equired a free sample before an order is placed. • We recommend that your equired a free sample before an order is placed. • We recommend that your equired a free sample before an order is placed. • We recommend that your equired a free sample before an order is placed. • We recommend that your equired a free sample before an order is placed. • We recommend that your equired a free sample before an order is placed. • We recommend that your equired a free sample before an order is placed. • We recommend that your equired a free sample before an order is placed. • We recommend that your equired a free sample before an order is placed. • We recommend that your equired a free sample. • We recommend that your equired a free sample. • We recommend that your equired a free sample. • We recommend that your equired a free sample. • We recommend that your equired a free sample. • We recommend that your equired a free sample. • We recommend that your equired a free sample.	0.02945	6.6	10	5.40	6.1		\$0.63			
	nducto e results do not commend that	imply an ex	der Re act match to a free sam	esults your require plo before a	ements an order	r is plac	ed.			
	sults by: Foot	pint • E	CR •			DT)				
Part sampler Woulding Other OC Trail Trail <thtraili< th=""> Trail Trail<td>a inputs: Any</td><td></td><td>47</td><td>1000</td><td>1.5</td><td>-</td><td>1</td><td></td><td></td><td>0</td></thtraili<>	a inputs: Any		47	1000	1.5	-	1			0
Part manufact Wounded Others (Jed 2000) Model			L DCR	1 141	I cms	SRF	1	w	н	P1
Image: State State At the image: State Construction Construction<	ber Moun	ting Other *	nH) (Ohm	t) (A)	(A)	(MHz)	(mm)	(mm)	(em)	0
Address of a construction of a cons	NP SM N1 SM		5 10 0.074		0.83	12070	0.05	0.53	0.45	50
Step 1, 2.3 Enter the operating conditions (at hear request) Step 1, 2.3 Enter the operating conditions (at hear request) Step 1, 2.3 Enter the operating conditions (at hear request) Step 1, 2.3 Enter the operating conditions (at hear request) Step 1, 2.3 Enter the operating conditions (at hear request) Step 1, 2.3 Enter the operating conditions (at hear request) Step 1, 2.3 Enter the operating conditions (at hear request) Step 1, 2.3 Enter the operating conditions (at hear request) Step 1, 2.3 Enter the operating conditions (at hear request) Step 1, 2.3 Enter the operating conditions (at hear request) Step 1, 2.3 Enter the operating frequency (bt set the operating freq		144		2000 00	-	100	5.00	0.00	0.66	50
Step 1,2,3 Enter the operating conditions (at hear request) 0.61 36 Step 1,2,3 Enter the operating conditions (at hear request) 0.61 36 Step 1,2,3 Enter the operating conditions (at hear request) 0.61 36 Step 1,2,3 Enter the operating conditions (at hear request) 0.61 36 Step 1,2,3 Enter the operating conditions (at hear request) 0.61 36 Step 1,2,3 Enter the operating conditions (at hear request) 0.61 45 Step 1,2,3 Enter the operating conditions (at hear request) 0.62 400 Step 1,2,3 Enter the operating conditions (at hear request) 0.62 400 Step 1,2,4 Double of the operating for the	e & Wi	nding	Loss	Calc	ula	tor		11	0.61	50
Step 1,2.3 Enter the operating conditions (at hear square) 61 98 Hear squares Immunas All pack pack 61 98 500 km/ 3.50 Amps 0.20 Amps 620 Amps Results Immunas All pack pack 661 98 Statement Immunas 0.20 Amps 0.20 Amps Results Immunas 0.20 Amps 0.20 Amps 0.20 Amps Results Immunas 1000000000000000000000000000000000000	and the restance and the	18-11-10-10-10-10-10-10-10-10-10-10-10-10-							0.61	50
If me max All peak peak 0 61 90	er the ope	erating	conditio	ons (as t	ielas ree	sered)			6.61	50
600 kmy 3.50 Amput 0.02 Manue 0.01 50 Style Results (notaccor 2 Inductor 3 Inductor 4 Highest Q 0.03 80 Style Notaccor 4 Notaccor 4 Homesee 0.03 80 Style Notaccor 2 Inductor 7 Style Notaccor 2 Inductor 3 Inductor 4 HUDDESAR2 0.03 80 Style Notaccor 4 Notaccor 4 Style Notaccor 2 Inductor 3 Inductor 4 Highest Q 0.03 80 Style Notaccor 4 Notaccor 4 Notaccor 2 • Use this tool to find the RF Inductor with the highest Q factor at a specific frequency Notaccor 4 Market Notaccor 0 • Use this tool to find the RF Inductor with the highest Q factor at a specific frequency Notaccor 5 Market Notaccor 0 • Use this tool to find the RF Inductor with the highest Q factor 4 Notaccor 5 Market Notaccor 0 • Use this tool to find the RF Inductor 4 Notaccor 5 Notaccor 5 Market Notaccor 0 • Use this tool to find the RF Inductor 4 Notaccor 5 Notaccor 5 Notaccor 5 Market Notacocor 0 • Style • Style	incy <u>11</u>	ms max	Ali pe	ak peak			— j		0.61	30
000 200 Colspan="2">000 200 Colspan="2">Colspan="2" Colspan="2">Colspan="2" Colspan="2" Colspan="2" Colspan="2" Colspan="2" <th< td=""><td>500 km</td><td>1.50 A</td><td>nga</td><td>0.20 Atron</td><td></td><td></td><td>1</td><td></td><td>0.61</td><td>50</td></th<>	500 km	1.50 A	nga	0.20 Atron			1		0.61	50
Control Description Description Description Control Contro Contro Control<	- 11								0.01	20
PPCB12472 D03819477 PPCM109472 D038141477 Distance of interest Bid server (interest) Bid server (interest) Bid server (interest) Distance of interest Bid server (interest) Bid server (interest) Bid server (interest) Distance of interest Interesting Bid server (interest) Bid server (interest) Distance of interest Interesting Bid server (interest) Bid server (interest) Distance of interest PI inductors with the highest Q factor at a specific frequency. Bid server (interest) Bid server (interest) Distance of interest PI inductors with the highest Q factor at a specific frequency. Bid server (interest) Bid server (interest) Distance of index PI II inductors with the highest Q factor at a specific frequency. Bid server (interest) Bid server (interest) Distance of index PI II inductors with the highest Q factor interest interest interest interest. Bid server (interest) Bid server (interest) Distance of index PI II inductors with the highest Q interest interest interest interest interest interest interest. Bid server (interest) Bid server (interest) Distance of index PI II inductors of interest interest interest interest interest interest interest interest interest. Bid server (interest) Bid server (interest) Part number Description 23 H Gaussian (interest) Bid server (interest) Bid server (or 1 in	idiactor 7	Induct	of 3	Induc	tor 4				
Distance Distance Distance Continuence Highest Q Finder Instance • Use this tool to find the RF inductor with the highest Q factor at a specific frequency. Continuence • Use this tool to find the RF inductor with the highest Q factor at a specific frequency. Temperature • Use this tool to find the RF inductor with the highest Q factor at a specific frequency. Temperature • Enter your inductance or 4/1 requests Mi2 1900 • Or of other Pacific frequency. Matter annaber Q factor 1 factor 1 factor 1 factor Vocation Q factor 1 factor 1 factor 1 factor Vocation Q factor 1 factor 1 factor 1 factor Part number Q factor 1 factor 1 factor 1 factor Vocation Q factor 1 factor 1 factor 1 factor Vocation Q factor 2 factor 1 factor 1 factor Vocation Q factor 2 factor 1 factor 1 factor Vocation Q factor 2 factor 1 factor 1 factor Part number Description Quantify 1 factor 1 factor Part number Description Quantify 1 factor 1 factor Part number	15-442 D	03216P-472	XPL70	30:472	LP54	114 4/2				
Contractional Contraction	9194-1-000-cty, 30	55 apr # 1 090	1911		30.10 *	101 A 1 6	10, az			
Measurements at 9000 MHz Measure	nest Q is tool to find th your inductance 8 Inductance	Finde te RF induct to value and i m 41	f or with the h sperating fit Frequenc	lighest Q fai iquoncy, the y Mrize 1900	ctor at a on pres	a speci s GO	ic frequ	iency.	1000	1
Part number O Backor Monitorial Leit SSE Mar Free Mark QUUID 2200 178 15.05 95 2006 15 16 15 16 15 16			1000 100 20					March 10	Access	
Operation Tail Tailis Tail Tail	Marine .	In the second se	and the second second	Kominal L n	H SR	FMHz		2 FLA	operation in provide	
Operation 014 22.56 47 10.06 10 Operation 02<	Mean ber Citactor	iurements at Indu	ctance n11			10		21	15	
Operation N2 22 96 65 1000 Image: Constraint of the state	Meas ber Q factor 10 126	urements at Indu 19.0	ctance nH	39	200					
Part number Description Quantity Delete KAL7021 Strift_D Strift power inductor 22.0/4 1 0 2	Mean aber G factor 30 126 70 104	urements at Indu 19.6 22.5	ctance nH	39 47	200	.0		23	15	
Part number Description Quantity Deleter MATCR:::22006B Staff Server Houster 22.014 1	Mean iber Q factor 30 126 20 104 60 92	Unements at Indu 19.6 22.5 24.9	ctance nH	29 47 16	200 112 142	ло .0 .0		11	100	
Part number Description Quantity Deleter Provide the second secon	Meas aber Q factor 30 126 70 104 80 92 21 74	urements at Indu 19.6 22.5 24.9 51.0	ictance nH 6 5 7	39 47 46 42	200 112 492 210	10 10 10 30		12		
Val. rozzaski Xal. rozzaski Kal. rozzaski rozzaski rozzaski Kal. rozzaski Kal. rozzaski Kal. rozzaski Kal	Mean aber Q tactor all 126 an 124 an 92 119 74 Sample	19.0 22.5 24.9 51.0	ctance nH	39 47 42	200 112 122 210	.0 .0 :0		12	NEEN	
AALOOCAZZERE OHT DOWN HOUSEN 22114 1 CLIME II KALOOY GOMEN OHT DOWN HOUSEN 6.0 pH 8 CLIME II	Mess 126 Q factor 121 126 120 104 121 124 121 124 121 124 121 124 121 124 121 124 121 124 124 124 1	19 0 22 5 24 9 51 0	ictance n11	33 47 42	200 112 102 216	.0 .0 .0		12	N IN N N N N	
KVT/055 REAW 0 CITLE Dawer (regeliges and bit (S + And Titles 1	Mean aber Q factor 126 126 104 au 92 10 14 Sample Description	19.0 22.5 24.9 51.0	ictance nº I 6 5 7	39 47 42 42 Quantit	200 112 402 216	0 0 0 0 0 0	eter	11 22 22		
The second s	Mean sher Q factor 20 126 20 104 an 90 21 74 Sample Description CMT power indu	10000000000000000000000000000000000000	22µH	99 47 42 42 Quantit	200 112 100 210	0 0 0 0 0 0	lete J	11 12 13		
Courtes Courte		nducto results do not commend that uits by: Foot a ingute: Any ber Wound the &	nductor Find results do not imply an ex- commend that you request suits by: Tostpan • I in ingute: Ing • the Boundary Others and Boundary Others and Boundary Others and I boundary Other and I bound	nductor Finder Re results do not imply servact match to commend that you request a free sam uits by: compare • DCR • ingents: reg • i	nductor Finder Results results do not imply selexact match to your requir commend that you required a free sample below of utils by: [corport • DCR • • • • • • • • • • • • • • • • • • •	nductor Finder Results results do not imply an exact match to your requirements commend that you require a free sample before an order with by: Comment DCR	nductor Finder Results results do not imply an exact match to your requirements. commend that you request a free sample before an order is plac uits by: Tempre OCR Commend results do not imply an exact match to your requirements. In the provide of the commend that your requirements. In the provide of the commend that your requirements. The provide of the provide of the commend that your requirements. The provide of the commend that your requirements. The provide of the provide of the commend that your requirements. The provide of the commend that your requirements. The provide of the commend that your requirements are commend to the provide of the commend to the commend t	And use of a methy is eased match to your requirements. commend that your required a five sample belore an order is placed uits by: compare or CR • • • • • • • • • • • • • • • • • •	And uctor Finder Results results do not mply an evact match to your requirements commend that your required a free sample before an order is placed. utils by: Compare DCR C C C C C C C C C C C C C C C C C C	Anductor Finder Results results do not mpty an exact match to your requirements. commend that your requires a five sample before an order is placed. uits by: require 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0

Now in a handy pocket size.

coilcraft.com/mobile







WWW.COILCRAFT.COM

International Microwave Symposium IEEE 2-7 June 2013, Seattle, WA MTT-S

THERE ARE SO MANY WAYS TO EXPERIENCE IMS!

ATTEND A WORKSHOP OR SHORT COURSE!

IMS Workshops and Short Courses offer practical, applicationoriented material to advance your career! Whether you're a seasoned professional, recent graduate, or student, IMS will provide a variety of topics that appeal to academia and industry alike. Hear the latest developments in R&D for emerging areas or hone your skills in a specific microwave subject.





MAKE A NEW CONNECTION!

IMS brings together the largest concentration of top engineers and scientists in the RF & Microwave Field. IMS2013 will also be home to over **50 first time exhibitors!** From the exhibition floor, to a variety of social activities, IMS is THE place to network with colleagues and companies both established and new.

VARY YOUR VIEWPOINT!

RF & Microwave technology is always on the cutting edge and that comes with lots of varying opinions. Panel Sessions are a great way to engage with colleagues on the forefront of these hot topics. The open discussion format is perfect for sharing a variety of viewpoints and getting the inside track on future directions!





WHAT WILL YOUR EXPERIENCE BE? REGISTER TODAY AND SAVE UP TO 25%!

f in 🕒 SHARE YOUR IMS STORY

COMPLETE CONFERENCE DETAILS ARE AVAILABLE AT: HTTP://IMS2013.MTT.ORG



Best Dimmer Performance Single-Stage LED Driver

CS1615/16 Provides Extended Dimming Range of Zero to 100 Percent.

CS1615/16: New LED driver ICs drive down cost while maintaining best-in-class performance

Cirrus Logic continues to set the standard for dimmer compatibility while enabling a cost-competitive bill of material for high-volume, low-cost lamps. Through patented digital algorithms, the new cost-reduced single-stage CS1615/16 sets industry benchmarks for flicker-free performance, extended dim range and minimum dimming – with a significant performance advantage on smart dimmers.

Like their Cirrus Logic LED driver IC predecessors, the CS1615/16 includes output open circuit protection, output short circuit protection and external over temperature protection using NTC. And a small form factor makes designs easier and enables solutions for smaller form factor lamps, including GU10. All at a total BOM cost comparable to single-stage solutions.

- Best-in-class dimmer compatibility
- Flicker-free operation across all types of dimmers
- Enables zero-100% dim range
- Compatible with smart dimmers
- Supports isolated or non-isolated topologies
- Bill of material equivalent to single-stage competitors

Stay current at www.cirrus.com/edcs1615 and request a free sample.



TIRRUS LOGIC

1111111



© 2013 Cirrus Logic, Inc. All rights reserved. Cirrus Logic, Cirrus, the Cirrus Logic logo designs are trademarks of Cirrus Logic, Inc. ED05022013



High-Voltage Buck Control ICs for Constant LED Current Regulation









IRPLLED7 Demo Board LED Current vs Input Voltage



	Part Number	Package	Voltage	Gate Drive Current	Startup Current	Frequency
	IRS2980S	SO-8	450V	+180 / -260 mA	<250 µA	<150 kHz
_	IRS25401S	SO-8	200V	+500 / -700 mA	<500 µA	<500 kHz
	IRS25411S	SO-8	600V	+500 / -700 mA	<500 µA	<500 kHz

LEDriv**IR**[™]

IRS2980

Rectifier

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

IRS2980 Features

- Internal high voltage regulator
- Hysteretic current control
- High side current sensing
- PWM dimming with analog or PWM control input
- Free running frequency with maximum limiting (150kHz)

IRS2980 Benefits

- Low component count
- Off-line operation
- Very simple design
- Inherent stability
- Inherent short circuit protection

Demo Board Specifications

- Input Voltage 70V to 250V (AC)
- Output Voltage OV to 50V (DC)
- Regulated Output Current: 350mA
- Power Factor > 0.9
- Low component count
- Dimmable 0 to 100%
- Non-isolated Buck regulator

International **TER** Rectifier THE POWER MANAGEMENT LEADER

THE AUTHORITY ON EMERGING TECHNOLOGIES FOR DESIGN SOLUTIONS

Vol. 61 No. 5 **05.02.13** |electronicdesign.com

Features

18: LEDs Gain Ground On Their Illumination Rivals | ENGINEERING FEATURE • Roger Allan

Prodded by government and private initiatives to save on energy and become eco-friendly, LEDs are improving and grabbing a greater share of the market.

36: Understanding LED Application Theory And Practice I

Contents

Learn some basics about how LEDs work, how their manufacturers characterize them, and how circuits that drive and/or control them are designed.



Columns



EDITORIAL | Joe Desposito

13: LED Lamp Mimics Cozy Incandescent Lighting



ENERGY ZARR | Richard Zarr

14: LEDs Line Up To Replace Residential Incandescent Bulbs

T

80:

LAB BENCH | Bill Wong

Standards Bring CCFL And LED Technologies To Light

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 00134872) 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. Copyright *2013 by Penton Media Inc. all rights reserved. The contents of this publication may not be reproduced in whole or in part without the consent of the copyright owner. For subscriber services or to order single copies, write to Electronic Design, P0 Box 2100, Skokie, IL 60076. Canadian Post Publications Mail agreement No. 40612608. Canada return address: INEX Global Solutions, P.O. Box 25542, London, ON N6C 682.

28: Dynamic Display Technologies Compete For Eyeballs | TECHNOLOGY REPORT •

Bill Wong



Today's display technologies are attempting to deliver the best viewing performance for the lowest cost and least power in the thinnest packages around.

Distribution Resource

- 43: Top Distributors
 Anticipate Modest Growth In 2013 • Victoria Fraza Kickham
- 52: McClendon Prepares Allied For Global Challenges In A Slow Economy • Victoria Fraza Kickham
- 54: Switches Get Smaller And More Specialized • Victoria Fraza Kickham
- 56: Industry Leaders Connect At EDS • Victoria Fraza Kickham
- 58: Defense Spending Tops Distributors' Concerns • Victoria Fraza Kickham
- 60: Today's Supply Chain Requires Stronger Links • Victoria Fraza Kickham

.



The Newest Products for Your Newest Designs®

wer Wi

CREF

The Next Big Thing Is Here.

M maxim

MAX1132x

0

More New Products More New Technologies More Added Every Day

.



Authorized distributor of semiconductors and electronic components for design engineers.





Vol. 61 No. 5 05.02.13 |electronicdesign

Techview

16: Recent ZigBee Standards Target Lighting Applications I **COMMUNICATIONS** • Louis E. Frenzel



Design Solutions

- 64: Design A Lower-Cost Touchscreen System | Chitiz Mathema and Christiana Wu • Cypress Semiconductor
- 68: Great Thermal Design Enhances LED Reliability Darvin Edwards • Contributing Technical Expert

Ideas for Design

- 72: Use An LED Dot-Graph Display To Complement Your DVM Readout | Nedjeljko Lekic and Zoran Mijanovic • University of Montenegro
- 73: Lamp Eliminates Need For Limit Switches In Flap-Motor Control | Gunnar Englund GKE Elektronik AB

Engineering



Product Features

79: AD INDEX



Permission is granted to users registered with the Copyright Clearance Center Inc. (CCC) to photocopy any article, with the exception of those for which separate copyright ownership is indicated on the first page of the article, provided that a base fee of \$2 per copy of the article plus \$1.00 per page is paid directly to the CCC, 222 Rosewood Drive, Danvers, MA 01923 (Code No. 0013-4872/94 \$2.00 + \$1.00). Copying done for other than personal or internal reference use without the express permission of Penton Media, Inc. is prohibited. Requests for special permission or bulk orders should be addressed to the editor. To purchase copies on microfilm, please contact National Archive Publishing Company (NAPC) at 732-302-6500 or 800-420-NAPC (6272) x6578 for further information.











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





EREN **REAL-TIME VS. SAMPLING** OSCILLOSCOPES

Joel Woodward | Agilent Technologies

The path to digitalization for both real-time and sampling scopes is essentially the same, but the underlying technology for each varies dramatically.





DESIGN SOLUTION A PRACTITIONER'S GUIDE TO **CRITICAL SOFTWARE CERTIFICATION**

Jared Fry and Shan Bhattacharya | LDRA Ltd.

Software tools guide code development and test to bring better products to market for high-reliability applications





ENGINEERING ESSENTIALS **UNDERSTANDING WIRELESS RANGE CALCULATIONS**

Chris Downey | Laird Technologies



Wireless designers need to identify the factors involved in calculating range and

accurately estimate it to ensure reliable communications links in their devices.

INTERVIEW **NYU WIRELESS DIRECTOR THEODORE** RAPPAPORT

Louis E. Frenzel | Communications Editor



communications grows, ing. First, how

traffic? Second, where will we find the engineers who

these nextgeneration problems?

As the volume of wireless two challenges are emerg-

will we manage all of this

will solve



FROM ELECTRONIC DESIGN EUROPE

DESIGN BRAINWAVE COMBINES EEG EFFICIENCY WITH ELEGANCE

Paul Whytock | Editor in Chief



Imec and Panasonic

have developed a wireless EEG system that uses ultra-low-power electronics, continuous impedance monitoring, and active electrodes to improve the quality of EEG signals recorded in clinical settings.



ANALOG BETWEEN THE BITS MOORE'S LAW MAKES HOUSEHOLD **ROBOTS POSSIBLE**

Bill Laumeister | Contributing Technical Expert

Improvements in microprocessors have enabled

modern lifestyle that relies on robots to do the dirty work not only in industry but also around the office and around the house.



ENGINEERING TV **QB AVATAR TELEPRESENCE ROBOT LETS YOU GO TO WORK** VIRTUALLY

Don Tuite | Analog/Power Editor



The QB Avatar telepresence robot from Anybots enables anyone to assume a virtual presence in a remote location and connect and communicate from anywhere in the world. See the video at engineeringTV.com.



TAILORED.

AVNET SOLUTIONS MEET YOUR UNIQUE NEEDS

From big to small - we do it all.

Even big products begin small, with millions of sizes in between. We see them all. Here at Avnet, no order is too small. Avnet provides products and services to match your needs. No matter the location; whether you are in the new product introduction phase or extending a product's life. If you need design support, or supply chain assistance – we're here to help. With Avnet, you determine the scale of interaction – or complexity – and we will support you every step of the way, so it's a perfect fit!

What can we do for you? www.avnetexpress.com



electronic design

WIRELESS & PSTN MODULES

Radicom Research designs and builds reliable, highperformance, simple to implement embedded WiFi, Bluetooth, GPS and PSTN modem modules for OEM's, competitively priced.

WIFI Modules



WiFi 802.11b/g/n USB / Serial interfaces -40°C to +85°C operating temp. Available AP and device

BLUETOOTH® Modules



V.2.0, V.3.0 and V.4.0 (BLE) Serial TTL interface SPP, HID, A2DP, Audio support -40°C to +85°C operating temp.

PSTN Modems



USB, Serial TTL, RS232, ISA PC/104 available Leased-line & Dial-up Up to 56kbps data, fax, voice -40°C to +85°C operating temp.

Founded in 1993, Radicom Research builds Modems for OEM's. We can quickly engineer to your specs or recreate one from our proven designs to suit you. Contact us for your modem needs, wireless or wired.



EDITORIAL

EDITOR-IN-CHIEF: JOE DESPOSITO T | 212.204.4368 joe.desposito@penton.com MANAGING EDITOR: RICHARD GAWEL T | 212.204.4381 richard.gavel@penton.com CREATIVE DIRECTOR: DIMITRIOS BASTAS T | 212.204.4372 dimitrios.bastas@penton.com ANALOG/POWER: DON TUITE T | 650.367.6268 don.tuite@penton.com COMMUNICATIONS: LOUIS E. FRENZEL T | 512.243.5173 lou.ferazel@penton.com DISTRIBUTION: VICTORIA FRAZA KICKHAM SourceES8editor@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.vitalo@penton.com SENIOR ARTIST: JAMES M. MILLER T | 212.204.4371 jim.miller@penton.com

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 2728-3886

ONLINE

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

DESIGN ENGINEERING & SOURCING GROUP

VICE PRESIDENT & MARKET LEADER: BILL BAUMANN GROUP DIRECTOR OF EDITORIAL CONTENT: NANCY FRIEDRICH GROUP DIRECTOR OF OPERATIONS: CHRISTINA CAVANO GROUP DIRECTOR OF MARKETING: JANE COOPER RESEARCH MANAGER: JULIE RITCHIE MARKETING & EVENTS SPECIALIST: CYNTHIA RODRIGUEZ MARKETING COMMUNICATIONS SPECIALIST: CYNTHIA RODRIGUEZ



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

PENTON MEDIA INC.

CHIEF EXECUTIVE OFFICER: DAVID KIESELSTEIN david.kieselstein@penton.com 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





Agilent Digital Multimeters. Speed. Accuracy. Confidence.

You deserve throughput among the fastest in the industry. That's what you'll get with the Agilent 34450A 5½ Digital Multimeter. It also gives you more connectivity options for transferring and analyzing data on a PC. In short, it's built to anticipate everything you need to succeed.

J44JUA DIGILAI WUULINELEI, J /2 UIGILA	3445	50A	Digital	Multimet	ter, $5\frac{1}{2}$ digits
---	------	-----	---------	----------	----------------------------

High speed	190 readings/sec throughput
New OLED display	Real-time statistical parameters Histogram analysis Simple pass/fail limits
Easy connectivity	USB, serial interface (RS-232) and GPIB



Scan or visit http://qrs.ly/mp2dv9h to view 34450A video demos Agilent and our Distributor Network Right Instrument. Right Expertise. Delivered Right Now.

Sewark elemently

800-463-9275 www.newark.com/agilent Limited-time offer: FREE upgrade to 50k memory and GPIB licensing key: www.newark.com/Agilent_DMM

© Agilent Technologies, Inc. 2013



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.

Laberter

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

800 453 6202

D2012 Netional Instruments. All rights reserved, LabVIEW, National Instruments, NJ, and ni com are trademarks of National Instruments Other product and company namek lists of an strudemarks or trade names of their respective companies. D2010



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

LED Lamp Mimics Cozy Incandescent Lighting

WELCOME TO OUR annual One Bright Issue, where we cover the latest in LED and display technologies. I thought I would write about a couple of LED products that I saw at Electronica late last year and International CES earlier this year.

WHAT COLOR IS YOUR LED LAMP?

At Electronica, I had a long talk with Radu Surdeanu, principal scientist at NXP Semiconductors. He explained that many people are dissatisfied with the light that's emitted by LED bulbs and lamps, at least compared to the good old incan-

descent light bulb. This is especially true when dimming the LED bulb.

With incandescent bulbs. light becomes "warmer" as the bulb is dimmed. This essentially means the color of the light changes as the incandescent bulb dims. Since this isn't the case with LED bulbs, NXP $\,$ NXP's "sensorless sensing" technology researchers set out to mimic those color changes. The idea is to give consumers the same lighting experience they are used to with incandescents.

The solution NXP developed

is based on "sensorless sensing" technology. As you dim an LED lamp with this technology, the light appears warmer and cozier (see the figure). Developed and patented by NXP, the solution not only affects the light, it also drives down LED system costs by eliminating external temperature sensors, reducing the size of the heatsinks required for LED system cooling and significantly improving reliability.

Surdeanu explained how NXP makes an LED mimic an incandescent when dimming. First, the company combines white and amber LEDs to create colors that are most pleasing to the human eye, following the black-body radiation curve. Then it implements a logarithmic correction for eye sensitivity that entails an analytical model for achieving the desired color points while dimming. Finally, it uses the sensorless sensing technology to measure LED junction temperature directly, which provides accurate, efficient real-time temperature correction-a must for reliable control of LED performance under any conditions.

I asked a representative from NXP if this technology would remain in lamp form or be incorporated into a bulb, but she said the company has not released any products using it yet. If you want to find out more, NXP's R&D team has produced a video available on YouTube at http://youtu.be/ bRieORS6g1w.

A NEW BULB FROM RAMBUS?

Known for its prowess in memory technology, Rambus has developed a new LED bulb-well, not exactly. But Rambus did buy a company that

> had developed a new LED bulb technology. When I walked by the Rambus booth in January at Pepcom's Digital Experience, a small trade show the evening before the exhibits open at CES, I stopped dead in my tracks and tried to digest the news.

> John Thomas, a vice president at Rambus, explained how the LED bulb works. Instead of providing direct lighting, the LEDs shine on a light guide that provides the illumination.

The cylindrical, edge-lit light guide-the bulb uses three

of them-is patterned with MicroLens optics to deliver the maximum amount of light from the LEDs. Using this technique, the Rambus light bulb provides an efficient, controlled light distribution without the need for additional diffusers that can reduce efficiency. By varying the size, shape, density, and location of the MicroLens optics in the light guide, the bulb delivers an even, spherical, and high-quality light distribution, just like a traditional incandescent.

You can view a video of the Rambus bulb on Engineering TV at www.engineeringtv.com/video/Rambus-Debuts-New-LED-Light-Bul. This technology is not just for bulbs, though. Thomas showed me a modern lamp that used the same technology, sans bulb.

At home, we've switched out most of our incandescents for compact fluorescents, not LED bulbs. My chief complaint with fluorescents is the warmup period until they achieve full brightness, not with the color. LED bulbs will certainly solve this problem, and I'm sure I'll be trying some soon.





drives down LED system costs by

improving reliability.

eliminating external temperature sensors,

reducing the size of the heatsinks required

for LED system cooling and significantly



RICHARD ZARR | CONTRIBUTING TECHNICAL EXPERT ti_rickzarr@list.ti.com



LEDs Line Up To Replace Residential Incandescent Bulbs

WITH THE UBIQUITOUS incandescent light bulb passing 130 years in age, we should have an economical and efficient replacement by now. Compact fluorescent lamps (CFLs) boast higher efficiency but include toxic mercury. Other candidates such as exotic RF plasma bulbs have been investigated for noncommercial use, but they have issues as well.

Previous LED replacement fixture (bulb) designs have been relatively expensive and suffer from poor life spans, even though they have excellent efficiency. But as other market forces beyond efficiency drive the selection of next-generation residential light sources, LEDs are standing their ground.

A BRIGHT HISTORY

Artificial light has been with mankind since the dawn of the fire age. It has let us continue activities that normally would require daylight and extended the time when people could be social or productive. The arrival of oil lamps and candles civilized artificial light into a technology for extending the day past sunset. With the industrial age came gas lighting, which lined the streets of many cities. Yet it wasn't until the late 19th century that electric lighting, first in the form of arc lamps and later incandescent filament lamps, was introduced.

For more than 100 years, the incandescent bulb was ubiquitous in homes across most of the globe. But only a small percentage of its light is visible, and this trait has been well exploited. Over 90% of the emission spectrum of an incandescent bulb falls in the infrared (non-visible) range (*see the figure*).

Incandescent light bulbs are highly inefficient for visible lighting tasks, and replacements have entered the market. Competing technologies such as florescent lighting and lowpressure metal lamps are now widely available. The CFL often has been used as a symbol for eco-friendly technology due to its high efficiency, despite the small amount of toxic mercury metal it includes.



SOLID-STATE LIGHTING

In the last 10 years, great improvements have been made in the efficacy of LED emitters. White LEDs with efficacies exceeding 100 lm/W are common. However, there are cost constraints still associated with LED lamps. To help bridge the gap, the U.S. Department of Energy hosted the L-Prize contest to drive competition and reduce the price of producing LED bulbs. Philips won the 60-W L-Prize, and the bulb is available for purchase today. All of the bulbs entered in the contest are designed to retrofit a standard fixture, and standard TRIAC dimmers can dim many of them, including the Philips design.

Nevertheless, the need to be compatible with dimmers and operate off of higher voltages found worldwide complicates the electronics and raises the cost of the bulb. Additionally, these bulbs only replace the conventional bulb in a standard fixture. For example, the BR30 light is found in many homes with recessed lighting across the U.S. It screws into the standard Edison E26 (26 mm) socket, which only supplies highvoltage (110 V ac) alternating current.

Such replacement LED lights must deal with an environment designed specifically for the incandescent bulb. Most of an incandescent filament-based light source's emission is in the infrared range, which is heat. The heat is "radiated" away

> from the bulb, which has been exploited as heating elements for restaurant passes and the early Easy Bake Ovens from Kenner (later Hasbro).

> LED emitters, however, do not radiate waste heat. They need to conduct it away instead, which introduces yet another engineering challenge in retrofitting a fixture designed more than 100 years ago. This leads to strange looking designs with fins and sometimes even active elements, such as the Nuventix SynJet cooling technology.

THE FUTURE OF RESIDENTIAL LIGHTING

There is a market for millions of replacement bulbs that are far more effi-



The emission spectrum of an incandescent bulb mostly falls into the invisible infrared region.

cient than the old incandescent versions. Still, other forces beyond energy savings ultimately will drive more sophistication into home lighting. Beyond efficiency, LEDs offer additional features that have yet to be fully realized by designers, such as the ability to change color.

Tricolor (red, green, blue) fixtures allow color mixing, which can change the look of a space and affect mood. A recent area of study called color psychology is connecting colors with feelings. The color blue, for instance, is thought to instill feelings of relaxation and comfort. Using this knowledge, Boeing's new jets have tray lighting with blue and white LED emitters to help passengers relax.

The ability to change color brings another dimension to the traditional dimming paradigm, requiring controls either in the infrastructure or the fixtures themselves. One solution is to add wireless technologies such as ZigBee, 6LoPAN, or 802.11 (Wi-Fi) inside the fixture, along with standardized protocols for communication. Controls then can be as simple as a mobile application on a cell phone to change the color or level of lighting in a room.

The problem today is the lack of standards for the communication physical layer and the protocol. Unlike the simple and ubiquitous E26 socket, a wirelessly connected mesh networked light fixture needs standards for adoption. The industry may find applications in commercial settings first, but ultimately a minimum number of standards will be required for this kind of control to reach the home.

When it does, a new power system will be needed. Like the E-Merge Alliance commercial standards proposals, there needs to be a residential dc power grid. High-voltage transmission won over Edison's dc transmission by reducing the resistive losses in cables over long distances. This is fine for large-scale transmission, but most of our modern devices run on de low-voltage power.

Every electronic device that has an ac power plug also has a complex power supply to convert that high voltage to the correct internal dc voltages required to operate the electronics. Several proposals for a standardized dc connector, or at least a residential dc bus, have been introduced. However, no standard yet RICHARD ZARR is a technologist at Texas has been adopted. Additionally, a dc plug standard could also bring Ethernet or other wired communication standards into the plug, allowing for a physical layer that is already widely deployed.

Instruments focused on high-speed signal and data path technology. He is a member of the IEEE and holds a BSEE from the University of South Florida as well as several patents in LED lighting and cryptography.

Looking to save energy?

CFE 400M SERIES -High Efficiency Power Supplies

Can't find a solution? No need to lose sleep over it, TDK-Lambda has the new digitally controlled CFE-M series of 400W power supplies with efficiencies as high as 94%.

Don't want fan cooling? The CFE400M will deliver 300W without forced air cooling and has both IEC 60950-1 (ITE) and IEC 60601-1 (Medical BF rated) safety certifications.

Don't get caught cat-napping, contact TDK-Lambda for an evaluation unit or check our website for distribution inventory.

http://us.tdk-lambda.com/lp/products/cfe-series.htm

For more information on how TDK-Lambda can help you power your unique applications, visit our web site at www.us.tdk-lambda.com/lp/ or call 1-800-LAMBDA-4

- Small Size: 1.6" x 4" x 7"
- 85 264VAC Input
- 12V to 48V Outputs
- Five Year Warranty
- 0.5W Standby Power
- ORing FET for Redundant Operation
- Standby Voltage
- Remote On/Off & DC Good signals



RECENT ZIGBEE STANDARDS TARGET LIGHTING APPLICATIONS

wo new standards from the ZigBee Alliance are a great fit for lighting applications: Light Link and ZigBee IP. Based upon the IEEE 802.15.4 standard for personal area networks, Zig-Bee works in the 2.4-GHz unlicensed industrial, scientific, and medical (ISM) band and adds extra layers to the protocol to implement wireless mesh networks (see "What's The Difference Between IEEE 802.15.4 And ZigBee Wireless?" at electronicdesign.com).

Light Link is a ZigBee application as well as an open global standard designed for consumer lighting and

control products. It lets consumers implement wireless control over all of their LED fixtures, light bulbs, timers, remote controls, and switches (see the figure). For example, they can easily change lighting remotely to develop the right environment for ambiance or a task. It also helps manage energy consumption.

With Light Link, all of the various lighting products form a self-organizing, self-healing mesh network that can be controlled over the Internet via computers, tablets, or smart phones. The protocol also makes it easy to add new items or delete items. Best of all, the ZigBee Alliance's testing program ensures that all certified products interoperate for foolproof application. The Light Link standard is now fully

With ZigBee Light Link, consumers can control all of the enabled lights in the home from a tablet or smart phone by way of a wireless gateway or router.

ratified and ready for distribution. Go to www.Zig-Bee.org/LightLink for more information. ZigBee IP is an open specification for IPv6-based wireless mesh networking solutions that provides Internet connections to control low-power, low-cost devices like LED lighting. It targets companies creating wireless solutions for energy management or commercial and consumer applications. It

enhances the basic IEEE 802.15.4 standard and ZigBee mesh architecture by adding network and security layers and an application framework. The IP application provides a

scalable architecture for IPv6 networking and lays the foundation for the Internet of Things without the need for intermediate gateways. It offers a cost-effective and energyefficient wireless mesh network based on standard Internet protocols such as 6LoWPAN, IPv6, PANA, RPL, TCP, TLS, and UDP. It also features proven security using the TLS1.2 protocol, link layer frame security based on the AES-128-CCM algorithm, and support for public key infrastructure using standard X.509 v3 certificates and the ECC-256 cipher suite. A ZigBee Alliance testing program will certify interoperability. Details are available at www.zigbee.org/IP. ZIGBEE ALLIANCE

www.zigbee.org LOU FRENZEL

TH EXPE

Overall U.S. television shipments will decline for a second year in a row in 2013, says the IHS iSuppli U.S. Television Market Tracker Report. Yet growth will resume as LCD TVs like Panasonic's 55-in. TC-L55WT50 regain



some of the market strength they lost in the past year, with 3% growth in their segment this year and 6% growth in 2014, pulling the overall market out of its slump.





Driven by smart phones like Samsung's Galaxy S4, active-matrix organic LED (AMOLED) panels designed for mobile

handset applications will total 447.7 million units in 2017, up from 195.1 million in 2013, according to the IHS iSuppli Emerging Displays Service.

VERSATILE SMART-BUILDING LED DIMMER IC FAMILY PROVIDES DESIGN FLEXIBILITY

ily of LED-control ICs, LED matching lighting effects to lighting fixture manufac- natural sunlight. An I²Cturers can create new, more compatible two-wire serial sophisticated products for interface (TWSI) that can smart office buildings and connect with many different factories. The devices pro- communication units, such vide 10-bit precision pulse- as ZigBee, power-line comwidth modulation (PWM) munications (PLC), or Widimming control for two Fi, provides lighting control. LED strings. The light output level can be precisely smart external LED driver varied from full brightness reference design kit sup-

(OTP) memory block lets 88EM8042 baseboard and lighting manufacturers cali- two 88EM8801 controllers. brate each string to its respec- It also can be enhanced with tive target LED current optional plug-in modules during manufacturing. As a that support ZigBee RF result, manufacturers don't or wired 0-10V or Digital need to hand-select LEDs by Addressable Lighting Interbins for consistent brightness face (DALI) wired control, from fixture to fixture.

in the string with cool white cise dimming, occupancy LEDs or bluish green LEDs sensors, and precise color to create light with desirable management (see the figure). "warm" correlated color MARVELL temperature (CCT) char- www.marvell.com acteristics or a high color

With Marvell's 88EM8801 fam- rendering index (CRI) for

A two-stage, four-channel down to 0.1% deep dimming. ports designs up to 40 W. A one-time programmable The basic kit comprises one enabling lighting manufac-Red LEDs can be mixed turers to provide more pre-

DON TUITE

Marvell's 88EM8042 starts with a basic board (upper left) that constitutes the ac-dc stage for multiple 88EM8801 drivers and an I²C interface that operates with the company's ZigBee RF and DALI wired controllers or a simple microcontroller programmed to handle the traditional 0-10V interface that's the industry's long-standing standard for old-fashioned dimmable lighting.





CONSISTENT AND RELIABLE ELECTRICAL CONTINUITY

Uneven mating surfaces, floating height requirements, and exposure to extreme vibration all challenge the integrity of electrical connections. Field proven for performance and reliability in harsh environments, Mill-Max spring-loaded connectors ensure continuity across a wide variety of length and stroke configurations, including new low and ultra-low pin profiles.

Don't see what you need? Rapid prototyping and custom designs are our specialty.



EngineeringFeature

ROGER ALLAN | CONTRIBUTING EDITOR rsallan@optonline.net

LEDS Gain Ground On Their Numination Rivals

Prodded by government and private initiatives to save on energy and become eco-friendly, LEDs are improving and grabbing a greater share of the market.

he use of solid-state LED light bulbs is catching on, driven by better performance and lower costs. This is particularly obvious in the commercial and industrial sectors as well as in outdoor and infrastructure lighting. Despite their initially higher upfront costs compared to existing lighting solutions like incandescent and fluorescent bulbs, LEDs are proving to be more cost-effective and provide greater energy savings in the long run.

By most estimates, non-residential locations like manufacturing plants, business offices, commercial buildings, and infrastructure and other outdoor facilities account for half or more of all the energy BRIDGELUI

consumed by lighting. Many governments and companies worldwide are taking measures through funding to help reduce this energy usage through the use of more efficient LED bulbs and fixtures.

The United Kingdom's Energy Efficient Financing (EEF) scheme for non-residential users covers upfront costs of lighting equipment, with repayments over time aligned with lower energy-saving utility bills. The EEF was started under the U.K.'s Carbon Trust and Germany's Siemens Financial Services Ltd.

Cash for Clunkers, a supplier of Eagle LED lighting tubes in Philadelphia, Pa., is spurring its customers to save up to 50% more energy by reimbursing a portion of what their present T12 fluorescent bulbs are worth. The company also is covering the cost of their removal and the new installations.

A WIDE RANGE OF APPLICATIONS

LED bulbs are widely used for infrastructure (bridges, tunnels, street lighting, highways), stadiums, parking lots, airports, and events. For example, they were prominent in the commemoration of the 25th anniversary of the iconic San Francisco Bay Area Bridge with what the event's organizers called the world's largest light sculpture. The project involved more than 25,000 LED bulbs from Philips Semiconductor, installed on the suspension cables stretching 1.8 miles on the western span of the bridge and reaching heights of 500 feet (*Fig. 1*).

or 500 feet (*Fig. 1*). LED lighting is also prominent in historic and municipal structures. LEDtronics employs its post-top LED lamps to illuminate City Hall in Pasadena, Calif., as part of the city's plan to replace all of its much higher-dissipation metal-halide bulbs (*Fig.* 2). Pasadena is one of the early cities that signed on to the U.S. Conference of Mayors Climate Control Agreement in 2005 to reduce energy waste, cut maintenance costs, and promote a greener environment.

> LED lighting is also growing in automotive and consumer electronics display backlighting applications. Edge lighting for digital signage is getting more popular too. Strategies Unlimited projects the \$13.7 billion LED worldwide component market to grow to \$16.4 billion by 2017, at a compound annual growth rate of 3.7%. Lighting constitutes the largest growth sector of the market. Solid-state lighting is an international trend as well, with China aiming to be a major player (*see "China Emerges In The LED Market," p. 24*).

> The U.S. government's estimate for future growth of LED light bulbs of all types is telling. The Energy Information Administration estimates that total sales of all light bulbs, LEDs included, will fall by 40% by 2015, with LEDs making up a continuing larger portion of the total market. This is because LEDs will last longer once installed, so users won't have to change them as often in subsequent years.

> Growth in the consumer and home markets is picking up speed, but at a slower rate than the commercial sector. Major LED bulb manufacturers like Philips, Osram Semiconductor, and General Electric (GE) as well as mass-market retailers like the Home Depot, Lowe's, Wal-Mart, and Best Buy are aggressively taking advantage of lower initial costs, offering low-cost LED light bulbs to make them more attractive and appealing to home owners.

> A 40-W equivalent LED light bulb like the EcoSmart at the Home Depot now can be had for about \$10. Philips is offering a three-pack

allows the production of LED chips with increased luminous output by 20% but at the same power level. It employs modular connectors and other design innovations to make it easier to create lighting fixtures, leading to a greater variety of fixtures at lower price points.

Bridgelux's Vero Technology

DETODOR



1. Some 25,000 Philips Semiconductor LED bulbs light up the iconic San Francisco Bay Area Bridge with what the city calls the world's largest light sculpture. The lighting commemorates the 25th anniversary of the bridge.

set, the Hue, at Apple Computer stores as part of a kit that includes hardware and software. For about \$200, the Hue kit lets users control their lights including color changes via their tablets and smart phones.

Major LED bulb makers like Cree Lighting and Philips Lighting are offering consumers looking to retrofit their lamps' 60-W equivalent A-lamp LED light bulbs for less than \$15. Cree's bulbs offer omnidirectional light distribution and include dimming support. They range in price from \$9.97 (6-W equivalent 450-lm 2700K bulb) to \$13.97 (60-W equivalent 800-lm 5000K bulb) (*Fig. 3*). Philips is offering LED bulbs for \$14.97 (60-W equivalent 800-lm 3000K bulb) without the dimming capability.

BETTER PERFORMANCE

Brighter and higher-efficacy LED light bulbs continue to emerge. Light-output and efficacy levels are effectively doubling every six months. Philips Lighting's Luxeon S emitter LEDs deliver the highest luminous density and the best centerbeam candle power on the market. At twice the lumen density of existing offerings, the second-generation illuminationgrade multi-chip emitters offer an R9 value (R9 is a measure of the color-rendering index, or CRI) that exceeds 80 and has a 50% better color over angle figure compared to other LED bulbs. Designed for architectural and entertainment applications, they deliver 50 lm/mm² and a light output of up to 8000 lm in narrow beams with sharp shadows.

Correlated color temperatures (CCTs) now range from 2700K to 6500K with CRI values ranging from 70 to 95. So, LEDs now can be used for a broader range of applications. Luminous LED efficacy is also on the rise. Many LED semiconductor manufacturers regularly obtain efficacies in the 100- to 160-lm/W range.

Cree broke the 10,000-lm barrier with an expanded family of integrated LEDs that deliver the industry's highest-efficacy lighting class arrays. The CXA2540 and CXA3050 deliver 5000 to more than 10,000 lm, enabling high track lights and downlights, outdoor area lighting, and high bay lighting.



2. LEDtronics' post-top LED bulbs illuminate the historic and municipal City Hall of Pasadena, Calif. It is part of municipal efforts to replace citywide metal-halide bulbs for a greener city environment.

Some experts say that 200-lm/W efficacies can be reached by 2016. Cree Lighting achieved higher efficacy levels in the lab a couple of years ago. The company now claims that it has achieved 276 lm/W from a white LED bulb in an R&D setting.

Lifetimes for LED bulbs are also improving to 50,000 hours or more, a benchmark set by the U.S. Department of Energy (DoE) for commercially available LED bulbs. 3M plans to sell 450-Im 40-W and 60-W equivalent LED light bulbs at Wal-Mart with a 25-year lifetime for \$25. The key is the use of the company's multi-layer optical film, adhesives, and clever thermal management that allows the bulb to dissipate just 8.5 W.

Gallium-nitride (GaN) on GaN technology also forebodes well for the future of LED performance. Soraa has demonstrated that GaN on GaN can handle significantly more current and emit 10 times more light per unit area than conventional LEDs. Last year, the company demonstrated a 12-V ac MR16 lamp with integral drivers that operates with several combinations of transformers and dimmers. The standard 2700K and 3000K versions boast a CRI of 80. A high-CRI version of 95 won the prestigious Red Dot Award (*Fig. 4*).

MHT Lighting also offers LED lighting fixtures where the application calls for them. MHT is the design and manufacturing arm of PMI. In keeping with PMI's focus on energy savings, it uses PMI's SP1000 hybrid energy management and correction system (see "Intelligent Energy Optimization System Slashes Large-Scale Electric Bills" at electronicdesign.com).

One of the most important parameters governing LED light bulb performance and lifetime is how it is driven. The implementation of the right driver circuit, thermal management, dimming control, and reliability are all key elements in an LED light bulb's success (*see "Understanding LED Application Theory And Practice," p. 36*).

MORE FORMS FOR GREATER FLEXIBILITY

To compensate for different design life cycles for LED chips and illumination end products, chip manufacturers are packaging their die into various forms for greater end-user flexibility. Some packaging options combine a chip-on-board



ANALOG INTEGRATION ISN'T FOR EVERYONE

www.maximintegrated.com



© 2015 Maxim Integrated Products, Inc. All rights reserved. Maxim Integrated and the Maxim Integrated logo are trademarks of Maxim Integrated Products, Inc., in the United States and other jurisdictions throughout the world.

RF Quiz







Wireless made simple

RF Modules Remote Controls Antennas RF Connectors Custom Designs

www.linxtechnologies.com



3. Cree's Filament Tower arrangement for an A-lamp LED bulb uses 20 LEDs, arranged in 10 pairs in a circular manner, that leads to a lower-cost product for consumers. It uses Cree's phosphor-coated XLamp-E high-voltage LEDs.

(CoB) arrangement, where several LED die are clustered to form a round shape that provides optimal efficiency and light quality. Most LED light sources are rectangular and square and covered by a lens or plastic coating.

Solid-state lighting uses various LED form factors like strips, straight and angled bars, canopies, modules, domes, track lights, light sticks, pucks, and troffers to make for more interesting and appealing lighting solutions. For example, the LED modules in the XSM family from Xicato produce 3000 lm for brighter and more efficient illumination.

Of course, packaging several die in a small enclosure involves careful thermal management with heatsinks and other techniques, which many chip makers are offer-

ing with their die. This is particularly true for some applications like automotive exterior lighting that cannot tolerate designs that take up more space like fans and cooling systems. Thermal-interface materials that work with the LED's substrate are finding favor.

"There's more to LED lighting than meets the eye," says Arunava Dutta, director of R&D LED Lamps, Americas, General Lighting, at Osram Sylvania. "A good knowledge is needed in chemistry, colorimetry, optics, mechanical issues, thermal management, and a host of other sciences to optimally design a lighting fixture. Ultimately, everything shows up in the lm/W number."

Sylvania says it has designed very lightweight LED lamps in PAR20, PAR30, and PAR38 form factors that weigh onefourth the weight of conventional retrofit fixtures, thanks to very good thermal



management and advanced integrated driver circuitry.

A new packaging technology allows Bridgelux to produce LED chips that increase luminous output by 20% but at the same power level. The Vero Technology employs modular connectors and other design innovations to make it easier to create lighting fixtures, leading to a greater variety of fixtures at lower price points (see the opening figure).

Cree's XLamp ceramic-based XQ LEDs feature a unique combination of small size, novel light distribution, and high-reliability design to enable applications that require broader light distribution such as omnidirectional lamps and fixtures (*Fig. 5*). Designed to accommodate upgrades as well as new construction, the company's improved LEDway series of LED streetlights offers a 20% additional energy savings over previ-

Low Drift, High Accuracy

frequency counter with rubidium timebase



SR625 \$6,950 (U.S. list)

The SR625 combines the atomic accuracy of a rubidium timebase with the best available single-shot time resolution (25 ps) of any counter — at an unbelievable low price. It measures time interval, frequency, period, phase, pulse width, event counting, and much more.

- Rubidium atomic timebase
- 2 GHz prescaler input
- 25 ps single-shot time resolution
- 11-digit frequency resolution (1 s)
- Statistical analysis & Allan variance
- GPIB and RS-232 interfaces

The SR625 Frequency Counter consists of a frequency counter (SR620), a high-accuracy rubidium timebase (PRS10), and a 2 GHz input prescaler. The rubidium timebase ensures excellent frequency accuracy with a long-term drift of less than 5×10^{-11} /month.

The SR625 is ideal for critical measurements like clock jitter, pulse-to-pulse timing, oscillator characterization, and frequency stability. Please contact us for details.



(408)744-9040 www.thinkSRS.com

Surface Mount (and Plug In) Transformers and Inductors

See Pico's full Catalog immediately www.picoelectronics.com



Audio Transformers

Impedance Levels 10 ohms to 250k ohms, Power Levels to 3 Watts, Frequency Response ±3db 20Hz to 250Hz. All units manufactured and tested to MIL-PRF-27. QPL Units available.

Power & EMI Inductors Ideal for Noise, Spike and Power Filtering Applications in Power Supplies, DC-DC Converters and Switching Regulators

Pulse Transformers 10 Nanoseconds to 100 Microseconds.

ET Rating to 150 Volt Microsecond. Manufactured and tested to MIL-PRF-21038.

Multiplex Data Bus Pulse Transformers

Plua-In units meet the requirements of QPL-MIL-PRF 21038/27. Surface units are electrical equivalents of QPL-MIL-PRF 21038/27.

DC-DC Converter Transforme

Input voltages of 5V, 12V, 24V And 48V. Standard Output Voltages to 300V (Special voltages can be supplied). Can be used as self saturating or linear switching applications. All units manufactured and tested to MIL-PRF-27.

400Hz/800Hz

Power Transformers 0.4 Watts to 150 Watts. Secondary Voltages 5V to 300V. Units manufactured to MIL-PRF-27 Grade 5, Class S (Class V, 155°C available).

Delivery-Stock to one week for sample quantities

> DÔ Call toll free 800-431-1064

in NY call 914-738-1400 Fax 914-738-8225 Electronics, Inc. 143 Sparks Ave. Pelham, N.Y. 10803 E Mail: info@picoelectronics.com www.picoelectronics.com





improved luminous output.

SOFTWARE TOOLS EASE DESIGNS

Software is becoming an indelible tool for making the design of LED bulbs and fixtures more flexible and simpler. The WebBench Designer tool suite from Texas Instruments includes powerful software algorithms and visual interfaces that deliver complete power, lighting, and sensing applications in seconds.

4. Soraa has demonstrated that GaN on GaN can handle significantly more current and emit 10 times more light per unit area than conventional LEDs. Its 12-V ac MR16 lamp with integral drivers operates with several combinations of transformers and dimmers.

ous versions and John Perry, TI's product marketing manager for lighting and power products.

The LightTools software tool suite from Synopsys Corp. is an illumination design environment that integrates 3D CAD, optical modeling, and an interactive user interface to simplify the design of illumination applications, including LED die packaging and LED-driven illumination systems.

SMARTER LIGHTING

LED lighting technology will make "This is one tool that vastly simplifies its mark on society through greater the complexity of LED-based designs, intelligence and more connectivity, a especially for newer designers," explains trend that has already begun. Speaking

CHINA EMERGES IN THE LED MARKET

The Chinese government views the growth of the LED industry as a national security matter. As a result, it is driving a vast LED manufacturing effort and offering subsidies from central and local government agencies to help build its own LED industry. In 2010, China embarked on an ambitious "Many Cities, Many Lights" program for streetlamp lighting to help its own LED industry. China has been in the LED bulb business for more than a decade but has more recently concentrated its efforts to acquire LED growth and manufacturing know-how.

Chinese local government agencies have anointed companies like Xiamen SanAn Photoelectric Co. and Electro-Tech International Co. Ltd., offering subsidies to purchase metal-oxide chemical vapor deposition (MOCVD) technology, offering free land and other incentives for the establishment of LED plants and companies.

The Chinese government questions the need for 50,000-hour lifetimes being pursued elsewhere and believes a lower figure is more practical for applications requiring medium-output to low-output LED bulbs. It has been writing its own standards and testing methodologies for shorter-lifetime LEDs.

Advanced Micro-Fabrication Equipment Inc. (AMEC), China's leading provider of advanced process technology for LEDs, offers dielectric and through-silicon via (TSV) etch tools. Two months ago, it launched an MOCVD platform for the low-cost, high-volume manufacture of high-brightness LEDs, the patented Prismo D-Blue, which is extendable to the manufacture of gallium-nitride (GaN) on silicon applications. It can accommodate up to four independently controlled reactors and can process up to 216 2-in. wafers simultaneously. According to the company, this capability is extendable to 4-, 6-, and 8-in. wafers.

"The solid-state lighting market is an essential element of our growth strategy," says Zhiyou Di, sensor vice president and general manager of AMEC's MOCVD product business division.

China's Chongquing Silian Optoelectronics & Technology Co. Ltd., an established supplier of materials, devices, and systems for the lighting industry, is partnering with Soitec, a European manufacturer of semiconductor materials, to jointly develop GaN template wafers using Silian's sapphire substrate and Soitec's HVPE technology. The aim is to validate the manufacturability and commercialization of GaN-based LEDs, which are viewed as the next step in LED development.

05.02.13 ELECTRONIC DESIGN

Supertex inc.

Specialty ICs Telecommunication ICs

HV Interface ICs

e ICs HV Amplifier Array ICs

Power Management ICs

Ultrasound ICs

PWM Controller ICs r ICs Depletion Mode MOSFETs

• Sequential Linear LED Driver ICs

Device	V _{IN}	V _{out}	Output Current	Dimming	Parallelable	Package	Features
 CL8800 CL8801	90 - 275VAC	70 - 350VDC	115mA 200mA	Phase Compatible	Yes	QFN-33	No capacitors or magn Cics

Backlight LED Driver ICs



	Device	Application	Тороlоду	Input Voltage	Output Current	Dimming	Package Options
	HV9803	DC/DC	Buck	7.0 - 13.2V	External FET	PWM/Linear	SOIC-8
	HV9821	AC/DC, DC/DC	Buck/Linear	10 - 700V	Integrated FET	No	DFN-19
-4	HV9861A	DC/DC	Buck	12 - 450V	External FET	PWM/Linear	SOIC-8, SOIC-16
	HV9912	DC/DC	Boost, SEPIC, Buck-Boost	9.0 - 100V	External FET	PWM	SOIC-16
	HV9963	DC/DC	Boost, SEPIC, Buck-Boost	8.0 - 40V	External FET	PWM/Linear	SOIC-16

General Purpose LED Driver ICs





Device	Application	Topology	Input Voltage	Output Current	Dimming	Package Options
HV9801A	AC/DC	Buck	15 - 450V	External FET	4-level switch	SOIC-8, SOIC-16
HV9861A	AC/DC, DC/DC	Buck	12 - 450V	External FET	PWM/Linear	SOIC-8, SOIC-16
HV9910B	AC/DC, DC/DC	Buck	8.0 - 450V	External FET	PWM/Linear	SOIC-8, SOIC-16
HV9910C	AC/DC, DC/DC	Buck	15 - 450V	External FET	PWM/Linear	SOIC-8, SOIC-16
HV9921 HV9922 HV9923	AC/DC	Buck	20 - 400V	20mA 50mA 30mA	No	TO-92, SOT-89
HV9930	DC/DC	Hysteric	8.0 - 200V	External FET	PWM	SOIC-8
HV9931	AC/DC	Single-switch PFC	8.0 - 450V	External FET	PWM	SOIC-8
HV9973	DC/DC	Flyback	7.0 - 11V	External FET	PWM	SOIC-8

Current Linear Regulator ICs





• LED Driver ICs (AEC-Q100 Certified)





Device	Application	Topology	Input Voltage	Output Current	Dimming	Package Options
AT9917	Automotive	Boost, SEPIC	5.3 - 40V	External FET	PWM/Linear	TSSOP-24
AT9919	Automotive	Buck	4.5 - 40V	External FET	PWM	DFN-8
AT9932	Automotive	Boost-Buck (Ćuk)	5.3 - 40V	External FET	PWM/Linear	TSSOP-24
AT9933	Automotive	Boost-Buck (Ćuk)	9.0 - 75V	External FET	PWM	SOIC-8

To download datasheets, visit www.supertex.com and search the device number.



5. Cree's XLamp ceramic-based XQ LEDs feature a unique combination of small size, novel light distribution, and high-reliability design that addresses applications requiring broader light distribution such as omnidirectional lamps and fixtures. Applications include downlighting, recessed fixtures, can lights, retrofit bulbs, color-changing lighting, portable and personal lighting, outdoor lighting, and more.

at last year's Street and Area Lighting Conference (SALC), keynote speaker Niels Van Duinen, global marketing director at Philips Lighting, said that "adaptive control can bring energy savings

up to 80% through the use of smarter LEDs." He foresees solutions on unified networks connecting street and other infrastructure lighting that offers greater user control through using Internet protocol (IP) communications.

Redwood Systems helps lighting fixture developers achieve smart LED lighting through sensing and driving innovations. "We put three sensors in each lighting fixture in a pod: an infrared (IR) sensor for motion detection, a temperature sensor, and an ambient light detector, allowing the user to cut down on unnecessary waste of power, like when no one is in a room, an office is not occupied, a plant is idle, and a building's heating ventilating and air conditioning (HVAC) is not in a peak demand time," says Marco Sciorelli, head luminaire specialist at Redwood Systems.

AN ALTERNATIVE TO LEDS

An alternative illumination method, induction lighting, offers longer lifetimes (up to 100,000 hours), lower maintenance costs, superior lumen maintenance (70% output at 60,000 hours), better color matching, and greater energy savings than LEDs. Like a fluorescent bulb, an induction bulb uses mercury in a gas that's inside the bulb. It doesn't use electrodes to strike the arc and initiate current flow, though, so it's arc-less. A high-frequency generator with a power coupler produces an RF magnetic field that excites the gas.

Induction lighting provides a maximum return on investment for applications where bulbs are difficult to access and change, resulting in lower overall maintenance costs. However, they cannot be focused on a spot or area (due to the nature of the bulb's operation) and aren't fully dimmable. MHT Lighting's patented A-19 induction light bulbs and fixtures are designed for indoor, outdoor, and roadway applications in various forms like domes, bars, strips, and custom formats.

INDUSTRIAL POWER EXPERT

MORNSUN® is not only a manufacturer but also provides added value & solutions with our innovative unique designs and products. Along with MORNSUN's more than 200 engineers, and over 1000 employees MORNSUN is a leading light in the industry's development. Certified: ISO9001:2008, ISO14000, OHSMS18001, and Ts16949; UL60950, EN60950, UL60601-1, EN60601-1



MORNSUN®

Email: info@mornsun.cn http://www.mornsun-power.com







LL: 800-647-3343 30HEMIA, NY 11716 EMAIL: edge@edgeelectronics.com -ITTP: //www.edgeelectronics.com

Ever wished for a better bench scope?

The new R&S®RTM: Turn on. Measure.

Easy handling, fast and reliable results – exactly what users expect from a bench oscilloscope. Rohde & Schwarz opens the door to a new world: Work with two screens on one display. Access all functions quickly. Analyze measurement results while others are still booting up. See signals where others just show noise. That's the R&S®RTM.

Ever wished there was an easier way? Ever wished for more reliable results? Ever wished you could do your job faster?

Then take a look. www.scope-of-the-art.com/ad/rtm-video



Analysis Mixed

Analysis

RÖHDE&SCHWARZ

Signal

Warranty program available until June 2013:

SCHWARZ

RTM 2054

OSCILL

Register your new scope and get a five year warranty instead of three! www.scope-of-the-art.com/ad/warranty.

TechnologyReport

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

DYNANIC DISPLAY COMPETE FOR EYEBALLS

Today's display technologies are attempting to deliver the best viewing experience for the lowest cost and least power in the thinnest packages around.

isplay technologies have always competed with each other, but there has never been such a wide variety of approaches. For example, many displays now incorporate touch technology, expanding the possible number of solutions. The challenge lies in delivering the best viewing experience while meeting a range of requirements that depend on the application. Today's displays must offer great color, high resolution, and fast refresh rates. They also have to be rugged, thin, and inexpensive. Size and viewing distance come into play as well. And, they can't consume that much power.

ON THE MARKET

Apple's iPad led the way to high quality (*Fig. 1*). With a resolution of 264 pixels/in., its Retina display provides non-pixelated images, assuming 20/20 vision and a viewing distance of at least 15 in. or a tablet's typical viewing distance. Apple's iPhone 5 has a higher resolution of 326 pixels/in. with a typical viewing distance of only 10 in.

A measurement that takes viewing distance into account is pixels per degree (PPD). The retina display starts at about 53 PPD. The actual resolution of the screen becomes less of an issue for mobile devices once this limit is reached.

On the other hand, large displays tend to be limited by resolution and standards. HDTV 720p (1280 by 720 pixels) and 1080p (1920 by 1080 pixels) displays now dominate. The p stands for progressive scan versus

the interleaved scan utilized by old-style televisions and some HDTVs. In the past, computer monitors with resolutions higher than television were common. These days they tend to be the same with high-resolution monitors being the exception rather than the rule.

The next step up will be 4K Ultra High Def (UHD or Ultra HD) with a resolution of 3840 by 2160 pix-



I. Apple's latest iPad (right) leads in the use of high-definition displays in mobile devices, requiring a closer look to see the difference between its Retina display and its predecessor (left).



MyMultitouch's Alvero 84-in., 4K UHD multitouch display is likely to find a home in museums or other high-traffic areas where people need to interact with high-res displays. els, which is four times the resolution of 1080p (Fig. 2). Double 4K and you get 8K UHD. The 7680- by 4320-pixel 8K Ultra HD is great for displaying images from a 33.2-Mpixel camera.

The problem for 4K and 8K in the consumer space will be content delivery, but that's another discussion. Keep in mind that the RED EPIC digital camera that's used to shoot many of the latest films has

a DCI 4K output with 4096- by 2160-pixel resolution (see tive since the LEDs affect overlapping regions of the screen. "Prometheus Takes Flight With Cutting-Edge VFX Technology" at electronicdesign.com).

DISPLAY TECHNOLOGIES

LCDs have become the dominant display technology, though there are challengers like organic LEDs (OLEDs). LCDs come in a variety of forms, but they require a light source. Reflective LCDs use an external source like the sun. Transreflective displays reflect and transmit light so they can employ backlighting technology. Reflective and transreflective displays are useful in sunlight where a backlight source would be washed out. Backlighting allows viewing in the dark and provides better control of the display quality.

Most mobile and HDTV LCD displays are backlit. There are several ways to do this, but basically a light source is placed behind the display. Cold cathode fluorescent (CCFL) lighting used to be common, though it has been replaced by LED backlighting. LEDs are more expensive, but they are more reliable. They also provide improved control and a wider color gamut. And, they are very small.

The LEDs normally are placed behind the display or on the edge (Fig. 3). Different approaches are used based on the thickness of the display. Edge-mounted LEDs allow a very thin display, and this approach is often used on smaller displays. Larger displays that are thicker allow placement of the LEDs behind the display.

The simplest implementation keeps the backlight on at a consistent level. This works for either approach. The other alternative is dynamic backlighting, also called local dim-



3. Backlit LCDs are typically lit using an array of LEDs behind the display (top) or from the side (bottom).



2. 4K Ultra HD doubles the resolution of today's 1080p displays.

ming. In this case the LEDs are individually controlled and changed based on what is being displayed. The LED intensity affects an area, unlike other displays such as OLEDs where individual pixel control is possible.

This condition is a challenge because the display controller needs to account for lighting from both the LED backlight perspective and the LCD perspec-

Likewise, the controller needs to account for the speed at which the LCD and the LEDs can change. Dynamic backlighting is possible regardless of the LED placement.

Dynamic backlighting reduces power consumption and improves color quality because it allows darker areas on the screen. However, it requires significantly greater controller complexity and produces visual artifacts like halos around bright objects. The type and impact of artifacts depends on the quality of the control algorithm, the hardware, and the image being displayed. The worst case would be a bright star field on a black background.

LCDs have been getting thinner and lighter while using less power. They have also been getting larger, with displays over 80 in. readily available.

OLED displays provide their own light. Each pixel is individually controlled, and they provide brighter, higher-contrast displays compared to conventional LCDs. OLEDs come in passive matrix (PMOLED) or active matrix (AMOLED) versions. Samsung's Galaxy S4 will ship with a 5-in. AMOLED 1080p display (Fig. 4).

OLEDs are even more power-efficient than LED LCDs. Plus, they have a wider field of view that exceeds 165°. They are brighter with higher contrast than LCDs, which are designed to block light. They're used in small, battery oper-

ated devices like smart phones because they're brighter and require less power.

Additionally, OLEDs can be used to make thin, flexible displays. Samsung demonstrated large and small flexible displays at January's International CES in Las Vegas (Fig. 5). The displays are not available yet, but they will offer some interesting design options.

OLED displays can be built using three methods. Vacuum deposition or vacuum thermal evaporation (VTE) is one method, but it is expensive and inefficient. Organic vapor phase deposition (OVPD) also has been used. It generates a thin film using a low-pressure, hot-wall reaction



4. Samsung's Galaxy S4 will utilize a 5-in. AMOLED display.

NEW T-CLAD® PA STICKS IT TO HEAT.

Peel and place thermal solution withstands the heat of solder reflow.



Thermally conductive insulated metal substrate boards specifically configured for LED applications.

Easier assembly, cooler LEDs.

Bergquist's T-Clad with pre-applied Bond-Ply®450 allows you to adhere your mounted LEDs to a variety of heatsinks and surfaces while thermally optimizing

your application. This version of peel and place T-Clad can withstand the high temperatures of solder reflow during LED assembly and then be positioned in the lighting application using its strong thermally conductive adhesive. Call or visit to qualify for your FREE sample.



Sample Board

Call **1.800.347.4572** or visit www.bergquistcompany.com/preapplied



18930 West 78th Street • Chanhassen, MN 55317 • A ISO9001:2008 registered facility (800) 347-4572 • Phone (952) 835-2322 • Fax (952) 835-0430 • www.bergquistcompany.com chamber with a carrier gas to deliver evaporated organic molecules onto a cool substrate. Finally, OLED displays can be built inexpensively using inkjet technology, enabling the creation of very large displays.

Sharp's IGZO (indium gallium zinc oxide) OLED displays range from 4 to 32 inches. The company demonstrated a 32-in. 4K IGZO display at January's International CES. Like OLEDs, IGZOs are more energy efficient than LCDs, have faster switching, and deliver brighter, higher-contrast images.

Sharp's thin-film transistor (TFT) technology employs a C-axis aligned crystal (CAAC) structure (Fig. 6). Normally, a crystal is aligned in the A, B, and C axis. The CAAC structures are only aligned in the C axis, allowing the crystals to be employed in films. 5. Samsung demonstrated flexible displays at A crystal typically would have a cubic January's International CES in Las Vegas. structure. The technology may also



have applications outside of the display realm.

IGZO has some characteristics found in older CRT displays. The on-screen data is maintained for a short period of time even when power isn't provided. This is different from but functionally similar to the CRT phosphors, helping to reduce power consumption. And when mixed with a touch interface, IGZO displays drastically minimize the noise related to touch input for a more accurate touch response.

TOUCHING THE DISPLAY

Touch is critical to the smart-phone and tablet markets, with digital stylus activity taking off as well (see "The Year Of The

Digital Pen" at electronicdesign.com). A thinner display is useful for mobile devices, but accurate touch and stylus responses are key. Reduced noise from the display greatly improves accuracy and speed, providing a much better user experience.

Microsoft's Surface tablet is one place where displays, touch, and stylus are coming together. The Surface uses a conventional LCD along with Windows 8 and an Intel Core i5 processor. The Surface Pro and Surface RT platforms compete with Apple's iPad and the array of Android-based tablets like Amazon's Kindle Fire (see "Will Apple Take On The Kindle Fire And Nexus 7 Tablets?" at electronicdesign.com).

Capacitive touch systems dominate the smaller end of the display spectrum from smart phones through tablets and all-in-one PCs (see "Trends In Capacitive Touch Panels" at electronicdesign.

com). They mesh well with LCD and OLED technologies. The Kindle Touch and a few other e-readers used infraredbased sensors, but they have been eliminated by the falling costs of capacitive systems.

Resistive touch systems are used on displays up to 17 in. The technology tends to be used where capacitive touch systems won't always work such as with gloved fingers. Fujitsu's Feather Touch technology addresses two of the issues that had prevented resistive touch systems from being selected: pressure and multitouch support.

The four-wire system reacts like capacitive systems instead of requiring a significant amount of touch pressure. It



6. Sharp's planar C-axis aligned crystal (CAAC) structure can be used in films.

InO

(Ga, Zn) O

InO₂

(Ga, Zn) O

InO₂

(Ga, Zn) O

InO₂

Baseband & RF MIMO & Fading Rohde & Schwarz SMW 200A

The new vector signal generator for wideband communications systems Unique generator with baseband, signal calculation, fading, MIMO, AWGN and RF generation in a single box. Two paths up to 6 GHz. Full modularity. Convenient touch operation for confident control of the most complex signals. In 3G and 4G scenarios as well as in aerospace & defense applications.

- 160 MHz I/Q modulation bandwidth with internal baseband
- I All key MIMO modes, including 3x3, 4x4 and 8x2
- I All key communications standards
- Comprehensive help for efficient working
- Outstanding modulation and RF characteristics

R&S[®]SMW 200A. The fine art of signal generation

www.rohde-schwarz.com/ad/smw-mr





Watch the video



pinch and zoom. Resistive touch sysdemanding application areas.

like MyMultitouch's \$43,100 Alvero or maybe the latest police TV show. It

can also handle two-finger gestures like *(see the opening figure)*. The 84-in., 4K Ultra HD display has a multitouch tems fit industrial, medical, and other interface that can be tickled by up to 32 fingers at one time. It likely will find a At the high end, there are platforms home in museums, high-tech lobbies,



One less hat to wear.

Let us be your power expert. We understand that you don't have the time to master every aspect of electronic design. As a leading manufacturer of power supplies we are here to collaborate with you to ensure your next project is a success.



Novum® Advanced Power



Ac-Dc **Power Supplies**



Dc-Dc Converters



www.cui.com/PowerExpert

plugs into a 4K Ultra HD display card and has Windows 8 multitouch support. It can be mounted on the wall or as a table. The multitouch system is infrared-based.

THE NEXT GENERATION

Transparent displays and 3D displays also are emerging. Planar is delivering transparent displays like the 32-in. open-frame LT3200, and Crystal Display Systems offers Samsung-based transparent displays up to 70 in.

Transparent displays may look great on TV shows, but their primary use now is in retail merchandising, trade shows, points-of-sale, and museums (see "Transparent Displays Move From Sci-Fi Into Digital Signage" at electronicdesign.com). They are expensive, and brightness and transparency make them challenging for general use. They're designed to show what's behind them, though seeing what's behind the display can be rather distracting.

3D HDTVs that use active and passive 3D glasses are generally available. The marginal success of the 3D aspect of these products is really due to the limited 3D content. There also is additional cost because of the glasses, which are getting lighter but can still be annoying. The cost and annoyance would be less of an issue if the content were more compelling. 3D content on cable is almost non-existent and usually available at a premium.

3D display technology that doesn't require glasses has been steadily improving and on display at trade shows for a few years. It may eventually reach the consumer realm, but that is probably a decade away for large screens. It's more practical on small displays now. Hopefully the content will catch up by the time they are more common.

THE OUTLOOK

For now, LCDs will continue to dominate simply because of availability. OLEDs have crossed the horizon and represent a challenge to LCDs, making a designer's choice more of a challenge since different technologies must be considered. The tradeoffs aren't always apparent, and each has its strengths and weaknesses. ed
Jerry Fishman

Thank you.

For your intellect, your challenges, your never-ending support and for always expecting more. For your candor, wit and humor that inspired us all. For your respect and commitment to the global family that is ADI.

We are shocked and saddened by the loss of our CEO, colleague and friend. We extend our deepest sympathies to your family.

To paraphrase you—it's how you manage transitions that determines if you will prosper and last.

This transition will be the hardest of all. Because of you, we are up to the challenge. Collectively and individually, we are better... thanks to you.

The 9,000 employees of Analog Devices, Inc.



EngineeringEssentials

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

Application ND PRACI

Learn some basics about how LEDs work, how their manufacturers characterize them, and how circuits that drive and/or control them are designed.

EDs are the most efficient way to turn **ELECTROLUMINESCENCE** an electric current into illumination. When a current flows through a diode in the forward direction, it consists of surplus electrons moving in one direction in the lattice and "holes" (voids in the lattice) moving in the other. Occasionally, electrons can recombine with holes. When they do, the process releases energy in the form of photons.

This is true of all semiconductor junctions, but LEDs use materials that maximize the effect. The color of the light emitted (corresponding to the energy of the photon) is determined by the semiconductor materials that form the diode junction.

The latest high-brightness (HB) white LEDs are made possible by semiconductor materials that produce blue or ultraviolet photons. In addition to the diode, an HB package contains "yellow" phosphors on the inside of its lens. Some "blue" photons escape, but others excite the phosphors, which then give off "yellow" photons. The result can be tuned in manufacturing to produce "white" light.

Lots of engineering relates to controlling the quality of this light, with several ways to interconnect multiple LEDs to increase and manage light output. The general approach is to drive series strings with a constant current, but there are subtleties to interfacing the drivers with ac supplies and control schemes.

When current is flowing forward through a semiconductor junction diode, each time an electron and a hole recombine, energy is released as a photon. The color of the light (the energy of the photon) is determined by the energy band gap of the semiconductor material. Aluminum gallium arsenide (AlGaAs) yields red, indium gallium nitride (InGaN) yields green, and zinc selenide (ZnSe) yields blue.

The light from red, green, and blue LED diodes can be combined to produce white light, but with limited brightness. More commonly these days, HB white diodes combine a blue InGaN diode with a yellow phosphor, usually cerium-doped yttrium aluminum garnet (Ce3+:YAG) on the inside of the device package. Photons from the phosphor are perceived along with photons from the diode junction.

Broadly speaking, the eye perceives the result as white. More narrowly, it's a bit more complicated. There is a quantum effect called Stoke's shift in which a photon emitted by the phosphor has less energy than the photon it absorbed from the blue LED (Fig. 1). In an HB white LED, a fraction of the blue light is Stokes-shifted. LED makers take advantage of this phenomenon by using multiple phosphor layers with different photon energies to spread the emitted spectrum, which results in a more natural lighting effect.



LUMINOUS EFFICACY

LEDs for lighting are rated in terms of luminous efficacy: the ratio of luminous flux to electrical input power. It is expressed in lumens/watt. Lumens are defined in terms of the light from a source that emits a standardized level (one candela) of luminous intensity (which most people would call brightness) of over a solid angle of one steradian. Those units account for the sensitivity of a human eye by accounting for something called the luminosity function, which standards bodies have agreed represents the eye's response to different wavelengths.

In other words, the lumen part is calibrated to what has been decided is an average human's visual system. For a rough comparison, the sun has a luminous efficacy of 93, and an ordinary tungsten light bulb has a luminous efficacy of 15. The best HB LEDs today hit between 130 and 150, and the rate of improvement doesn't seem to be flattening out. That doesn't





1. High-brightness LED makers use the Stokes shift to spread the "yellow" portion of the device's light that comes from phosphors that are excited by the blue light from the diode. The activated material emits photons at a different wavelength than the photons it absorbs. By using multiple "yellow" phosphors, they achieve a higher CRI, at the cost of some luminous efficacy.

mean they're brighter than the sun, though. They're just more efficient than the sun's thermonuclear reaction at putting out photons at the wavelengths we can see. In fact, they're 10 times more efficient at it than old-fashioned light bulbs.

CRI & COLOR BINNING

LED improves the color-rendering index

colors when they are viewed under actual sunlight. For the LED maker, a high CRI implies lower luminous efficacy than single-color LEDs. But for naturallooking colors, good CRI is essential, so it presents an engineering tradeoff with luminous efficacy.

For individual white LEDs, "whiteness" varies from unit to unit, so LED makers sort and bin them to enable lighting designers to mix and match bins to achieve the precise flavor of white they want. This binning follows a model developed in the 1950s for then-new fluorescents. But month by month, the bins are getting tighter, making it easier to achieve a specified color with fewer LEDs. That's a good thing, because those steady improvements in luminous efficacy mean that it takes fewer and fewer LEDs to achieve a specified intensity of light output.

As mentioned, HB white LEDs work by combining blue-emitting LED diodes with phosphors that emit photons for different colors that when mixed add up to white light. According to Cree, most of the recent advances in HB white LED manufacturing arise from the techniques used for depositing the phosphor so it will be struck by the maximum number of primary photons and will, in turn, radiate the maximum number of secondary photons in an optimum pattern. In other words, just laying down a "glob" of phosphor on top of the diode junction isn't a very good approach. (An "optimum pattern" facilitates the use of lenses and reflectors in shaping the light from all the LEDs in the fixture.)

LED PACKAGING AND PRICING

Basic optical principles create a bit of difficulty in getting photons out of the diode semiconductor material, which tend to have high refractive indices. If a photon cannot cross the interface between the semiconductor material and the air (or vacuum) surrounding it, it's reflected back into the material and absorbed. If the semiconductor material were cubic in shape, it would only emit light more or less perpendicular to one face or another of the cube. (Think back to Physics 102 and the part of the chapter on optics that dealt with "critical angle.") So, simply dicing a wafer of LEDs and treating them as if they were just another semiconductor chip would be unsatisfactory.

If one weren't dealing with epitaxial diode materials deposited on a flat substrate, one might think of emulating a diamond cutter and faceting the material. But the more practical approach is to pot the LED in a transparent plastic material with a refractive index between the indices of the semi material Using multiple "yellow" phosphors with a blue or ultraviolet and air while shaping the glob of plastic into something more

(CRI) of the device. CRI is a measure of 2. This basic LED edge-lighting driver can be powered by 5 to 48 V dc. It uses dc-dc boost to provide how closely the colors of an object being voltage to a constant current driver and LED string. The design represents a constant current chopper illuminated artificially resemble those driver that provides a dc current with 10% ripple to an LED string used to edge light an LCD.







THINK Keystone Self Retaining LED Spacer Mounts

Designed for Bi-Lead T-1 LED's
Unique internal retaining teeth secures LED leads onto spacer
Reduce labor costs by preassembly of LED and Spacer
Internal tapered barrier design eliminates crimping or shorting of leads
Dual purpose boss design dissipates heat and eases post soldering clean-up
Available in lengths from .120(3.1) to .925(23.5) long

• No special tools required • Request Catalog M60.2



It's what's on the inside that counts.

Designers and Manufacturers Tel: (718) 956-8900 • (800) 221-5510 e-mail: kec@keyelco.com • Web: www.keyelco.com

There's a keystone in every great invention ... Follow, THiNK & Learn at:



spherical, or hemispherical, that increases the critical angle at both interfaces.

Logic devices have Moore's law, which has little validation except history. LEDs have Haitz' law, named after Roland Haitz, which says that commercial LED maximum light output doubles approximately every 36 months. Haitz' law leads to implications for designers of LED-based products: whatever the rated light output of the most expensive LED is today, it will be available at baseline prices a year and a half from now. Future products with the same light output will require fewer and fewer LEDs.

DRIVING LEDS

It seems as if driving LEDs ought to be simple. They're diodes, they have a certain forward voltage drop, and their light output depends on current, for which there is a do-not-exceed value for any given diode. That seems like a manageable set of parameters, doesn't it? But then it starts getting complicated. As with conventional diodes, LED current varies exponentially with the voltage, i.e., a small change in voltage can cause a large change in current. That's why, in most cases, LEDs are driven with constant-current sources.

Few applications use only a single LED, though. Whether it's for a screen-backlighting array or for LEDs in a streetlight or a replacement for an incandescent or fluorescent lamp, most designs need more than one LED. Therefore, one of the first decisions a designer must make is whether to drive the LEDs in series, in parallel, or as a parallel array of strings. Generally, it isn't a good idea to drive a number of single LEDs in parallel because that can lead to non-uniform current sharing, even when the LEDs are all rated for the same forward-voltage drop.

3. The Digital Addressable Lighting Interface (DALI) two-wire standard has all but totally replaced early dimmable control interfaces for tube lighting in office and industrial applications. This Marvell controller takes it a step further for smart buildings by including a ZigBee wireless interface.



Driving LEDs in series introduces the question of what happens when a single LED fails as an open circuit. That can be dealt with somewhat expensively by providing parallel Zener diodes or silicon-controlled rectifiers (SCRs) across each LED. SCRs are the more attractive choice because they dissipate less power if they have to conduct around the failed LED.

In a design using multiple parallel strings, including a separate driver for each string is obviously more expensive than using fewer drivers (ideally one) with sufficient output capacity. Even though an approach using parallel strings also tends to even out the current-sharing problem, it is still necessary to use a ballast resistor for each string to accommodate variations in forward voltage drop (V_f) across the diodes.

To calculate a resistor value, assuming a $\pm 10\%$ variation in forward voltage drop across the string and a need to match the currents in each parallel string to within $\pm 20\%$, start by assuming that for each string the sum of the LED forward drops, plus the voltage across the ballast resistor, should equal 80% of the nominal output voltage of the driver. From that, it's possible to calculate both the necessary ballast resistance and the maximum current capacity of the driver. An easier alternative is to buy the series/parallel string arrays matched and crossconnected, as in Philips' Luxeon Flood products.

DRIVING-CIRCUIT DESIGN EXAMPLE

To illustrate a common design approach in a backlighting application, consider this design from Endicott Research Group, where a constant current-chopper driver provides a dc current with low ripple to an LED string used to edge-light a graphic display (*Fig. 2*).

The pass switching device (P at the top of the LED string) is a P-channel FET that provides the current to the string and, in conjunction with the inductor, sense resistor, and boost voltage, establishes the chopping current and frequency. The dc-dc boost stage is a closed-loop boost supply that provides sufficient voltage to drive current to the LED string with at least 2 V of headroom.

The part of the diagram designated Section A shows a comparator and associated resistors that form a positive hysteresis circuit. It compares the voltage across the sense resistor to a known reference. Section B shows another comparator and associated resistors that buffer the Section A output to ensure proper hysteresis and provide drive to the pass device. Section C supplies LED on/off and dimming control. The +ENABLE input turns the backlight on or off, and +PW pulse-width modulates the chopper driver on and off for dimming.

SPECIAL CONSIDERATIONS

When a general lighting system requires a lot of power, then the first power-conversion stage, the ac-dc stage, gets interesting. That's because while it's a long way from the LEDs, the U.S. Department of Energy (DoE) and the European Union have made it clear that they want it to exhibit a very clean power factor, which is difficult because of that darned capacitance on the output of the rectifier bridge.

This is approached in different ways. The EU's IEC61000-3-2 specifies acceptable levels for the first 32 harmonics of the ac line frequency, while the DoE's Energy Star program (which is voluntary but enforced by the buying power of the U.S. government) specifies a power factor of at least 0.7. On top of that, real customers for general lighting applications demand a minimum power factor of 0.9, so that's what designers aim for.

That in turn requires a somewhat sophisticated flyback topology for the first stage, with operation in critical conduction mode. Subsequent stages of switching regulation, buck, boost, or buck/boost support a final stage that provides the drive to the string or parallel strings of LEDs. This is generally a switcher also.

Alternatively, it is possible to use linear regulators, which makes it less expensive to achieve the required overall efficiency. The output stage, in that case, could be designed to supply the full voltage needed by the sum of the string's forward voltage drops while dissipating less than a volt in its own pass transistors.

BUILDINGS AND STREET LIGHTING

Some LED-replacement-bulb dimming ICs are compatible with legacy triac controls intended for incandescent bulbs. The fundamental challenge in that environment is to present a load that looks like the resistive impedance of a tungsten filament and to convert the triac's time-chopped line-voltage ac waveform, which is based on the position of the dimmer's control knob into a series of duty-cycle controlled, constantcurrent dc pulses at a low voltage suitable for the screw-in LED replacement bulb or fluorescent tube. A further challenge is to achieve a power factor close to unity on the ac line.

Generally, all this is accomplished with a critical-conduction mode flyback ac-dc stage and a dc-dc back end, although some IC manufacturers manage to do it in one stage. Another differentiator between manufacturers is how the feedback is accomplished. Some IC makers have ways of getting around the need for optical isolation. The more interesting differentiators include designing ICs versatile enough to be used in all the different variations in other manufacturers' triac dimmers and reducing the number of external components so that unit cost is low and the entire circuit can fit into the base of the replacement bulb, even if the base of the bulb is much smaller than a conventional bulb base (*see the opening figure*).

All of this is only relevant if a circuit designer works for a company that makes replacement bulbs. A newer challenge relates to LEDs that are used for street lighting, parking garages, warehouses, and general outdoor lighting. There, the dimming requires a different approach, because it is being applied in new construction or large retrofit jobs to external LED fixtures that have been driven by external ballast circuits.

Traditionally, an analog interface called 1-10V has been used. It uses a simple 0- to 10-V dc control level to set brightness. But in these applications and in smart buildings, the Digital Addressable Lighting Interface (DALI) is replacing 1-10V. It is described in the fluorescent lamp ballast standard IEC 60929 under Annex E. The ZVEI committee of the German Central Association of the Industry controls the standard for electric and electronic Products within the Activity Group "DALI."¹

Of course, a hard-wired DALI connection is only the beginning. LED lighting in modern smart buildings is just as likely to be controlled by the ubiquitous ZigBee interface (*Fig. 3*). \blacksquare

REFERENCE

 For a detailed explanation of DALI, in English, go to http://www.dali-ag.org/c/ manual_gb.pdf.

MORE FROM DON TUITE

For more from Analog/Power Editor Don Tuite, check out his blog, Secondary Emissions, at http://electronicdesign.com/blog/ secondary-emissions and see:

- APEC 2013 Was Biggest Ever
- Super Bowl Blackout? Try Working With A Blimp
- What's All This About Van Gogh And LEDs?
- Dreamliners Shouldn't Smoke
- Amateur-Radio Emergency Services And Disasters

High Voltage to 500 VDC 0UT. High Power to 50 Watts.

Regulated/Isolated DC-DC Converters



New Input Voltages available 125-475 VDC (Consult Factory)

High Voltage, Isolated Outputs 100-500 VDC

Output Voltages from 500VDC High Power: to 50 Watts, Efficiency to 90%

Miniaturized Size package: 2.5" x 1.55" x 0.50"

Safe: Short Circuit, Over/Under Voltage, and Over Temp. Protected

Options Available: Expanded Operating Temperature, -55°C to +85°C Environmental Screening, Selected from MIL Std.883

Ruggedized for Operation in Harsh Environments

External Bias Control: For Charge Pump Applications

Custom Modules: Available to optimize your designs, Special Input or Output Voltages Available

Rely on Pico for Thousands of ULTRA Miniature, High Reliability DC-DC Converters, AC-DC Power Supplies, Inductors and Transformers

www.picoelectronics.com E-Mail: info@picoelectronics.com





www.mouser.com

The Newest Products for Your Newest Designs®



The widest selection of the newest products.

Over 3 million products from over 500 manufacturers.



Authorized distributor of semiconductors and electronic components for design engineers.



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



The Internet, the economy, and increasing regulatory issues dominate the Top 50 Electronics Distributors' list of concerns for 2013.

he largest distributors of electronic components in North America aren't expecting blockbuster growth this year, but they do anticipate a slow and steady upturn in business by the time 2013 is over. Following a 2012 in which many companies focused on internal investment and development, this year is turning out to be one of incremental growth and gaining market share, with most companies predicting midsingle-digit increases for the year.

"I think distributors spent 2012 working on their inventories, on their productivity, on their efficiencies," says Faris Aruri, vice president of corporate marketing for Sager Electronics, number 11 on SourceESB's 2013 Top 50 Distributors report (*see the table*). "Margin continues to be a challenge and I believe that companies devoted the bulk of the year addressing their structure, their strategy."

"I think this year is almost as difficult for predictions as last year," adds Jimmy Seifert, senior vice president at Newark element14, number six on this year's list. "Growth estimates are in the single digits, heavily leaned on the back half of the year."

As they battle the sluggish conditions here at home, electronics distributors are also sharpening their focus on the Internet, watching the global economy closely and trying to keep their fingers on the pulse of an increasingly active regulatory environment that has customers placing new demands on them almost daily. These regulations have come to a head in the last year as the federal government has clamped down on contractors supplying electronic equipment to the armed services in an effort to curtail the flow of counterfeit parts into the defense supply chain. Government contractors have naturally turned to their component suppliers for additional levels of quality assurance.

Despite these challenges, the top distributors are optimistic about the electronics industry's long-term outlook, helped largely by the growing amount of electronics in all aspects of daily life. The proliferation of smart phones and other handheld gadgets combined with the ever-increasing "smartness" of everything from refrigerators to cars and trucks makes the electronics supply chain a good place to be, distributors say.

GAME CHANGER: THE INTERNET

When asked about the greatest change in the industry since last year's Top 50 report, TTI's Michael Knight doesn't hesitate when he says "the Internet factor." Though electronics distributors have been steadily increasing their online investments and development for the last several years, Knight says 2012 stands out as a year of heightened investment and growing struggles about how to best integrate the technology into the electronics distribution model. The Internet's presence as a leveler and at the same time a disruption makes it a force difficult to manage, he adds.

"Last year, it seemed the Internet factor became more prevalent and more obvious," explains Knight, senior vice president, Americas for TTI, number four in this year's report. He points to new competition from non-traditional sources and distributors' pursuit of new ways to best serve customers online as key examples. He also points to pricing as a key challenge in the Internet age. A lack of Internet resale pricing guidelines is a particular sticking point, and one the industry will eventually have to confront.

"The Internet is the place where people go to shop," Knight explains. "I do think it's a growing challenge for distributors and OEMs [original equipment manufacturers], and we really need to give some thought to Internet pricing. Otherwise, we run the risk of creating a leak where there's just a tremendous amount of margin that can be sucked out of our business."

Newark element14's Seifert agrees that the Internet is an industry game-changer, most notably for its value as a research and information tool. As more and more engineers, hobbyists, and procurement professionals search for products online, distributors must be at the ready not only with

44

product and pricing information, but with the resources, tools, and technical support customers need to do their jobs, he explains.

"Just as the trend has exploded in the consumer world, it's becoming more prevalent in ours as well," Seifert says. Challenges aside, he notes that the trend fits well with the electronics distributor's role as a provider of information and solutions.

"It really bodes well with how we go to market to support customer needs," says Seifert, pointing to Newark's element14 online community in particular, which functions as a professional social media outlet for engineers, offering product information, technical support, and online forums where they can connect with peers.

Knight agrees that the collaborative spirit of the Internet offers a key opportunity for distributors to harness the technology's power.

"How best to integrate the Internet into our business, which is a more traditional model of people on people, that's the question," says Knight. "[We need to address] how best to inte-

grate the Internet element in a way that's good for our customers, good for our suppliers, and truly additive to our business."

STRUGGLE: THE ECONOMY

For many distributors, 2013 has been a year of pleasant surprises thus far. Most entered the year expecting little by

THE METHODOLOGY BEHIND OUR SURVEY

THE SOURCEESB STAFF and Penton Media's research department began our 2013 Top 50 Distributors survey in February, contacting hundreds of North American electronics distributor locations via e-mail and via our online sister publication, Globalpurchasing.com. Throughout February and March, the staff narrowed the online submission forms to 50, ranking each company based on total sales volume and ensuring that each had a major presence in the North American electronic components distribution market.

Each company in the list is ranked according to its total global sales volume, and all figures are reported in U.S. dollars. We used self-reported data from each company and verified the information against annual reports and earnings statements, where possible, as well as in follow-up interviews with some of the companies at the top of the list. Yet there's more than meets the eye with some of the companies at the top of our list.

Figures for Avnet Inc., ranked number one, and Arrow Electronics, ranked number two, include the sale of computer products, which comprise large segments of each company's business. Other companies in the list also sell computer products along with electrical products and equipment. As a result, figures in the "active" and "I/P/E" categories may not add to 100% for each top-ranked distributor.

Sales listed for privately held Future Electronics, number three, are based on SourceESB estimates.

Figures for Allied Electronics, number four, reflect its worldwide sales as part of Britain-based Electrocomponents plc, which also operates RS Components in Europe. The figure here is a company-provided, fiscal-year estimate for global sales. Allied's sales were roughly \$420 million in 2012. Likewise, sales for number six, Newark element14, reflect worldwide sales as part of its parent company, Britain-based Premier Farnell.

Our goal is to provide a comprehensive list of the largest electronic components distributors doing business in North America. We will begin compiling information for next year's report early in 2014.

We welcome your input as we develop next year's Top 50 Distributors report. Send your questions or comments to sourceESBeditor@penton.com.

way of growth and were surprised by better than anticipated bookings in the first quarter. Although few will point to the quarter as a harbinger of what's to come, most of the Top 50 remain cautiously optimistic about the industry outlook given the tough global economic climate they're struggling against.

"I can't see anybody being unhappy with the first quarter. I think it was much better than expected. But these are good short-term trends. I'm unsure they'll hold for the year," says Sager's Aruri. "The economic backdrop has improved marginally. It's in an area you'd term stable versus robust. But even in this atmosphere there's an opportunity to pick up market share for those who really achieved something internally over the last year."

Lindsley Ruth, executive vice president for Future Electronics, which is number three on this year's list, agrees. He says 2012 was an investment year for Future and that the company is already seeing the benefits of that internal focus this year.

"At Future, we're very optimistic about this year. Last year was a year of investment, and we're beginning to reap the benefits of that investment," Ruth explains, noting investments in new salespeople, inventory, and customer-focused programs around supply chain management and e-commerce. "We're seeing an uptick in demand, so we're gaining confidence as we



"I think this year is almost

as difficult for predictions

as last year," says Jimmy

Seifert, senior vice president at

Newark element 14. "Growth

estimates are in the single

back half of the year."

digits, heavily leaned on the



TOP GUNS.

IP&E SOLUTIONS FROM AVNET

Your top flight semiconductor cannot work alone.

You need world-class interconnect, passive and electromechanical components to support your design. Avnet's legacy in the IP&E business dates back to 1921 and is stronger than ever today. As a worldwide distributor of IP&E products, we source from the leading global manufacturers – and you can count on us to provide top quality components to meet your needs. We are ready to help your products take flight.

What can we do for you? www.avnetexpress.com



global & purchasing	2013 TOP 50 DISTRIBUTORS			
Company		2012 global sales revenue	% active*	% I/P/E*
1. AVNET INC. ¹		\$25.2 billion	43%	8%
2. ARROW ELECTRONICS INC. ²		\$20.4 billion	66%	20%
3. FUTURE ELECTRONICS ³		\$7.4 billion	N/A	N/A
4.TTI INC.		\$1.6 billion	41%	54%
5. ALLIED ELECTRONICS INC. ⁴		\$1.5 billion	5%	45%
6. NEWARK ELEMENT14 ⁵		\$1.5 billion	12%	50.4%
7. DIGI-KEY CORP.		\$1.4 billion	46%	54%
8. MOUSER ELECTRONICS		\$615.3 million	66%	34%
9. DAC/HEILIND		\$584.6 million	0%	100%
10. N.F. SMITH & ASSOCIATES, LP		\$465 million	59%	11%
11. SAGER ELECTRONICS		\$217 million	0%	100%
12. PEI-GENESIS INC.		\$214 million	0%	100%
13. AMERICA II ELECTRONICS		\$210 million	75%	24%
14. MASTER ELECTRONICS		\$163 million	0%	0%
15. POWELL ELECTRONICS INC.		\$120 million	0%	100%
16. BISCO INDUSTRIES INC.		\$116.3 million	1%	10%
17. RAND TECHNOLOGY INC.		\$104 million	40%	10%
18. FLAME ENTERPRISES		\$98.2 million	0%	100%
19. ELECTRO ENTERPRISES INC.		\$81.3 million	0%	100%
20. ELECTRO SONIC INC.		\$70.5 million	6%	67%
21. BEYOND COMPONENTS/NEDCO		\$60.3 million	0%	100%
22. HUGHES-PETERS		\$60 million	3%	95%
23. EDGE ELECTRONICS INC.		\$56.3 million	67%	9%
24. STEVEN ENGINEERING		\$50.6 million	1%	42%
25. SYMMETRY ELECTRONICS		\$46.1 million	99%	0%

go. We're looking at a year in the supply chain that will be up in the high single digits to low double digits."

Ruth points to customer-relationship management as another key investment area for Future Electronics. Salespeople are trained to focus on building relationships and streamlining operations throughout the channel, for instance.

"We like to move from a pure transactional relationship with the customer to more of a true partnership [in which we] share resources and help the customer increase their business," Ruth explains. "If we can help the customer with their customer, we're adding more value than the competition."

Looking at particular markets, many of the Top 50 say they anticipate continued growth in the automotive industry, resurgence in the medical markets, and growth in the aerospace segment, particularly commercial avionics. This will be offset by a downturn in military and defense, according to some. Smaller niche market distributors such as Sager are capitalizing on the trends.

"Sager focuses on the industrial, medical, and instrumentation markets," explains Aruri. "All of these markets have been either stable or growing, and I'm confident in our ability to pick up market share in this environment."

For larger players such as Avnet, who cast a wider net, the outlook is a bit more complex. Ed Smith, Americas president for Avnet Electronics Marketing, characterizes 2013 as steady and "not very exciting." Despite the tough market conditions, Avnet remains number one on SourceESB's Top 50 for the third straight year. Smith points to strength in automotive and aerospace industries and slowing conditions in military/ defense markets this year.

"When I look at the industrials, I think they're still pretty flat and not very exciting—and in the Americas, we're driven by that," Smith says. "So, [conditions] are not very exciting, but there are some glimmers of hope in automotive and aerospace."

Regionally, Avnet has seen growth in Mexico as customers begin to move manufacturing business from Asia back to the Americas, Smith adds. The re-shoring trend has been the topic of much industry buzz in the last year, and many say it's unfolding more slowly than they'd hoped. Large independent



We Do Business Your Way

Catalog



The **Allied Catalog** features thousands of products from 300+ world-class suppliers.

Online



Choose from more than two million product solutions at **alliedelec.com**.

Local Service



We are ready to assist you. Call your **local sales rep** at 1.800.433.5700.

Buy it your way from Allied Electronics

alliedelec,com | 1.800.433.5700





1.800.433.5700

© Allied Electronics, Inc 2013. 'Allied Electronics' and the Allied Electronics logo are trademarks of Allied Electronics, Inc. 🖸 An Electrocomponents Company.

alliedelec.com

A

global & purchasing	2013 TOP 50 DISTRIBUTORS		source esb		
Company		2012 global sales revenue	% active*	% I/P/E*	
26. CPN/DENELEX GROUP		\$41 million	0%	100%	
27. IBS ELECTRONICS INC.		\$40 million	45%	45%	
28. ASTREX ELECTRONICS INC.		\$36.6 million	0%	100%	
29. HAMMOND ELECTRONICS		\$36 million	2%	91%	
30. COMMODITY COMPONENTS INTERNAT	IONAL INC.	\$30 million	0%	60%	
31. DEE ELECTRONICS INC.		\$23.4 million	N/A	N/A	
32. AIR ELECTRO INC.		\$23.4 million	0%	0%	
33. PUI (PROJECTIONS UNLIMITED INC.)		\$23.3 million	12%	88%	
34. SMD INC.		\$22.8 million	5%	95%	
35. CRESTWOOD TECHNOLOGY GROUP (C	TG)	\$22.3 million	34%	54%	
36. HOUSE OF BATTERIES		\$22 million	0%	100%	
37. PHOENICS ELECTRONICS CORPORATIO	N	\$20.3 million	85%	0%	
38. MARCH ELECTRONICS		\$20 million	0%	100%	
39. KENSINGTON ELECTRONICS INC.		\$19.3 million	0%	85%	
40. COMPONENT TRENDS		\$15.1 million	65%	20%	
41.4 STAR ELECTRONICS INC.		\$15 million	50%	40%	
42. CUMBERLAND ELECTRONICS STRATEGIC	C SUPPLY SOLUTIONS	\$15 million	20%	60%	
43. AREA51-ESG INC.		\$14.1 million	48%	22%	
44. COMPONENTS CENTER		\$13 million	0%	100%	
45. IXES USA		\$12.9 million	80%	15%	
46. VIRGINIA ELECTRONIC COMPONENTS (VEC LLC)	\$12.7 million	N/A	10%	
47. ADVANTAGE ELECTRIC SUPPLY		\$10.5 million	50%	2%	
48. EAST COAST MICROWAVE DISTRIBUTOR	S	\$10 million	100%	0%	
49. MARINE AIR SUPPLY		\$10 million	0%	100%	
50. INDUCTORS INC.		\$9.6 million	0%	100%	

* Percentages may not add to 100

1 Figure includes sales of computer products

2 Figure includes sales of computer products

distributor N.F. Smith & Associates, number 10 on this year's list, expanded its operations in Guadalajara, Mexico, last year to accommodate increased business among its manufacturing customers in the region, for example. Company COO Matt Hartzell points to rising wages and housing costs in China in particular as a key reason some manufacturers are beginning to move or consider moving some manufacturing operations back toward North and Central America.

"You might see a continuation of that if labor and real estate prices continue to climb in China," he says.

For others, re-shoring is still a distant trend they hope is soon realized. TTI's Knight says the issue is still more talk than reality among his customers, but adds that he thinks such opportunities will eventually materialize.

"I am watching out for it like a hawk," Knight says. "I'm reading a lot about it. In our own business we're aware of some

3 SourceESB estimate

4 Company-provided fiscal year estimate

5 Figure reflects worldwide sales for Premier Farnell, Newark, element14

customers who are talking about doing it, but I can't say I can actually yet put my finger on a piece of business that is booking and shipping in North America that yesterday was booking and shipping in Asia or somewhere else. But I do have reason to believe it is coming. And that has good long-term implications for our economy and our industry."

NEW WRINKLE: REGULATORY ISSUES

Counterfeit components and the need for quality assurance is a growing concern among the Top 50 distributors. The issue transcends the authorized/independent line as customers seek quality assurance documentation on a range of levels from all their trading partners, placing new pressure and more work on distributors of all shapes and sizes.

The issue has been building since the late 2011 passage of the National Defense Authorization Act, which includes

INTRODUCING THE STAFF AT TTI......THOSE WHO SERVE YOU.....



PAUL ANDREWS PRESIDENT



PEGGY WHITE ACCOUNTING



RONNIE BRYAN CUSTOMER SERVICE



VINCE MANFREDINI SALES



RICHARD MATSLER SALES



TAMARA NICKELL PRODUCT



MIKE MORTON PRODUCT



JERRY STANLEY SALES



CHESTER SWINNEA WAREHOUSE



GARY PETASKY CUSTOMER SERVICE



SANDY HUNTER PRODUCT







IN 1971, TTI, (formerly Tex-tronics) HAD A \$500.00 INVENTORY AND ONE EMPLOYEE. TODAY, SEVEN YEARS LATER WE HAVE MULTI-MILLION DOLLAR SALES, A MILLION DOLLARS IN INVEN-TORY AND 32 EMPLOYEES. OUR SUCCES WAS THE RESULT OF ONE THING...WE GAVE OUR CUSTOMERS WHAT THEY EXPECTED...SERVICE!

OUR ANTICIPATION OF A BRIGHT FUTURE IS BASED ON OUR:

- ★ GOOD CUSTOMER RELATIONS
- ★ IN-DEPTH STOCK OF STANDARD AND NON-STANDARD PARTS
- ★ TWO LOCATIONS TO SERVE YOU TEXAS AND CALIFORNIA

We said it in '78, and it's still true today: TTI is committed to great customer service and in-depth stock. Today, we remain the best specialty component distributor in the business with 100 locations globally and a continued commitment to our employees, which is why so many of them are still here.



SAME COMPANY. SAME PEOPLE. ttiinc.com | 1.800.CALL.TTI new rules and regulations around counterfeit electronic parts found in the defense supply chain. The NDAA includes, or directs government agencies to include, new rules for defense contractors and impose steep penalties on those who supply counterfeit components to the military. As a result, contractors are seeking new assurances from their suppliers that the parts they are purchasing are authentic.

The issue has shined a light on the independent distribution market, and distributors such as N.F. Smith & Associates say they have seen a consolidation in that market that may signify a turning point for the industry. The heightened focus on quality is raising the bar among independents, and those that don't offer testing and other vital quality assurances simply aren't making the grade.

"We've seen a lot of consolidating among the independents and the cream has kind of risen," says Marc Barnhill, chief trading officer for N.F. Smith. "There aren't as many as there used to be, and we think that's a trend that will continue."

The focus on counterfeits is also affecting the

authorized distribution channel. Authorized distributors purchase products directly from the manufacturer or other authorized distributors, ensuring authenticity. But many large distributors are finding that some customers don't understand the authorized model and are placing new demands on those distributors as well, most notably seeking certificates of compliance with every

THE TOP 50 BY THE NUMBERS

SOURCEESB'S 2013 TOP 50 Distributors report bears considerable resemblance to the 2012 report, with 80% of companies featured last year returning to the list this year. Here's a look at some facts and figures on this year's list.

Distributors in the Top 10 last year maintained their status this year, although not necessarily in the same order.

Among returning distributors from last year's report, most saw their sales decline in 2012 (51%); 43% of returning companies experienced a sales increase, and 5% reported flat sales.

Among returning distributors, 36% said the percentage of their revenue from active components increased during the year, 16% said it decreased, and 48% said it remained the same.

Among returning distributors, 25% said the percent of their revenue from interconnect, passive, and electromechanical (I/P/E) products increased during the year, 43% said it decreased, and 32% said it remained the same.

The top-ranked distributor in our survey is also the oldest distributor on our list—Avnet Inc. was founded in 1921. The youngest distributor on our list is Component Trends, ranked number 38 and founded in 2003.



"At Future, we're very optimistic about this year. Last year was a year of investment, and we're beginning to reap the benefits of that investment," says Lindsley Ruth, executive vice president at Future Electronics. order. As a result, a group of authorized distributors is working through the industry's G19 Committee—an SAE International group that works to address prevention, detection, and electronics industry response to the counterfeit threat—to define authorized distribution.

Pete Shopp, senior vice president, business operations for Mouser Electronics, number eight, points to customers' growing demand for traceability, noting that some customers are demanding access to manufacturer packing slips to ensure authenticity, for example.

"It's all centered around making sure they have genuine parts, and that's understandable given the emphasis by the Department of Defense," says Shopp. "We're involved with several industry groups promoting authorized distribution and what that means. We even have someone working with the G19 committee trying to come up with a definition of authorized distribution."

The issue concerns Sager's Aruri, as well, particularly because it's beginning to spill over to non-defense industries.

"The need for [certificates of compliance] has crossed from the military world to the commercial world," says Aruri. "Customers have a need to cover themselves in this area, so they're starting to require [certificates of compliance] with every order. Distribution is not set up to do this. We all have traceability if we're requested to go back, but it's very challenging to do it [up front]."

Aruri says Sager is likewise involved in industry efforts to explain and promote the authorized channel.

"We're participating in any initiative that encourages people to buy from authorized distributors," he says.

OUTLOOK: MORE ELECTRONICS, MORE BUSINESS

Despite the challenges ahead, SourceESB's Top 50 Electronics Distributors say the long-term outlook is bright for the electronics supply chain. Avnet's Smith points to the growing amount of electronics in the automotive industry as a shining example, and he also notes that increasing demand for electronics in areas of limited growth, such as defense, are good reason for a positive view. Others agree, pointing to the proliferation of electronics in industrial applications, consumer markets, and more.

"Certainly, one of the reasons to be enthusiastic about being in the technology industry is the expansion of these [components] to other industries. Industrial applications, oil and gas, automotive—every month, every year these components get put into equipment that they weren't in the year before. Just look at the technology in your refrigerator," says N.F. Smith & Associates' Hartzell. "We are poised to always stay on top of wherever that market expands."

SourceESB's 2013 Top 50 Electronics Distributors report is featured each May in *Electronic Design*'s Distribution Resource section and online at *Globalpurchasing.com*.

We know you're looking for outstanding value, excellent customer service, proven market intelligence, engineering expertise, state-of-the-art distribution facilities, global reach, on-time delivery and the most reliable security of supply in the industry...

AND SO WIL

YOU GOT IT!



www.FutureElectronics.com

1-800-FUTURE-1

$\leq \Lambda$

Allied Electronics' new president Scott McLendon discusses his outlook for 2013 and beyond and the road to becoming a global business.

op 50 Distributor Allied Electronics (number five on this year's Top 50 List) has promoted Scott McLendon to president, replacing longtime leader Lee Davidson. McLendon has been with Allied since 2007, most recently serving as vice president of product management and marketing. We caught up with him to talk about his outlook for the electronics industry over the next few years.

ELECTRONIC DESIGN: You officially took over as Allied's president in April. How is the transition going, and what are some of your goals for this year?

SCOTT MCLENDON: So far, so good. In any new role, the first time you make the cycle through all the things [you normally do], it's tough, but it gets easier. We just went through our [2014 fiscal year] budgeting process and that was good. I'm very pleased with the feedback I'm getting internally from our employees as well. Some of my goals for the year: First and foremost is having everyone in the company get to know me and my philosophies on business and what I expect, Electronics. "I don't see anything in place... Any customer that has any sort and then for me to get to know them. I feel like I can win the minds of people through strategy and planning and education, but I also want to win the hearts of employees, too. So, I'm doing a lot

of traveling. We have 53 sales offices across the U.S., and I'm trying to get in front of as many of them as I can.

ELECTRONIC DESIGN: What are some of the greatest challenges facing companies like Allied in 2013?

MCLENDON: The positive side of the word challenge would be opportunity. I think our greatest challenge and opportunity in 2013 and beyond is how we transition from being a local independent [operating company] as part of Electrocomponents [to] being a very important part of a global company and what that means [for the future]. How do we support the vision of Electrocomponents through the brands of RS [Components]



and Allied? How do we transition from these local [operating companies] to really coordinating the effort across the globe? Certainly it's something that is front and center within our entire business, how we go from good to great and do that by becoming a truly global business.

ELECTRONIC DESIGN: The economy continues to trudge along. What are your short-term and long-term outlooks for the electronics industry?

MCLENDON: I still think that it's slow growth. If I look at all the macro-economic indicators and some that are more

specific to the industry we play in, they all If I look at all the macroare predicting slow growth. That would be for 2013 and 2014, actually. I don't see economic indicators and some that are more specific to the anything coming that's suddenly going to industry we play in, they all are impact that very negatively or, conversely, predicting slow growth. That positively. One of the things I think has had would be for 2013 and 2014, more of an impact than I first thought is the actually," says Scott McLendon, federal budget crisis and the sequester and the draconian budget cuts that have been put coming that's suddenly going to of tie to the federal, state, or local governimpact that very negatively or, ment is being dramatically affected. It's not just the [Lockheed Martins] and Raytheons and companies like that. It's also companies

that build controls for water and waste water treatment plants, for example. With this first round of cuts, there are programs that have been cut, there are things that have been delayed. I originally didn't think it would have as big an impact as it has. And with the Congress we have in place right now, I don't see it getting fixed. I think it's going to be status quo.

the new president of Allied

conversely, positively. ??

ELECTRONIC DESIGN: Allied also continues to invest in its Web presence. What are some recent developments and enhancements?

MCLENDON: Our philosophy as it relates to the Web is that whatever you can do offline you should be able to do online. "America II is one of the leading independent distributors of electronic components, stocking nearly **4 billion components** from more than **1,900 different manufacturers.** We have the components you need, when you need them. **That's the America II experience.**"

- Brian Ellison, President

America II stocks active, passive and electromechanical components from the world's top manufacturers. We buy directly from hundreds of manufacturers while our purchasing team sources components around the world to secure hard-to-find and allocated parts, giving us one of the largest inventories in the industry.

Experience the difference at America II.

800.955.5302 www.americaii.com/ed





Scan for more info.



We're committed to building all of the tools and we're listening to the voice of the customer, giving them what they want online to deliver a great customer experience.

ELECTRONIC DESIGN: Allied's Britain-based parent company, Electrocomponents plc, has said it wants to conduct 75% of its business via the Web in the next few years. What percentage is the company at now and how fast do you expect that to grow?

MCLENDON: Right now we're north of 40%. From a dollar standpoint it's much greater than that on the number of line items transacted. I think we can get to 50% in the next three years or so at Allied. But we still have a lot of customers that want the local touch, that still want to transact offline, and we're not going to force them to transact online. We do business the customer's way and we'll continue to do so. [Doing] business online does drive some efficiencies and can drive a bit of additional profitability, too. But we're not going to make a right-hand turn out of the left-hand lane just to drive a percentage. We've got the customer's best interests at heart.

ELECTRONIC DESIGN: Allied implemented a new enterprise resource planning (ERP) system last year, putting Allied and RS Components on the same SAP platform. Are the two divisions working together in new or different ways as a result? **MCLENDON:** Yes, definitely. RS and Allied are working more closely than we ever have. And it's our desire for both companies to go from good to great in their own rights. We have seven global priorities that we're focused on [to help us get there]. One of them depends on us having a global platform, so what we're working on first is around the global offer, which is critical to our success. Across the RS and Allied world you would think that our portfolios are common, but they're not. There's only about 10% overlap in the actual materials. We have many of the same suppliers, but [the portfolios look different]. Some of that you can understand because different areas around the world have different standards [and requirements]. But there shouldn't be that much disparity.

In the next five years, our goal is to have a pretty common [product] range around the world—somewhere around 75% common portfolio and the remaining 25% left up to local [needs]. This allows you to leverage your supply chain better, leverage your demand, make your global inventory visible to your customer base... and then you build your service proposition around that. Our vision is that if it's in your country, you have it in one day. If it's in your region of the world, it's two days. [And if it's] anywhere in the world, it's three days. The vision is there for how we globalize our offer in order to deliver a great customer experience.

ELECTRONIC DESIGN: What other issues are you most concerned about as you take on your new leadership role? MCLENDON: For me, personally, it is to continue to figure out better ways to engage our employees. I believe if we have happy and engaged employees they'll be in a better position to deliver a great customer experience, and that will mean more share of wallet from existing customers as well as attracting new customers. In the end, our top line will grow, our profitability will grow, and our shareholders will be happy with our performance.

SWITCHES GET SMALLER AND MORE SPECIALIZED

The industry's top distributors, as featured in our 2013 Top 50 Distributors Report, have been promoting some of the latest switch offerings from leading manufacturers online this spring. Key features include smaller size, better LED illumination, and harsh-environment characteristics.



op-ranked Arrow Electronics has been promoting NKK's SK series of miniature, antistatic, snap-in keylock switches, which offer secure mounting and are ideal for designs requiring space-saving, minimum-security switching. The housing and bushing are made of high-insulating, glass fiber reinforced polyester that can withstand 15 kV of electrostatic discharge, providing superior antistatic protection. A behind-panel dimension of 0.089 in. (22.7 mm) makes the series a perfect solution for applications that require high-density mounting and a short behind-panel depth.

Panel cutouts measure 0.039 to 0.079 in. (1.0 to 2.0 mm). The SK series' crisp and positive detent mechanism ensures accurate switch settings. The devices also are offered with solder lug and 0.071-in. (1.8 mm) quick connect for simple installation. SK series devices are available in a single-pole, three-throw circuit configuration, and the contacts are non-shorting (breakbefore-make). The three-position ON-ON-ON model has 45° indexing with keys removable in positions 1, 2, and 3. They come with two brass keys with nickel plating and an ABS resin handle.

Top-ranked Digi-Key is also featuring innovative switch designs, touting Arcolectric's antimicrobial switches, which boast built-in protection against a range of microorganisms. The switch-

THE ASTREX INTERCONNECT ADVANTAGE STARTS WITH:

smiths connectors



Astrex Electronics is the largest stocking distributor of Hypertac products. We provide the best value added solutions for military, aerospace, space, test and industrial applications.

HYPERTAC KVPX

KVPX Series connectors perform under the most severe conditions, giving them the edge in demanding critical applications for military, aerospace and industrial devices where failure is not an option.

- Fully Footprint-Compatible with VITA 46 and VITA 48 Standards
- Designed for 6.25 Gbps Data Rate Performance Scalable to 10 Gbps
- 100 ohm Impedance for Differential Pair Configuration
- Superior Signal Integrity and High Speed
- Reliable Hypertac[®] Hyperboloid Contact Technology
- Flexible Modular Design for Standard 3U, 6U and Custom

GET THE ASTREX ADVANTAGE!



Astrex: Putting it all together for you since 1961.



(800) 633-6360 www.astrex.net es are made with BioCote's silver ion technology during the molding process, providing protection against bacteria, mold, and viruses for the expected life of the product. BioCote antimicrobial protection reduces levels of microbes on surfaces by 99.99% and inhibits growth and formation of yeast. Applications include medical equipment, dental equipment, ovens, blenders, exercise equipment, and more.

Connector specialist and top-ranked distributor Heilind Electronics has been promoting the TL3210 series illuminated tact switch from E-Switch. The surface-mount (SMT) switch offers LED illumination in blue, red, green, yellow, white, and bi-color red/green options.

Measuring just 5.6 by 3.5 mm, it is the tiniest illuminated tact switch E-Switch offers. It comes in tape and reel packaging at 2500 pieces per reel. Applications include audio/visual, computer peripherals, consumer electronics, instrumentation, telecommunications, and medical equipment.

New product specialist Mouser Electronics now offers the Marguardt Series 3250 Harsh Environment Rocker Switches (see the figure). The switches are available with a variety of contact forms, switch functions, and actuators. These are lighted switches with up to four integrated LEDs available for a wide range of background and function illumination options. Current ratings

vary from 0.5 mA up to 20 A at 12 V dc or 24 V dc. Options include various cap shapes and colors, laser etched symbols, and accessories. Features include high dust and water protection with IP 66 and IP 67; a unique snap-action switching system; long life; a highly flexible and attractive design with various cap shapes and varnished colors; and a large variety of laser etched symbols.

ARROW ELECTRONICS	
www.arrownac.com	
DIGI-KEY	
www.digikey.com	
HEILIND ELECTRONICS	
www.heilind.com	
MOUSER ELECTRONICS	
www.mouser.com	

INDUSTRY LEADERS CONNECT AT EDS

Electronics executives meet in Las Vegas this month for EDS 2013.

op executives from electronic component manufacturing, distribution, and independent sales rep companies will meet in Las Vegas this month for the **Electronics** Distribution Show (EDS). The annual event draws roughly 5000 attendees and offers a venue for networking, news, and new product and service announcements as these channel partners seek to cement existing relationships and form new ones aimed at serving design engineers around the world.

EDS bills itself as the place "where the electronics industry connects," and for many that means finding new distribution networks or adding new product lines to the mix to expand their business

2013 AT A GLANCE

ALL OFFICIAL EDS ACTIVITIES WILL BE HELD AT THE COSMOPOLITAN HOTEL. LAS VEGAS.

MONDAY, MAY 6

Manufacturer and rep pre-scheduled meetings and receptions

Conference center setup

- Hotel suite meetings as scheduled
- 4 to 6:30 p.m. All Industry Reception: Mission Possible, Gracia Ballroom, third floor

TUESDAY, MAY 7

Manufacturer-distributor-rep pre-scheduled meetings in suites and conference center 9 a.m. to 5 p.m. Display area in the Conference Center open, Chelsea Ballroom, fourth floor

WEDNESDAY, MAY 8

6:45 to 8 a.m. ECIA-ERA Breakfast, Castellana Ballroom, third floor Manufacturer-distributor-rep pre-scheduled meetings in suites and Conference Center 9 a.m. to 5 p.m. Display area in the Conference Center open, Chelsea Ballroom, fourth floor

THURSDAY, MAY 9

7:30 to 8:30 a.m. EDS debriefing meeting, Nolita 2 Room, fourth floor Manufacturers, distributors, and reps are invited to meet with EDS management to share their comments regarding EDS 2013 and offer suggestions on improving future EDS events. Manufacturer-distributor-rep pre-scheduled meetings in suites and conference center

9 a.m. to 12:30 p.m. Display area in Conference Center open, Chelsea Ballroom, fourth floor

opportunities. It's held in Las Vegas each May, and this year marks the second time it is being held in its new home, the Cosmopolitan Hotel. Sponsored by the Electronics Representatives Association International (ERA) and the Electronic



INSTANT SOLUTIONS.

OBSOLETE, HARD-TO-FIND AND ALLOCATED PARTS AT YOUR FINGERTIPS – FROM CTG

Frustrated with long lead times or out-of-production parts? CTG has the answers.

CTG maintains one of the largest, most diverse inventories of electronic and electromechanical components, hardware and more – tested for authenticity and ready to ship. Our expert Quality Control and Counterfeit Avoidance Program is unrivaled in the industry.

With a comprehensive inventory of immediately available, quality-assured parts, CTG is the supplier that buyers depend on for fast solutions in obsolescence and allocation.

We make it as easy as one-two-three. www.CTG123.com





One Odell Plaza, Suite 139, Yonkers NY 10701 (914) 779-3500 • info@ctgnow.com



LEADING SUPPLIER OF QUALITY-ASSURED PARTS

Components Industry Association (ECIA), the conference is scheduled for May 6-9.

First and foremost, EDS is a place where electronics manufacturing and distribution executives get together for one-onone business meetings, but the show also features some group gatherings aimed at strengthening the industry as a whole. The All-Industry Reception on Monday evening, May 6, and the ECIA-ERA Breakfast on Wednesday, May 8, bring attendees together for networking as well as industry updates.

EDS is also a place to groom the next generation of electronics industry leaders. Supply chain students from colleges and universities across the country attend each year to see the channel at work and meet potential employers. In the months leading up to this year's event, EDS organizers were touting Project Host, a 20-year-old program aimed at bringing students and executives together. Participating companies pair their executives with students who then attend their EDS business meetings for half-day sessions. Students get the chance to see the manufacturer/distributor relationship at work and executives get a glimpse at what some of the country's top supply chain programs are churning out.

"The more we can get the younger generation to participate, the better," said Chuck Delph, senior vice president-director of sales for Avnet Electronics Marketing. "It's not only great for the show, but great for our industry as well."

For further information about EDS 2013, including details about registration, who's coming, and additional conference events, go to *http://edsconnects.com*.

DEFENSE SPENDING TOPS DISTRIBUTORS' CONCERNS

Leading distributors maintain mixed views on how military budget cuts will affect the electronics industry in 2013.

he sequester and looming budget cuts to military and defense spending held the attention of the Top 50 distributors this spring as they waited to see how deep the cuts would go. For some of these distributors, the waiting game had yet to play out, while others said they'd already begun to feel the effects of shrinking budgets.

Avnet Electronics Marketing is already feeling a slowdown. Company president Ed Smith says that its defense sector sales were down by single digits as of March and that he expects a continued struggle in the market this year. Uncertainty is a large part of the problem, as defense contractors took a conservative approach to the market early in the year since they did not know which particular programs or departments would be most affected by the sequester in the long term.

"It's already had an effect, but I don't think it's the complete effect until all the information is out there," says Smith. "I think there's still a story to be written there. And whether it's positive or negative, I'm not sure."

A bright spot is the increased electronics in military equipment today, a trend that isn't going away and ensures opportunity in the long run

despite the pending cuts, Smith adds. Commercial avionics represents an even brighter opportunity under the current conditions, he says, as does the automotive market.

"All the fleets having to get younger has driven nice growth in aerospace," Smith adds. "When I look at the industrials, I think they're still pretty flat and not very exciting. And in



"All the fleets having to get younger has driven nice growth in aerospace. When I look at the industrials, I think they're still pretty flat and not very exciting. And in the Americas we're driven by that," says Ed Smith, president of Avnet Electronics Marketing. "But there are some glimmers of hope in automotive and aerospace." the Americas we're driven by that... but there are some glimmers of hope in automotive and aerospace."

Allied Electronics' president Scott McLendon says the defense budget cuts have had more of an impact on the industry than he expected and that he doesn't see the situation improving any time soon (*see "McLendon Prepares Allied For Global Challenges In A Slow Economy," p. 52*). He points to large and small contractors tied to federal and state government business for a wide range of projects as being particularly hard hit.

"Any customer that has any sort of tie to the federal, state, or local government is being dramatically affected. It's not just the [Lockheed Martins] and Raytheons and companies like that. It's also companies that build controls for water and waste water treatment plants, for example. With this first round of cuts, there are programs that have been cut, there are things that have been delayed. I originally didn't think it would have as big an impact as it has," he says of the sequester in particular. "And with the Congress we have in place right now, I don't see it getting fixed. I think it's going to be status quo."

Michael Knight, senior vice president of the

Americas at TTI Inc., holds a different view. He says it's unsettling that no standout market or technology is driving industry growth this year, but that he's pleasantly surprised by the strength of some industry segments—and defense is one of them.

"From my viewpoint, there's really no standout—no barnburner region, application, technology, or end market segment.



Sager Electrical Supply, Congress St., Boston, MA.

We've been distributing confidence the same way since 1887.

One customer at a time.

Technology changes. The ability to adapt, cost-effectively and confidently doesn't. Our products have kept pace with the times. Our service has also evolved... tried, tested, and improved time and time again. We have built a reputation for providing solutions, not just fulfilling orders. Field sales representatives and application engineers who listen and *know* your business can help grow your business. We deliver expert, pro-active advice, and support your time-to-market issues with a quick, well-qualified response. Competence creates confidence. Sager continues to give your company that one timeless competitive edge. Contact your local service center or Sager sales representative at **1.800.SAGER.800** or visit us at **www.sager.com**.

Sager. Distributing Confidence.



service



Sager Electronics is a wholly-owned subsidiary of TTI Inc., a Berkshire Hathaway Inc. company.

© 2013 Sager Electronics 19 Leona Drive, Middleborough, MA 02346-1404



It's really more about pleasant surprises. I'm pleasantly surprised how well defense electronics is holding together, for example. And I'm pleasantly surprised how well the transportation market is holding together," he says. "Distribution has a really nice market there these days."

Mouser senior vice president of business operations Pete Shopp maintains a similar view, pointing to growth among small electronics manufacturing service (EMS) providers and OEMs serving the defense and aerospace sector. Defense budget cuts had not affected Mouser as of mid-March, he says, but he doesn't rule out a slowdown at some point this year.

"We're still seeing a lot of growth in RF communications, industrial, and in the aerospace/defense markets," Shopp explains. "The budget cuts to defense are not affecting us so far. There's still design work going on. But small manufacturers will eventually have to slow down."





he globalization of today's supply chains is presenting new challenges to operations managers, purchasing professionals, and design engineers alike. Distributors play an important part in the process, offering the products, technologies, and services those professionals need to develop leaner and more productive supply chains.

We spoke with Lalit Wadhwa, vice president of global supply chain operations for Avnet Electronics Marketing, about some of the greatest issues facing supply chain professionals today and how companies can work together to mitigate risk and develop more resilient global supply chains. He is a 20-year Avnet veteran who specializes in seamlessly moving supply chain operations from one region of the world to another across multiple sites.

ELECTRONIC DESIGN: What are the greatest obstacles facing operations executives in supply chain visibility?

LALIT WADHWA: There are four or five things happening for high-tech companies. You have globalization, as most companies are now engaged in manufacturing products in different parts of the world. This is not limited only to the supply chain or the manufacturing piece of the equation. We are now seeing design being done in different parts of the world. So now you have multiple companies attempting to collaborate to create a product, and they are operating in different parts of the world, on different systems, and in some cases in different languages. This introduces new challenges.

There are also things like the rate at which demand changes for a product when it's launched. We must also look at things like shrinking product lifecycles and rate of obsolescence. These issues also present new challenges. And I would say one

Coming soon to a market near you!

Entoden 21 LAF



1-888-7FAI-NOW www.FAlelectronics.com additional criterion that creates challenges moving forward is sustainability and concerns around regulatory issues. Addressing these challenges adequately requires visibility across the entire supply chain.

ELECTRONIC DESIGN: How has globalization complicated supply chain management, and what other, similar factors must operations executives take into consideration?

WADHWA: Beside the points that I just shared, there are a couple of other things. The first is extended supply chains, multiple partners, and an explosion of data. What to do with this data is something I don't think too many companies in the high-tech arena are aware of. This explosion of data continues to be a significant challenge and complication of the globalization.

[Design challenges are also an issue.] It's an understated but very critical fact: How you design your product ends up affecting your supply chain. The design chain has a very significant impact on your supply chain. I'm not sure if everyone looks at this in a very careful manner. We can have customers who are choosing components from manufacturers or who are choosing components for their new products and the components are at the end of their lifecycle. By the time the design is complete, they may face problems sourcing some of the components if enough focus hasn't been put on the component availability and the manufacturer's roadmap in the design chain. I think there is some room for improvement here in the industry.

From a design chain perspective, our focus is to share data with customers—share with them where in the overall lifecycle that product is and provide predictions for future pricing and availability, and also to provide information on alternate or equivalent products that can be used if that product really goes EOL [end-of-life].

ELECTRONIC DESIGN: What solutions are available to help companies proactively manage their supply chain risks?

WADHWA: From an Avnet perspective, this is something that we have been doing actively over the last decade. Loosely, I'll refer to our current set of solutions, which are very widely adopted by our customer base. I'll refer to them as legacy solutions. In the legacy category, what we continue to do is provide customers access to a secure Web portal into their supply chain that links back to Avnet.

What that fundamentally means is the customer can log into a Web portal and extract information from Avnet's Web portal. They look at data points such as what inventory Avnet is holding [for them] and in what parts of the world, what is its age, what is the backlog. And they can ask, "What is my cost across different parts of the world? Do I have excess inventory in one



March Electronics is an authorized distributor of TE Connectivity products now including Microdot & Nanonics connectors and Raychem brand tubing products.





A Woman Owned Small Business



(800) 444-6056 www.MarchElectronics.com

MICRODOT, NANONICS, Raychem, TE Connectivity and the TE connectivity (logo) are trademarks of the TE Connectivity Ltd. family of companies. $\$

part of the world and do I have it somewhere else?" These data points have been made available to customers through Supply Chain Central, our secure Web portal.

Customer needs have become far more complex. In the evolving set of solutions, what Avnet has done is partner with [cloud-based software solutions provider] E2open and created solutions that are cloud based. These solutions bring together all partners in the supply chain on a single cloud-based platform. So, theoretically, you have information across the supply chain in one single system. These are some ways we are meeting the complex demands of our customers.

ELECTRONIC DESIGN: What benefits should companies expect from increasing their supply chain visibility?

WADHWA: First, look at the strategic benefits—supply chain visibility across an extended supply chain that circles the globe. For many of our customers, this is the fundamental building block for driving supply chain maturity. Once you have that ability, companies can take up things like cost-to-serve analysis, cost-to-serve optimization, risk identification, risk management, response management, and supply chain segmentation. These are things that companies wish to do to improve their profitability and help them deal with risk in the global supply chain. In a global environment, you need to have

the fundamental building block of supply chain visibility in place before you can address all these things.

ELECTRONIC DESIGN: What are the next big steps needed to improve extended supply chains?

WADHWA: Number one, many companies have yet to leverage the significant benefits that come into play when gaining supply chain visibility. Getting there is goal number one because the benefits are real, measureable, and significant. Also, identifying the risks in your supply chain, understanding that if an event occurs, how do you recover? Those are things that many companies in the high-tech arena have yet [to integrate].

ELECTRONIC DESIGN: Any closing thoughts?

WADHWA: This is not theoretical stuff. The benefits of all of this are very real, very measurable, and very significant, so customers will want to take the next leap into building resilient supply chains. Resilient supply chains are essential to growth. You can continue to have non-forecast events. The only way to mitigate risk is to understand those risks. The only way to understand those risks is to understand your supply chain. Our goal continues to be to educate our customers and to help them where they believe they need help—and also by helping them execute their overall plan related to these issues.



800-428-4844 • sales@cpndenelex.com • www.cpndenelex.com

CHITIZ MATHEMA AND CHRISTIANA WU | CYPRESS SEMICONDUCTOR cit@cypress.com, christiana.wu@cypress.com



Smart component selection can help you reduce the cost of the capacitive touchscreen in your mobile products.

CAPACITIVE TOUCHSCREENS HAVE increasingly become mainstream and are no longer a novelty. Their adoption continues to grow as devices such as smart phones and tablets ship by the millions. But now that they are ubiquitous, consumers are more reluctant to pay a higher premium for the technology.

To maintain profit margins in this competitive environment, OEMs must reduce device cost—and the touchscreen module is one of the most expensive components in touchscreen-powered devices. By using the right panel stack-ups and patterns, displays, materials, routing, and controller, designers can reduce their system costs.

COVER LENS AND TOUCHSCREEN SENSOR

A standard touchscreen system comprises a projected capacitive touchscreen sensor laminated to a protective cover lens, a bonded flexible printed circuit (FPC) with the touch-screen controller mounted to it, and a display (*Fig. 1*). The FPC connects the touchscreen controller to the host processor. The display sits under the touchscreen sensor and is usually separated by an air gap or is directly laminated.

The cover lens is the topmost layer of the touchscreen system. Its cost can vary widely depending on material type (glass or polymethylmethacrylate, or PMMA), special coatings (oleophobic, hydrophobic), decorative ink, or number of drill holes for cameras or sensors. PMMA, a cheaper, lighter, and shatterresistant alternative to the more durable and optically transmissive glass option, can reduce these costs by up to 50%.

However, PMMA sensors may suffer from lower signal sensitivity. Also, PMMA is more flexible than glass, so it can exhibit panel-bending issues when a finger or other object presses down with significant force. Panel bending can cause false and inaccurate touch reporting. Still, a glass substrate or an additional shield layer in the touchscreen sensor can prevent panel bending, so the cover lens material must be precisely considered for any touchscreen sensor stack-up (*Fig. 2*).

Touchscreen sensors are complex structures. They are built by sputtering indium tin oxide (ITO) onto a glass or polyethylene terephthalate (PET) substrate and then etching away a proprietary pattern into the ITO. The patterns and structures that compose each sensor layer are custom to the design needs of the system.

Standard touchscreen designs typically use two-layer ITO touchscreen sensors such as the MH3 and diamonds sensors in Figure 2 to achieve good accuracy, linearity, and multi-touch performance. Two-layer sensor designs use either glass or polyethylene terephthalate (PET) substrates. PET is cheaper and provides better display noise immunity but will suffer from slight optical clarity degradation. Ultimately, the most effective method of lowering touchscreen sensor costs is to reduce the number of stack-up layers.

By integrating single-layer sensors, system designers can decrease sensor costs by up to 50%. Fewer layers—substrate, ITO, optically clear adhesive (OCA)—help touch-panel vendors trim material and tooling costs. Handling fewer layers also improves manufacturing yield. Low-cost single-layer touchscreens use a single PET substrate with a simplified proprietary pattern with good optical transmissivity.



CHITIZ MATHEMA is a product marketing engineer for TrueTouch touchscreen solutions at Cypress Semiconductor Corp. He has nine years of experience in design and product marketing. He holds an MSEE from Mississippi State University.



CHRISTIANA WU is a product marketing engineer for TrueTouch touchscreen solutions at Cypress Semiconductor Corp. She holds dual BS degrees in electrical engineering and human-centered design & engineering from the University of Washington.



I. A standard capacitive touchscreen system comprises a projected capacitive touchscreen sensor laminated to a protective cover lens, a bonded FPC with the touchscreen controller mounted to it, and the display.



A Robust 10MHz Reference Clock Input Protection Circuit and Distributor for RF Systems – Design Note 514

Michel Azarian

Introduction

Designing the reference input circuit for an RF system can prove tricky. One challenge is maintaining the phase noise performance of the input clock while meeting the protection, buffering and distribution requirements for the clock. This article shows how to design a 10MHz reference input circuit and optimize its performance.

Design Requirements

RF instruments and wireless transceivers often feature an input for an external reference clock, such as the ubiquitous 10MHz reference input port found on RF instruments. Many of these same systems include a provision to distribute the reference clock through the system. Figure 1 shows a common scheme, where the reference clock supplies the reference input to two distinct phase-locked loops (PLLs).

A well-designed, robust input would accept both sine and square wave signals over a wide range of amplitudes. It would maintain a constant signal level drive to the destination PLL inputs inside the system, even in the face of varied inputs. The exposed-to-the-world reference input port should have overvoltage/overpower protection. Most importantly, the inevitable degradation in the phase noise performance of the clock signal should be minimized.

Design Implementation

The LTC[®]6957 is a very low additive phase noise (or jitter) dual-output clock buffer and logic translator. The input of the LTC6957 accepts a sine or a square wave over a wide range of amplitudes and drives loads at constant amplitude.





The LTC6957 offers various output logic signal options: PECL, LVDS and CMOS (in-phase and complementary), allowing it to drive a wide range of loads. Figure 2 shows a 10MHz reference input circuit using the LTC6957-3, which produces two in-phase CMOS outputs.

The transformer shown in Figure 2 serves several functions. First, in conjunction with the Schottky diodes following it, it offers input overpower/overvoltage protection. The diodes limit the AC voltage seen by the LTC6957-3. The WBC16-1T can handle up to 0.25W power $(3.5V_{RMS} \text{ into } 50\Omega)$.

The transformer also isolates the connector ground which is usually tied to the chassis of the RF system from the internal analog ground of the system.

Furthermore, the transformer applies a voltage gain to the incoming signal, thus steepening the edges seen by the LTC6957-3. This helps reduce AM-to-PM noise conversion, which in turn limits phase noise degradation, especially with small input signals. The WBC16-1T has a voltage gain of four. It is possible to rely on the transformer's voltage gain of four, as opposed to its maximum and ideal power gain of one, because the LTC6957-3 presents a high impedance load to the transformer.

R1 and R2 can be adjusted in combination to match the input port to 50Ω . For small input signals, the diodes are off and the transformer sees a load of 804Ω in Figure 2. That load is reflected to the input as approximately 50Ω because of the transformer's primary-to-secondary impedance ratio of 16. For larger input signals, the Schottky diodes turn on, reducing the 604Ω resistance to nearly a short circuit. This degrades the reference input return loss—a problem that can be avoided by adjusting the values of R1 and R2, but there are tradeoffs to doing so.

For large input signals, the input return loss can be improved by increasing R1's value, and reducing R2's

^{∠ ,} LT, LTC, LTM, Linear Technology, and the Linear logo are registered trademarks of Linear Technology Corporation. All other trademarks are the property of their respective owners.



Figure 2. 10MHz Reference Input Circuit Employing the LTC6957-3 with Front-End Protection, Shown with Test Signal and Phase Noise Measurement Set-Up

value, such that their combined series resistance remains around 800Ω . However, since R1 appears in series with the signal, it adds noise to it. A larger R1 comes in combination with a smaller R2, resulting in a smaller portion of the signal appearing at the LTC6957-3's input, further degrading the phase noise performance. In other words, the designer can trade off phase noise performance for input return loss by playing with the values of R1 and R2. The values shown in Figure 2 strike an overall balance of these two performance metrics.

The AC-coupling capacitor separating the connector from the transformer in Figure 2 offers input protection from DC sources.

The LTC6957-3 has internal lowpass filters that can be selected via the FILTA and FILTB pins. This option strategically limits the bandwidth of the LTC6957's first amplifier stage, and hence, the additive phase noise of the circuit, especially when the input signal is weak as shown below.

Performance

A 10MHz OCXO is connected to the input of the circuit via a step attenuator as shown in Figure 2. The reference input signal is varied between –10dBm and 10dBm while measuring the phase noise floor at the output of the LTC6957-3 with different input filter settings using the Agilent E5052A signal source analyzer. Figure 3 shows the phase noise floor of the 10MHz CMOS clock output of the LTC6957-3 measured at a 100kHz offset.

If the amplitude of the externally applied 10MHz reference signal is not known, pulling FILTA low and FILTB high yields good overall phase noise performance as

Data Sheet Download

www.linear.com/product/LTC6957

shown in Figure 3. Nevertheless, performance can be optimized if the applied signal level at the input is measured and appropriate filter settings are applied.

The R1 and R2 values chosen in Figure 2 result in an input return loss of -9dB when the reference input's power is 0dBm into 50Ω . The return loss is better at lower input powers and worse at higher powers.



Figure 3. 100kHz Offset Phase Noise Floor at the Output of the LTC6957-3 vs 10MHz Reference Input Power Level for Various LTC6957 Filter Settings

Conclusion

A robust, high performance 10MHz reference input circuit is built around the LTC6957-3. Features include a wide range of input signal type and level compatibility, protection and clock distribution with limited phase noise degradation. The circuit's phase noise and input return loss are evaluated and optimized. The LTC6957-3 simplifies the design process while achieving excellent overall performance.

For applications help, call (408) 432-1900





From a performance standpoint, single-layer sensors feature lowered accuracy and linearity and limit the number of supported finger touches (usually one finger or two fingers only). These low-cost single-layer sensor solutions are ideal for low-end smart phones and feature phones.

Designers who previously used resistive touchscreens or no touchscreens should find this stack-up option well suited to their design and budget needs. Compared to resistive touchscreens, single-layer capacitive touchscreens offer distinctive advantages, including improved optical clarity, lower power, increased durability, and enhanced user experience.

Single-layer multi-touch solutions such as Cypress's SLIM (Single-Layer Independent Multi-touch) can cut costs as much as 40% compared to dual-layer sensors. Single-layer sensors present slightly lowered performance but excel in supporting the thinnest form factors. Single-layer multi-touch sensors also support thin border or borderless touchscreen sensors, thus extending the touchscreen active area. Designers who are interested in reducing both cost and thickness can consider single-layer sensors as a viable option.

Smaller screen sizes are significantly more economical. The size of the active area will impact touchscreen costs. Clearly, system designers must consider all paths to optimize panel design and selection.

FPC DESIGN

Another avenue for reducing device costs is through FPC design. The FPC connects individual sense input/output (I/ Os) from the touchscreen panel to the touchscreen controller and from the touchscreen controller to the host processor.

FPCs can be active or passive. In active FPCs, the touchscreen controller and any other required external components such as resistors and capacitors are mounted onto the FPC itself. In passive FPCs, the FPC only includes routing traces and the touchscreen controller, and external components are mounted onto a printed-circuit board (PCB).

Whether active or passive, FPCs can be routed in several ways. The more efficient and versatile the routing, the easier it is for other hardware components to be integrated. However, costs do increase with the number of layers required for routing. Thoughtful routing on a single layer will help minimize FPC costs. Single-layer routing also has considerable advantages for both signal integrity and compact FPC design.

DISPLAYS

In a touchscreen system, the projected capacitive touchscreen sensor sits on top of the display. Displays are inherently noisy, which can cause display noise to directly couple with the touchscreen sensor (Fig. 3). This diminishes touch



Temperature Compensated Accuracy +/- 3ppm @ 25°C SPI & I²C Interface Sizes: C3: 3.7x2.5x0.9mm, C2: 5.0x3.2x1.2mm

Micro Crystal AG

Muehlestrasse 14 CH-2540 Grenchen Switzerland MICRO CRYSTAL SWITZERLAND SAIES@microcrystal.com www.microcrystal.com

A COMPANY OF THE SWATCH GROUP

sensitivity and produces false touch activation. Good design choices can mitigate display noise and have a substantial impact on performance and cost.

To block display noise, the industry traditionally implements an additional ITO "shield" layer between the display and touchscreen sensor. Though effective, the shield layer adds cost and increases the thickness of the touchscreen module. An alternative is using a tiny air gap, typically between 0.2 mm and 0.5 mm, to separate the display from the touchscreen sensor.

An air gap is more cost-effective than a shield layer, but it also increases the touchscreen module thickness, which is becoming undesirable to OEMs looking to build sleeker and thinner devices. A more important design choice will be the selection of the display itself.

Currently the most popular displays used for mobile phones and tablets are thin-film transistor (TFT) LCDs, which are commonly available in two flavors: dc common voltage (DCVCOM) and ac common voltage (ACVCOM). The difference is the method used to drive the common electrode layer (VCOM). Another increasingly popular display in high-end devices is the active-matrix organic LED (AMOLED) with its



3. Displays are inherently noisy. Noise from displays can capacitively couple with the touchscreen and diminish touch performance.

wide viewing angles, improved brightness and contrast, lower power consumption, and reduced thickness.

AMOLEDs emit very little display noise and are among the quietest displays, but they are expensive. DCVCOM is also generally a quiet display and expensive. In contrast, ACVCOM is high-noise but relatively cheap. The choice of a display greatly relies on the device's intent for end customers.



The target application will deem the hardware and performance that are suitable for its customers.

TOUCHSCREEN CONTROLLER

Though it isn't as expensive as the display or the touchscreen panel, the choice of the touchscreen controller has the most impact in terms of touchscreen system performance. The touchscreen controller incorporates capacitive sensing and processing technology to resolve finger touches and gestures by reporting their location and behavior to the host processor.

When a finger is placed on a projected capacitive touchscreen, the touchscreen controller detects a change in capacitance and converts that information into digital values. This digital conversion is further processed using sophisticated touch resolution algorithms within the touchscreen controller before passing on touch coordinates and other relevant data to the host processor.

Noise-sensitive signals are a major technical challenge for touchscreens. Controllers that employ high-quality analog front ends, built-in noise handling capabilities, and sophisticated processing algorithms is mandatory. With touch becoming the user interface of choice for many consumer electronic devices, the quality of touchscreen controllers will directly impact the end product user experience. Choosing the right touchscreen controller is integral to achieving performance and cost benefits.

A controller that provides high signal-to-noise ratio (SNR) and effective noise handling will be able to compensate for the signal strength degradation that comes from noise sources, such as a cheaper PMMA cover lens or a noisy ACVCOM display. To help optimize the performance of low-cost and multi-touch single-layer sensors, touchscreen controllers must supply compatible processing algorithms. In addition, the cost benefits of single-layer FPC routing can only be realized if the touchscreen controller pinout allows for flexible routing design.

Touchscreen controllers can also reduce system costs through some of the advanced features they support. For example, most touchscreen controllers interpret water on a touchscreen as a finger touch because the mutual capacitance signatures of water and a finger are similar. To solve this problem, touchscreen panel vendors can add an expensive layer of hydrophobic coating to the cover lens.

When drops of water land on the cover lens, the coating helps to break them apart into smaller droplets so they no longer register as touches. All the same, a touchscreen controller that enables water rejection natively through the use of its hardware and firmware features can detect and reject water on the touchscreen with built-in algorithms and can save the OEM additional coating costs.



www.4pcb.com

DARVIN EDWARDS | CONTRIBUTING TECHNICAL EXPERT rvin@ti.com

GREAT THERMAL DESIGN ENHANCES LED RELIABILITY

LED market penetration will continue to grow as costs decline and efficiencies improve. Thermal design will play a vital role in ensuring the market's growth.

195 180 165 150 135 120 105 8103 Aged at 30 mA □ Aged at 50 mA 2981 MTTF_{50%}(h) 1097 403 148 $\ln(MTTF_{50\%}) = -6.13 + 0.47*(q/kT_i)$ 55 25 26 27 28 30 31 29 q/kT_i (C/J)

Junction temperature (°C)

LED ADVANCES ARE revolutionizing the lighting landscape, enabling higher levels of energy efficiency, longer lifetimes, and new applications. LEDs can provide illumination for hours from solar-cell energy stored in batteries, bringing light to remote areas where electric grids haven't reached. They also can provide programmable color pallets for new lighting applications in the home. Replacing incandescent lights and other less efficient technologies can help reduce the world's overall energy usage as well.

If costs continue declining, LEDs should replace the now dominant but environmentally unfriendly compact florescent bulbs. Promisingly, LED technology is becoming more powerful and economical at a relentless pace. Haitz's law notes that the cost per lumen drops by 10 times while the light output increases by 20 times per decade.

As with any new technology, birthing hurdles need to be overcome. We've all been blinded by first-generation LED automobile headlights that concentrated too much light into pinpoint sources that were too bright. LEDs can be dangerously intense.

Panels of lower-powered arrayed LEDs can reduce this danger. In fact, rear panels covered with LED arrays light many widescreen LCD televisions. Designers are well advised to design for LED light safety as governed by mul-



DARVIN EDWARDS, TI Fellow, is responsible for chip/package interaction for analog products at Texas Instruments. He received his BS in physics from Arizona State University and holds 20 patents. He also has authored or co-authored over 45 papers, articles, and

book chapters and has lectured on thermal challenges, modeling, reliability, electrostatic discharge (ESD), and 3D packaging.

I. The lifetime to 50% luminance reduction for LEDs under various drive currents and junction temperatures ranges from a high of about 4000 hours at 100°C to a low of only 200 hours at 195°C, demonstrating the strong influence of temperature on LED life.¹

tiple standards such as IEC 60825-1 for LED lights and lasers or the more recent IEC 62471 on the photobiological safety of lamps.

FUNDAMENTAL CHALLENGES

Heat is a primary LED performance and reliability enemy. LED lifetimes often are classified by the time to reach either 50% or 70% of their original luminosity. Figure 1 shows a plot of mean time to failure (MTTF) for a sample of LEDs tested to a 50% decrease in luminous flux as a function of the forward bias drive current and junction temperature.¹ Lifetimes ranged from a high of approximately 4000 hours at a 100°C junction temperature to a low of approximately 200 hours at 195°C.

Manufacturers often specify operating junction temperatures of 80°C to 110°C to maximize the LED lifetime and avoid the luminosity falloff (*Fig. 2*).² To the system designer, this means controlling the system thermal performance to provide adequate thermal management for optimized LED reliability. A good understanding of LED failure mechanisms helps to explain why.

Heat drives most LED degradation mechanisms. Lattice dislocations in the LED active junction can nucleate and grow rapidly during high-current operation and high junction temperatures due to intrinsic lattice mismatches between the LED materials.^{3,4} These dislocations decrease light conversion efficiency. Better materials and processing of the fundamental LED substrates are minimizing this permanent wearout mechanism, but keeping the LEDs cool through design is still the number one defense.
A plastic lens that concentrates the LED light output surrounds many LEDs. At high temperatures and after long durations, the lens material can discolor and attenuate the LED light output.^{5,6} Lens crazing or cracking can also occur. Lens materials that can withstand the expected usage temperatures, as well as design to control the temperatures, must be selected to minimize lens yellowing.

High junction temperatures for prolonged times impact the LED color spectrum, especially the spectrum of white LEDs. White LEDs can be created in multiple ways by integrating two or more color-emitting diodes. Di-chromatic monolithic LEDs employ blue and yellow emitting diodes to create a white hue. Tri-chromatic diodes integrate blue, green, and red diodes, and tetra-chromatic diodes integrate blue, cyan, green, and red to improve the white balance.

Non-uniform color attenuation through thermal degradation of one LED over another changes the hue of the light. White LED chromatic balance is often enabled or enhanced by coating multiple phosphors on the LED surface. The phosphor coating performs a light spectrum conversion, absorbing photons at one frequency and emitting at other frequencies to provide a more pleasing and uniform light color. At high temperatures, phosphor material degradation has been reported, changing the spectrum of the light emitted and the efficiency of the LED.

Thermal path disruption can occur if the die-attach material adhering the LED to the heat spreader breaks down, fatigues, or loses adhesion during the device lifetime. A typical LED thermal path consists of an LED die-attach thermal interface material 1 (TIM 1) connecting the LED to a heat slug. A TIM 2 connects the LED heat slug to the system printed-circuit board (PCB) that heatsinks the LED package. The PCB is sometimes manufactured with a metal core (MCPCB) for improved thermal performance.



 As the junction temperature increases, luminosity decreases. For "white" LEDs derived from combinations of colored LEDs, this change in luminance impacts the color spectrum.²



3. Heat conducts from the LED die through the TIM I into a heat slug and then through TIM 2 into spreading planes in the PCB.

LED TIM 1 materials are similar to IC package die attaches. Both solders and epoxies are common. Silver sintered die-attach materials are available for extremely high thermal conductivity requirements. TIM 2 materials are most often metal filled epoxies, though solder can provide improved thermal conduction to the PCB. Thermal path degradation increases electrical resistance and reduces LED efficiency when the thermal path doubles as an electrode connection. Complete opens of the thermal path can result in catastrophic LED failure and must be avoided.

What is the source of high junction temperature? As with any standard IC, heat is generated in the LED when current flows through the resistive anode and cathode. The power to be dissipated can be calculated with the simple equation Power = $I^2R = VI$. High-power LEDs can dissipate 0.3 to 4 W, with many going to much higher levels. Small chip size and even smaller junction areas can drive power dissipation densities to 300 W/cm², higher than most IC devices.

As the temperature of the LED rises, heat is conducted through the package structure into the PCB (*Fig. 3*). Spreading planes in the PCB may be all that are needed to conduct heat away from the LED, providing area for radiation and convection into the system.

Providing the lowest thermal resistance from the LED junction to the system PCB or heatsink can thermally enhance the LED package. This is accomplished by selecting highly effective and thermally conductive TIM 1 and TIM 2 materials that have low thermal interfacial resistances; ensuring that the heat spreader is sized to optimally spread heat; and providing a robust means of heatsink attachment.

Other applications may produce more power, requiring more elaborate cooling schemes. For example, the LED bulb from Switch that's pictured in Figure 4 consists of a series of LEDs mounted on metal prongs. The entire volume of the bulb is filled with silicone fluid to provide natural con-

Keil MDK-ARM

MDK-ARM[™] is the complete development environment for ARM[®] Cortex[™]-M series microcontrollers.

www.keil.com/mdk

	The second secon
CAN Interface	File System
USB Host	USB Device
TCP/IP Networking	GUI Library

ARM DS-5

DS-5[™] Professional is a full featured development solution for all ARM Powered[®] platforms.

www.arm.com/ds5



ARM° ***** +1 800 348 8051

© ARM Ltd.AD364 | 01.13

DesignSolution

4. Some LED light bulb incandescent replacements rely on fluid convection around LEDs mounted on heatsinking prongs submerged in a silicone medium for thermal management. (courtesy of Switch)

vection, cooling the top of the LEDs in additon to the metal prongs, which serve as heatsinks. This bulb dissipates 20 W for an equivalent 100-W incandescent lumens output.

RELIABILITY AND COST EFFICIENCY

Depending on the application, the thermal management technologies can drive most of the LED cost. Design optimization is all the more crucial when thermal management is the primary cost driver. The analysis must incorporate system details to ensure all factors are considered upfront.

For example, cooling an LED in a flashlight requires different approaches than cooling an LED used in a com-

pact conference room projector. The thermal designer must work in concert with the system designers to ensure the most economical solution, performing cost/performance tradeoffs, and inventing innovative solutions to the thermal challenges.

Coefficient of thermal expansion (CTE) mismatches in the package create thermomechanical stresses just as they do in standard IC packages. These stresses fatigue solder joints, may result in interfacial delamination, may crack the LED housing, and can lift bond wires.

Many LEDs experience multimillion lifetime power cycles when they're run off of pulsed power sources. Other LEDs employ flip-chip solder bump technologies that are susceptible to the same solder fatigue as IC flipchip components.

A thorough understanding of the package's transient thermal performance is required to adequately calculate the heating and cooling experienced during each power cycle to estimate long-term reliability. Reliability test regimes should include accelerated power cycling to validate longterm reliability and reliability models. Understanding the coupled thermal and thermomechanical performance through modeling should guide the package and system design for the most reliable performance.

For example, increasing the thermal mass of the package or heat spreading board reduces the thermal swing seen on each power cycle, potentially extending the device lifetime. Additionally, increased thermal mass reduces the peak junction temperatures experienced during power cycling.

Other failure mechanisms must be designed out. Under extremely high burst currents, or electrical overstress (EOS), the wire bonds providing electrical connectivity between the LED and package can melt or fuse, which must be avoided. Electrostatic discharge (ESD) is another LED failure mode, but the use of a Zener breakdown diode in parallel with the LED can minimize it. Many LED light modules include the Zener diode built into the package.

Increasingly, LED lights are displacing older technologies with improved efficiency and reliability as well as lower maintenance costs. LED market penetration will continue to grow as costs decline and efficiencies improve. Thermal design of the LED system plays a key role in providing reliable operation and in finding the lowestcost cooling solutions.

REFERENCES

- L. Trevisanello, et al., "Thermally Activated Degradation and Package Instabilities of Low Flux LEDs," 47th International Reliability Physics Symposium, 2009, pp. 98-103.
- 2. Lumileds Luxeon Technical Datasheet DS25.
- M. Schubert, et al., "Effect of Dislocation Density on Efficiency Droop in GaInN/ GaN Light-Emitting Diodes," Applied Physics Letters 91, 2007.
- S. Keeping, "Understanding the Cause of Fading in High-Brightness LEDs," DigiKey article, February 21, 2012.
- C.C. Tsai, et al., "Decay of Radiation Pattern and Spectrum of High-Power LED Modules in Aging Test," IEEE Journal of Selected Topics in Quantum Electronics, Vol. 15, No. 4, July/August, 2009, pp. 1156-1162.
- G. Meneghesso, et al., "Recent Results on the Degradation of White LEDs for Lighting," Journal of Physics D: Applied Physics 43, 35 (2010).





NEDJELJKO LEKIC AND ZORAN MIJANOVIC | UNIVERSITY OF MONTENEGRO, PODGORICA, MONTENEGRO

Use An LED Dot-Graph Display To Complement Your DVM Readout

LEDS OFTEN ARE used to form a dot/bar graph display.¹⁻⁴ You also can use an LED dot-graph display as a complement to a digital voltmeter (DVM) with the LM3914 dot/bar display driver and nine LEDs.⁵ This is useful where the input voltage is unstable, so the voltmeter indications are variable and the result is hard to read and understand.

By adding an associated circuit, the DVM measures and displays the approximate mean value of the input voltage, while the LED dot-graph provides information about the voltage's stability. This approach is suitable for rapidly testing power supplies.

The input signal passes through low-pass filter R1C1 to a digital voltmeter (Fig. 1). The filter's output is the mean value of the input signal, so the voltmeter indicates it is stable, and it is easy to read. (If the digital voltmeter has a built-in averaging option, the low-pass filter is not required.) Capacitor C2 passes the variable component of the input voltage to U1, and the LED dot graph that U1 drives indicates the intensity of these variations.

Figure 2 (obtained by simulation) shows how the low-pass REFERENCES and high-pass filters pass the mean and variable components of the input signal, respectively. If the input voltage is stable and doesn't have any ripple, only central LED D5 lights up.

As voltage ripples increase, the adjacent diodes begin to flicker. For larger ripples, more of the adjacent diodes light. Potentiometer P controls the LED dot-graph's sensitivity, with maximum sensitivity of 0.125 V when P is set to 0 Ω . Nine of the 10 available LED outputs are used.



2. The simulation of the waveforms of V_{ln} (V[n001]) as well as the voltage at the low-pass filter output (junction of R1/C1) (V[n002]) and at the high-pass filter output (junction of R2/R3/C2) (V[n003]) show how the low-pass and high-pass filters pass the mean and variable components of the input signal, respectively.



I. The LED dot-graph display uses a standard display driver preceded by a high-pass filter. It visually complements a digital voltmeter's numeric output.

- 1. "LED bar-graph display represents two digits," Ajoy Raman, Bangalore, India, EDN, September 22, 2011.
- 2. "PIC microprocessor drives 20-LED dot- or bar-graph display," Noureddine Benabadji, University of Sciences and Technology, Oran, Algeria, EDN, September 1, 2006.
- 3. "Drive 16 LEDs with one I/O line," Zoran Mijanovic and Nedjeljko Lekic, University of Montenegro, EDN, June 9, 2011.
- 4. "Drive 12 LEDs with one I/O line," Charaf Laissoub, Maisons Alfort, France, EDN, February 4, 2010.
- 5. "LM3914 Dot/Bar Display Driver," National Semiconductor, February 2003, http://bit.ly/naDCRG.

NEDJELJKO LEKIC works at the University of Montenegro, Department of Electrical Engineering. He holds a PhD in electrical and computer engineering from the University of Montenegro. He has been working on designing identification systems based on RFID and/or biometrical identifiers as well as microcontroller systems for industrial automation.

ZORAN MIJANOVIC has been working as a professor with the electro-technical faculty at the University of Montenegro. He has designed many microcontroller devices for automation and control. He has a PhD in electronics from the University of Belgrade.

Lamp Eliminates Need For Limit Switches In Flap-Motor Control

A FRIEND OF a friend asked me how to best open and close a flap at the end of a tube: pneumatics, hydraulics, electrical, or what? It was an automotive application and no hydraulic system or compressor was available. So, the answer seemed obvious: a 12-V dc, small-gear motor.







2. The lamp's current-voltage curve (vertical versus horizontal) illustrates the nonlinearity that makes this solution possible.



3. A plot of the circuit's operation shows the smooth, well-defined movement of the flap despite the variations in the motor's current.

The friend said he had tried that already, but he ran into problems with limit switches. The need for a constant closing force at the end of travel was another complication. Adding a microcontroller was too complicated, he said.

There seemed to be no simple answer. But eventually a solution came to me. And all it requires is a low-wattage, low-voltage incandescent lamp added to the motor circuit (*Fig. 1*).

The relationship between voltage and current in a small incandescent lamp is very nonlinear (*Fig. 2*). The tungsten wire in the lamp has a low resistance when cold. That's in the region up to around half a volt. Cursors CI and CII indicate that the slope in that region is 0.439/1.267 = 0.35, while the slope between the origin and CIII (nominal voltage and current) is 2.12.

> So, the lamp acts as an automatically changing resistor with a low resistance when the load is low and a resistance six times higher when fully loaded. That's exactly what we need to run an actuator without limit switches, microcontroller, transistors, or whatever.

> Figure 3 shows flap position, motor voltage, and motor current in a close/rest/open/rest/power-off cycle. The motor current's variations (red trace) reflect a badly aligned coupling and noise in the commutator. That is always present in small dc motors. But the motor used in this application is worse than most other motors in that respect. Despite that, the movement (grey) is smooth and well-defined.

> When the flap hits the mechanical stop (flap closed), the motor stops and the back electromagnetic field (EMF) drops to a low value, which means that current would have risen to perhaps five or 10 times the running current, depending on which motor and which supply is chosen. That, of course, would destroy the motor and is why limit switches and controllers are needed to switch off, or reduce, current.

> By adding a simple low-wattage and low-voltage incandescent lamp to the circuit, you can avoid this problem and keep the motor current at a low level that the motor can tolerate indefinitely. You can even use the lamp as a visual indicator that the flap has reached its closed (or open) position. And, the reduced current needed to keep the flap tightly closed comes without even asking for it.

GUNNAR ENGLUND, electrical engineer, worked with ABB and Siemens for many years and is now an independent consulting engineer. He is mostly active in research and problem solving regarding EDM in bearings (bearing currents).

LED Lighting Depends On Drivers

LED lighting will drastically reduce energy expenditures, significantly reduce greenhouse gases, and provide increasingly sophisticated lighting options-but only with driver technology.

FIGURES INDICATE THAT widespread use of LED lighting by 2027 could save the equivalent electricity of that produced annually by 44 large electrical power plants, worth \$30 billion based on today's electricity prices. One fifth of global electricity is used in lighting, producing 1.9 billion tons of carbon dioxide (CO_2) annually. To put that into context, that's 70% of the world's passenger vehicle CO₂ output and 6% of global greenhouse gas emissions, so the potential for energy savings is immense.¹

LED lights and drivers continue to be among our most rapidly developing technologies with new innovations emerging on an ever-rolling production line (see "LEDs: In The Beginning," at electronicdesign.com). White LED efficiency has already increased by a factor of 10 since 2000. By 2020, the U.S. Department of Energy (DoE) estimates that commercial LED lighting efficiency will be as high as 258 lumens per watt, or two and a half times as efficient as today's fluorescent lamps, resulting in 90% energy savings. By then, the cost of LEDs will fall by 80% and global penetralog driver can be used to power hightion will be 60%. In fact, brightness LEDs from a mains supply. the DoE believes that no other

lighting technology offers the United States so much potential to save energy and enhance the quality of its building environments.

Shops, offices, factories, warehouses, art galleries, schools, and museums are just some on a long list of private and public spaces offering a massive potential market for the new technology. A significant proportion of that market will be retrofit rather than newly built, as 80% of the buildings that will be in use in 2050 have already been constructed.

LED lights are nothing without an LED driver. However, not many people are aware of drivers and how vital they are in providing the variable and highly adaptable range of lighting



ANTONY CORRIE is the vice president of Harvard Engineering Americas. He joined Harvard to set up its Americas division in August 2012. Previously, he was regional vice president for Southern California at Future Electronics, where he grew sales to more than \$100 million annually and managed 50 people.

designs now offered. LED drivers are the interface between the fittings and the mains power supply. Every lighting solution requires a unique driver design, and rapidly evolving driver technology is providing ever more comprehensive options to provide energy savings, definition, ambience, or old-fashioned wow factor.

WHAT'S NOT TO LIKE?

I. Harvard Engineering's

UL-approved CoolLED CL ana-

The initial cost of installing LED lighting is higher than traditional technologies, but energy and maintenance cost sav-

> ings cancel that out very quickly. They cost less over the life of the system and provide

> > a better, brighter quality of light. Also, exchanging incandescent bulbs for LEDs can reduce a building's carbon footprint from lighting by 85%.

LEDs have an average lifespan of over 100,000 hours, or 11 years of continuous operation or 22 years at half power. That's more than 10 times longer than any other light source on the market. LED lifetimes are rated differently from those of conventional lights, which go out when the filament

breaks. An LED's typical lifetime is defined as the average number of hours until light falls to 70% of initial brightness. By dimming over time in contrast to the abrupt failure of traditional bulbs, operators can replace the fitting before the lights go out, which is an advantage in safety-critical environments.

LEDs emit more light per watt than traditional light bulbs, which is where the energy savings come in. In addition, their efficiency is not affected by shape and size, unlike fluorescent light bulbs or tubes. Conventional light bulbs waste most of their energy as heat. For example, an incandescent bulb gives off 90% of its energy as heat, and a compact fluorescent bulb wastes 80% as heat. LEDs remain cool. This obviously leads to additional savings in air conditioning. Furthermore, LEDs give off light in a specific direction and are up to eight times more efficient than incandescent and fluorescent bulbs, which waste energy by emitting light in all directions.

LEDs light up very quickly and can easily be dimmed either by pulse-width modulation or by lowering the forward current. In addition, they don't use lead or mercury, so they're kinder to the environment. And since they don't have any glass components, they aren't vulnerable to vibration or breakage like conventional bulbs. LEDs are therefore well suited for use in areas like sports facilities and high-crime locations.

THE HEART OF THE LED

LEDs offer huge benefits. But to ensure optimum energy efficiency, reliability, and durability, they need the support of dedicated control gear. LED drivers play an important role in the overall design of lighting by regulating the power output. The main task of an LED driver is a constant light output, meaning a steady power supply to the LEDs, despite possible power variations (*Fig. 1*).

With LED drivers, users can choose between different power supply options, ranging from simple to sophisticated, to achieve maximum energy efficiency. Users also gain a variety of configuration options and adjustable soft start or emergency light functions. LEDs are ideal for applications using occupancy sensors, time-based switching, or switched daylight harvesting, which involves turning off half of the lights when a certain ambient light level is detected. The LED driver determines the quality of control performance.

Ultimately, efficiency and durability are tied not only to the LEDs themselves but also to the drivers that operate them. At their simplest, these drivers take the input current and input voltage and then reconfigure them for use by an LED. In that sense, they are a lot like the ballasts that have been used for decades in fluorescent lights.

Drivers are key in enabling market growth for LEDs in several ways. Innovations in design are allowing products to do more with less by improving the overall efficiency. Yet there is a misconception that driver technology is static and standardized. The reality is that there is no such thing as a "universal" LED driver. Every application requires a unique driver design, and the quality of the driver has a significant effect on the performance of the LED.

A range of factors determines the type of LED driver required, including the type and quality of LEDs being installed, whether they will be placed individually or in series strings, whether there are size limitations, and, ultimately, the main design goal of the installation.

Today's drivers come in two versions, constant current and constant voltage, with a number of variations. In simple terms, constant current drivers are used to power individual bulbs or multiple bulbs connected in series. Constant voltage drivers are best for applications where the user requires flexibility with the number of luminaires connected in parallel to one power supply. As lamps are added, the current will increase to the maximum limit.

DIMMING

With the overall design goal in mind, another important lighting concept is the availability of dimming functions. With

dimmable drivers, LEDs can be used to create a certain ambience or to highlight certain features. In addition, dimmable drivers allow for further energy savings to be achieved as they work on the premise that the human eye struggles to distinguish between LED lights that are on at 100% and those that are on at 90%.

It is a common mistake to think that dimming lights will result in a loss of light. The opposite is actually true. Although the driver efficiency will reduce a little as the LEDs are dimmed, overall significant energy will be saved. Also, dimming lights to half power can greatly extend the lifespan of LEDs, decreasing maintenance costs.

LEDs usually can be dimmed between 100% and 5%, or even lower, and are controlled by a phase dimmer switch, Digital Addressable Lighting Interface (DALI) controller, or 0-10V controller. DALI is widely recognized as the leading intelligent dimming protocol for LEDs. DALI drivers enable users to program their LED installations using digital signals to send control information to each light. Users then can set different lighting and ambient levels for displays, maximizing their investment.



board(FPC) connector with 0.4mm pitch spacing that is ideal for high-density mounting in slim information communication devices like mobile phones, smartphones, and notebook PCs.





HEILIND Performance: Trust. Innovation.

877-683-6723 www.heilind.com/rpages/jae_wp3_ed

Analog 0-10V drivers offer a less costly and more basic dimming solution to the DALI digital protocol. They can be easily programmed with a simple passive controller or a fixed or variable resistor. These controls use voltage input to manage the intensity of the light. For example, lights would be on at 100% at 10 V. At 5 V, lights would be powered at 50%. At 0 V, lights would be off.

typically use a phase control

dimmer switch: triac (leading edge) and THE RESULTS ARE CLEAR trailing edge. Triac is the cheapest and most common method of dimming, but it generates an undesirable amount of electromagnetic interference (EMI). Trailing edge dimming is more expensive than triac but produces much less EMI.



2. BMW installed LED lighting in its Rome showroom to save Two main dimming protocols energy and more dramatically show off its cars.

LED lighting gives off a better, brighter quality of light. When it's used with the right kind of driver, it also can provide a highly adaptable and flexible lighting environment using an array of color temperatures and profiles (see

"LEDs Kick Off A New Lighting Era At Manchester United" at electronicdesign.com). An expert lighting consultant is as important as a good builder.

In the workplace, good lighting can have a positive influence on health, improving absenteeism. It decreases eye strain, headaches, nausea, and neck pain. On the factory floor, better lighting improves performance. Increasing light levels from 300 lux to 2000 lux improves productivity by 8%,

increases task performance by 16%, and reduces rejects by 29%. It also makes a positive contribution to safety, reducing accident rates by 52%.2

In retail, clever lighting choices can subtly influence consumer buying decisions, and LED lighting provides

Block Unauthorized Access at the Device Level with Zilog's ZGATE™ Embedded Security

Zilog introduces ZGATE™ Embedded Security, which combines multiple world-class technologies for safer, faster and better deployment of your embedded communication applications. Incorporating the eZ80F91 MCU and Zilog's full-featured TCP/IP stack with a world-class embedded firewall produces technology that provides the tools to design, build and bring your communication product to market.

ZGATE Firewall Features

EMBEDDED SECURITY

- Ethernet, IP/UDP/TCP/ICMP filtering
- Extremely low latency; tests show improved network throughput under load by blocking packets earlier
- API for event logging
- Easily-configurable filtering rules:

ZILOG[®] Embedded in Life

An IXYS Company

- Static/rules-based filtering blocks packets based on configurable rules
- Dynamic filtering/stateful packet inspection (SPI) blocks packets based on connection state

- Choose your firewall package based on application requirements - see table below

Francis II Frankright	Firewall Package						
Firewall Features	Standard	Extended	Premium*				
Static filtering	Yes	Yes	Yes				
Stateful packet inspection	Yes	Yes	Yes				
Port, protocol and address limits	15 ports, 10 protocols, 10 IP addresses & 10 MAC addresses	100 ports, 100 protocols, 100 IP addresses & 100 MAC addresses	100 ports, 100 protocols, 100 IP addresses & 100 MAC addresses				
Threshold-based filtering	No	No	Yes				
*The ZGATE Embedded Security Development Kit (ZGATE000100ZCOG) ships with the Premium firewall package.							



Part Number	Firewall Package	Flash	SRAM	Temperature	Package	
EZ80F91GAZ0AEG	Premium	256 KB	16KB	-40°C to 105°C	144-pin LQFP	
EZ80F91GAZ0BEG	Extended	256 KB	16KB	-40°C to 105°C	144-pin LQFP	
EZ80F91GAZ0CEG	Standard	256 KB	16KB	-40°C to 105°C	144-pin LQFP	
ZGATE000100ZC0G	ZGATE Embedded Security Development Kit					



the flexibility to highlight products and save energy where less light is needed. Leading U.K. retailer Next plc recently announced the rollout of 110,000 LED luminaires across its stores. Luxury car manufacturer BMW is also in the fast lane, 2. "Lighting In The Workplace," http://www.iar.unicamp.br/lab/luz/ having already installed LED solutions in a number of show-

rooms including its prestigious premises in Rome, Italy (Fig. 2).

Well known for its high-end exclusive models, BMW wanted to update its lighting not only to be energy efficient, but also to provide a fresh and highly creative approach to showcasing its cars. A combination of Harvard Engineering's dimmable CoolLED drivers, Projection Lighting's AlphaLED Gyro Cube, and Xicato's LED modules proved to be the perfect solution.

These drivers can control the voltage within each light to provide diverse lighting levels in different areas of the showroom, while keeping the overall appearance of the lighting consistent. This means that BMW is able to dim the level in the general showroom to 600 lux, while maintaining light over the cars at a higher level of 800 to 900 lux, creating a visual and inspirational dynamic highly relevant to the luxury brand. The result? Diverse but sophisticated lighting levels that highlight the star quality of BMW's prestigious cars.

The LEDs installed in the showroom have provided BMW with a number of other advantages too. Due to their long lifespan and high efficiency, the LEDs offer a very low-maintenance solution that will last a number of years. They have also cut energy usage and CO₂ emissions substantially-proof that bespoke LED solutions can deliver significant results.

With immense energy savings, green gains, and a new and ever expanding palette of controllable lights now at our disposal, it is no exaggeration to say that LED lighting is poised to take over from traditional lighting. Infinitely scalable, extremely reliable, and improving all the time, LEDs are quickly becoming the new standard, and companies signing up to it will truly reap the rewards of this lighting revolution. ed

REFERENCES

- 1. "Lighting The Clean Revolution," The Climate Group, http://thecleanrevolution.org/_assets/files/LED_report_web1.pdf
- Id/Arguitetural/Handbooks/lighting_in_the_workplace.pdf



DISPLAYS & INDICATORS

BIPOLAR POWER-INDICATION LEDS MOUNT ON FRONT/REAR PANEL

Designed for front-panel or real-panel mounting, Wilbrect LEDCO's just released bipolar LEDs work directly off a 120- or 240-V ac line as LED power indictors or as drop-in replacements for neon indicators. They come in a pre-wired assembly of a red, green, or yellow bipolar LED and a resistor. Front-mount housing options include the 100/600 domed cylindrical and

USB Embedded I/O Solutions Rugged, Industrial Strength USB



16-Bit Multifunction Analog I/O, Up to 140-Channels 500kHz



Isolated Digital I/O 16 Inputs and 16 Solid-State Relay Outputs

ACCES I/O Products' PC/104 size embedded USB boards for OEM data acquisition and control.

OEM System SPACE Flexibility with dozens of USB/104® I/O modules to choose from and extended temperature options Explore the Possibilities!



<text><text><list-item><list-item><list-item>

ing Spac

Final Front

PC/104 USB/104 Systems

flush plastic lenses or the rugged CR/BR/CC series crew-on-metal housing for 0.312-in. holes. For rear-mount housing, there's the press-fit L61 series for 0.250-in. holes or the rugged screw-on CRM/BRM metal housing for 0.315-in. holes. Most feature IP66 sealing and can be supplied with wire leads or LED pin terminations. Customization is possible, using a variety of resistors, to meet specific ac voltage requirements (including 120 V ac). Popular options include custom lead lengths and custom symbol printing on flat lenses, in addition to a number of connector variations.

WILBRECHT LEDCO INC.

www.wilbrechtledco.com

POWER SOURCES

DC-DC HBLED DRIVERS BUILD IN DIMMING CONTROL Miniature dc-dc LED drivers from MicroPower Direct are specifically designed to power and control highbrightness LEDs (HBLEDs). The eight models comprising the LD48 series operate from a wide input voltage range of 7.0 to 60 V dc. Constant current output options include 150, 250, 300, 350, 500, 600, 700, and 1000 mA. Efficiency reach-



es to 97%. LED brightness (dimming) can be controlled by an analog voltage input or digitally from a pulse-width-modulated (PWM) input. The PWM input also may be used as a remote on/off control input. Mean time between failure (MTBF) per MIL HDBK 217F is greater than 950 khrs. The drivers come in a compact MiniDIP case with an industry-standard pinout. Units rated to IP67 are available with wire leads.

MICROPOWER DIRECT www.micropowerdirect.com



Otter Computer, Inc.

ricated

Electrical

Insulating

Bobbins

Electrical Insulating Bobbins

Fabricated or molded, hi-dielectric, hi-temp, choice of 12 materials, extra strong, with or without tie-offs, low cost, over 75 years of experience. Made In USA!

To receive literature & details fast: www.pptube.com

Precision Paper Tube Company 1033 S. Noel Avenue, Wheeling, IL 60090 Phone: 847-537-4250 Fax: 847-537-5777 email: sales@ptube.com *More Than 75 Years - The Original*

IR's High Current IR3847 Gen3 SupIRBuck® Delivers Superior Performance, Dramatically Reduces PCB size by 70% and Simplifies Design

IR has announced the introduction of the IR3847 high current Point-of-Load (POL) integrated voltage regulator that extends the current rating of IR's third generation SupIRBuck® family up to 25A in a compact 5x6 mm package.

As a result of a new thermally enhanced package using copper clip and several proprietary innovations in the controller, the IR3847 can operate at 25A without heatsink, and reduces PCB size by 20% compared to alternative integrated solutions and 70% compared to discrete solutions using a controller and power MOSFETs. A complete 25A power supply solution can be implemented in as little as 168mm2.



The new device integrates IR's latest generation power MOSFETs with a feature-rich, third generation SupIRBuck[®] controller that includes post-package precision dead-time trimming to optimize losses, and internal smart LDO to optimize efficiency across the entire load range. True differential remote sense essential for high current applications, 0.5% reference voltage accuracy in 25°C to 105°C temperature range, input feed-forward and ultra-low jitter combine to enable total output voltage accuracy less than 3% over line, load, and temperature, as required by high performance communications and computing systems.

More information is available on the International Rectifier website at

http://www.irf.com/whats-new/nr130319.html

For more information, contact Sian Cummins, scummin1@irf.com. 310-252-7148.

NEW SECOND EDITION – KEYSTONE M60.2 CATALOG



- Many New Products & Product Updates
- · Battery Clips, Contacts & Holders
- Fuse Clips & Holders
- Terminals & Test Points
- Spacers & Standoffs
- · Panel Hardware
- Pins, Plugs, Jacks & Sockets
- · PC Board & Multi-Purpose Hardware

Keystone Electronics Corp.

Request your M60.2 Catalog www.keyelco.com

Ad Page	Ad Page	Ad Page
ACCES I/O Products Inc	ExpressPCB71	Newark IBC
Advanced Circuits	Future Electronics	Orled/Sensoray71
Agilent Technologies11	Future Electronics61	Otto Engineering Inc77
Allied Electronics47	Hammond Mfg. Co 66	Pico Electronics Inc
America II Electronics Inc53	Heilind75	Pico Electronics Inc
Analog Devices	IMS 2013	Radicom Research Inc 10
ARM70	International Rectifier4	Rohde & Schwarz27
Astrex	Keystone Electronics Corp	Rohde & Schwarz
Avnet	Linear TechnologyBC	Sager Electronics
Avnet9	Linear Technology	Stanford Research Systems
Beta-Layout67	Linx Technologies	Supertex Inc
Cirrus Logic Inc	March Electronics	TDK-Lambda15
Coilcraft1	Maxim Integrated21	The Bergquist Company
CPN/Denelex Group63	Micro Crystal AG65	TTI
Crestwood Technology Group57	Mill-Max17	Zilog76
CUI Inc	MornSun	
Digi-KeyFC	Mouser Electronics6	For more information on products or services visit our
Digi-KeyIFC	Mouser Electronics	website www.electronicdesign.com, menu item Reader Service. The advertisers index is prepared as an extra
Ellsworth Adhesives60	National Instruments	service. Electronic Design does not assume any liability for omissions or errors.

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



Standards Bring CCFL And LED Technologies To Light

I JUST FINISHED putting corn gluten meal on my lawn. I do it every spring and fall. In the spring it acts as an organic, pre-emergent weed control that stops seeds from growing. This includes weeds and grass, so it cannot be put on newly planted grass. Then again, in most places in the northern United States you should only be planting grass in the fall.

The trick with corn gluten meal, or almost any pre-emergent herbicide, is timing. Put it down too late and the weeds will already be growing. The fertilizer then helps the grass and the weeds. Put it down too early and the protection it provides can run out.

Timing is also critical for the success of LED lighting.

STANDARD LED LIGHTING

In a sense, the success of cold cathode fluorescent lamps (CCFLs) and LEDs is due to government mandates. These technologies are more energy efficient and cost less in the long run, but they have a much higher upfront cost compared to the significantly less efficient Edison light bulb, which has seen limited improvement over the years.

The new laws established standards that must be met. These standards are slightly different from others Cree's 9-W LED that might specify a particular socket or frequency, though companies still have to deliver products that meet them.

The high costs of CCFLs and LEDs are one reason cent bulb. Cree they didn't show up earlier and on their own. There were markets where they existed, but the larger consumer market was essentially ignored.

Cree made a big splash when it started shipping LED light bulbs for \$10. The 9-W version costs a bit more but matches the output of a 60-W incandescent bulb (see the figure). The current prices are significantly lower than they were when these types of bulbs were first introduced a couple of years ago. They now have to compete with CCFLs, which were first out the chute and dominate store shelves today.

LEDs needed to address a number of challenges. They're inherently small, so most conventional lighting applications require multiple LEDs. Standard light bulbs have dozens of LEDs inside. Yet LEDs have many advantages over CCFLs. They are easier to dim, and they have attributes that have opened new venues.

LEDS DELIVER NEW OPTIONS

CCFLs provide more configuration options than incandescent bulbs, but their support hardware and general construction limit their possible deliverables. LEDs have fewer limitations. They can be extremely small, and their color gamut is much wider. They also can be adjustable, providing even more options unavailable to CCFLs and incandescents.

The number of products that already exist is changing the entire lighting arena. Take aquarium lighting, for exam-

ple. I recently replaced a fluorescent lighting system for my fish tank with an LED-based solution.

The new light system is a single device with no removable lights versus the two tubes from the original system, which had replaced the incandescent bulbs I had used decades ago.

The LEDs aren't replaceable, but there are lots of them. The theory is that the lighting system will still be viable even if a few of the LEDs die. The LEDs are adjustable, and there are two types of them to provide efficiency and color options. The system can even mimic sunrise and sunset.

The resulting system will probably last as long as the tanks and definitely longer than the fish. The amount of power used will be significantly lower too. The lights are also cooler, which is an issue even for tropical fish. Another application area that has seen significant

ens. Here, the LED's small size and low dc power

requirements are major advantages. It's easy to use



CREE 律

bulb matches the light output of a 60-W incandesprovides a 10-year warranty.

a string of LEDs to provide more controlled lighting placement. Color and intensity control are added benefits that would be impractical or very costly with other lighting technologies. Another aspect to LED solutions is microprocessor control. It is a lot easier than dealing with any other lighting technology. There are challenges, and optimized

designs like Cree's are beyond the average designer. However, the opportunity to incorporate more sophisticated lighting technology now exists. LED and microcontroller vendors provide plenty of app notes to help you get started.

Also, keep an eye out for quantum dots (see "QuantumFilm Increases Camera Efficiency" at electronicdesign.com). They can increase the brightness and extend the color gamut of LEDs. The problem is that making an efficient and cost effective LED for arbitrary colors isn't as easy as one might think.

Different technologies are employed for different color LEDs. Quantum dots have different absorption and emission spectrums that are often easier to customize to complement LEDs. Full-spectrum white light from low-cost LEDs could be on the horizon.

So ditch your old bulbs and those chemical fertilizers and stock up on LED bulbs and corn gluten meal. In the long run, they're better for the planet and the pocketbook.

Now Boarding.



It's easy to find all your development boards & accessories at our dev kit headquarters. newark.com/devkits





100W+, 98% Efficient **Buck-Boost LED Driver**



4.7V_{IN} to 60V_{IN}, Short Circuit Proof with LED Protection & Diagnostics

Here's the latest in our growing family of high power, high performance LED drivers designed to simplify power delivery to high brightness LEDs. The LT[®]3791's 4-switch buck-boost controller topology operates from input voltages above, below or equal to the output voltage while delivering constant currents from 1A up to tens of amps. The LT3791 also provides $\pm 4\%$ LED current accuracy and ±1.5% output voltage accuracy to ensure the highest performance LED solutions.

LED Drivers

Part Number	V _{IN} Range (V)	Topology	Comments		
LT3741	6 to 36	6 to 36 Synchronous Step-Down LED Current up to 20A			
LT3743	F3743 6 to 36 Synchronous Step-Down		LED Current up to 40A with Fast LED Current Transitions		
LT3755	4.5 to 40	Multitopology	V _{OUT} up to 75V		
LT3756	T3756 6 to 100 Multitopology		V _{OUT} up to 100V		
LT3791	4.7 to 60	4-Switch Synchronous Buck-Boost	V _{OUT} from 0V to 60V with Current Monitoring		

Info & Free Samples

www.linear.com/products/LEDdrivers

1-800-4-LINEAR



Management for LEDs Brochure

www.linear.com/ledsolutions

LT, LT, LTC, LTM, Linear Technology and the Linear logo are registered trademarks of Linear Technology Corporation. All other trademarks are the property of their respective owners.





28 | SIMULATOR TRAINS INFANTRY

30 MATRICES SWITCH TO 40 GHz



Ideal for Main Local Oscillator for Test Equipment, **Receivers and VSAT Applications**

The MLSP-Series of YIG-Based wideband synthesizers provide 1 kHz frequency resolution over the 600 MHz to 20 GHz frequency range. Power levels of +8 to +13 dBm are provided through out the series and full band tuning speed is 6mSec. Compact size will fit a 2 slot PXI chassis.

For more information about the MLSP Series or other products, please contact Micro Lambda Wireless.

See our complete line of frequency synthesizers



MLSL-series

2 to 12 GHZ



2 to 16 GHz



0.6 to 16 GHz



2 to 20 GHz

www.microlambdawireless.com



"Look to the leader in YIG-Technology"

Better performance. Less effort.

Right out of the box, a better inductor for your aerospace/MIL applications.



Shorten your time-to-market and improve performance with surface-mount chip inductors from Coilcraft CPS. These robust COTS Plus devices are ready to load without further handling or processing...tested to meet your specs, directly from Coilcraft CPS.

ML Series inductors designed, manuare factured and tested to ensure their suitability



for mission-critical applications under adverse environmental conditions. Alternate terminations, such as tin/lead, gold, and leach resistant alloy are featured for long term reliability.

Compared to other 0603 inductors, the ML Series offers higher inductance values, to keep board space to a minimum.

- Inductance values range from 47nH–22µH
- Q ratings are as high as 50 at 250MHz with Self Resonant Frequencies to 16 GHz
- Ceramic construction provides high-current handling
- *MTBF is an amazing 1 billion hours*

Learn more about ML Series and other Coilcraft CPS magnetics by calling us or visiting **www.coilcraft-cps.com** today.



Defense Electronics

A SPECIAL SECTION TO PENTON'S DESIGN ENGINEERING & SOURCING GROUP

APRIL/MAY 2013

TABLE OF **CONTENTS**

DEPARTMENTS

EDITOR			 	 	 	 	.7
News	Sho	RTS	 	 	 	 	.8

CONTRACTS 12

Design & Technology

Reviewing Phase Noise Measurement Methods.......... 14

PRODUCT FEATURES

Anvertigers Innex	21
Products	32
Switch Matrices Reconfigure To 40 GHz	30
Infantry Training	28
Simulator Assists	



Waveform Generators Run To 50 GSamples/s...24

Defense Electronics

EDITORIAL

EDITOR IN CHIEF: Nancy K. Friedrich

TECHNICAL CONTRIBUTOR: Jack Browne

MANAGING EDITOR: Jeremy Cohen

GROUP DESIGN DIRECTOR: Anthony Vitolo

ART DEPARTMENT

CREATIVE DIRECTOR: Dimitrios Bastas SENIOR ARTIST: James Miller INTERN: Luisanny Garcia

PRODUCTION

GROUP PRODUCTION DIRECTOR: Justin Marciniak justin.marciniak@penton.com AD PRODUCTION COORDINATOR: Kara Walby kara.walby@penton.com CLASSIFIED PRODUCTION COORDINATOR: Linda Sargent linda.sargent@penton.com

AUDIENCE MARKETING

AUDIENCE MARKETING MANAGER: Brenda Roode

ONLINE MARKETING SPECIALIST: Ryan Malec

Free Subscription • Status of Subscription • Address Change • Missing Back Issues (866)-505-7173 microwaves&rf@halldata.com

SALES & MARKETING

BRAND DIRECTOR, e/DESIGN: Tracy Smith (913) 967-1324 Tracy.Smith@penton.com

Northwest/Northern CA/ Western Canada REGIONAL SALES REPRESENTATIVE: Jamie Allen (415) 608-1959 Jamie. Allen@penton.com

REGIONAL SALES REPRESENTATIVES:

Bill Yarborough (713) 636-3809

David Madonia (212) 204-4331

stephanie compana (312) 840-8437 stephanie.compana@penton.com

Bill.Yarborough@penton.com

Dave.Madonia@penton.com

BRAND CHAMPION:

Midwest/Mid-Atlantic

Charles C.Y. Liu (866)2727 7799 Japan Hiro Morita 81-3-3261-4591 Korea Jo Young Sang (011)82-2-739-7840 LIST RENTALS, CUSTOMER SERVICE-SUBSCRIPTIONS: Marie Briganti (877) 796-6947 marie.briganti@meritdirect.com PENTON REPRINTS:

Mark Durham 44 (0) 7958 564137 mark.durham@penton.com

EUROPEAN SALES:

Taiwan, R.O.C

(212) 204-4373

(212) 204-4377

(212) 204-4243 jeremy.cohen@penton.com

nancy.friedrich@penton.com

jack.browne@penton.com

tony.vitolo@penton.com

dimitrios bastas@penton.com

james.miller@penton.com

brenda.roode@penton.com

ryan.malec@penton.com

wright's media (877) 652-5295 penton@wrightsmedia.com

GROUP DIRECTOR OF MARKETING:

MARKETING & EVENTS SPECIALIST:

Jane Cooper

Julie Ritchie

Adrian Piazza

RESEARCH MANAGER:

ONLINE

South

ONLINE DEVELOPMENT DIRECTOR: Virginia Goulding virginia.goulding@penton.com DIRECTOR OF DIGITAL CONTENT: Petra Andre petra.andre@penton.com

DESIGN ENGINEERING & SOURCING GROUP

VICE PRESIDENT & MARKET LEADER: Bill Baumann GROUP DIRECTOR OF

EDITORIAL CONTENT: Nancy Friedrich GROUP DIRECTOR OF OPERATIONS: Christina Cavano

Penton. Design Engineering & Sourcing Group

MARKETING COMMUNICATIONS SPECIALIST: Cynthia Rodriguez

Electronic Design • Machine Design • Microwaves & RF • Source ESB • Energy Efficiency & Technology Power Electronics Technology • Global Purchasing • Defense Electronics • Medical Design • Mobile DevDesign • Electronic Design China • Motion System Design • Engineering TV • Electronic Design Europe • Hydraulics & Pneumatics • Auto Electronics • Fluid Power Expo • Medical Silicon Medical Prototyping • One Powerful Day • Combating Counterfeit Conference

PENTON MEDIA, INC.

CHIEF EXECUTIVE OFFICER: DAVID KIESELSTEIN david.kieselstein@penton.com CHIEF FINANCIAL OFFICER/EXECUTIVE VP: Nicola Allais SENIOR VP, DESIGN ENGINEERING GROUP: Bob Macarthur bob.macarthur@penton.com

1166 Avenue of the Americas • 10th Floor • New York, NY 10036

HIGH RISK DEMANDS HIGHER QUALITY

PIC Wire & Cable is advancing high speed data and satellite communications technology. We also make customers' jobs easier by helping to improve platform and system performance, reduce development and manufacturing schedules and lower total costs.

PIC 🏴 Data MATES

PIC DataMATES are high speed data communications cable solutions with four tailored tiers addressing applications including:

Ethernet Communications Backbone Ground Vehicle Bus • Avionics Networks

PIC Micromates

PIC MicroMATES are high frequency cable solutions designed specifically to serve Ku Band and X Band applications, provide high bandwidth for data and support satellite communications.

Military & defense applications include: Command & Control • SATCOM • MUMT





SCAN THE CODE TO FIND THE RIGHT PIC FOR YOU

WWW.PICWIRE.COM/MRF EUI

ISO 9001 / AS 9100 800.742.3191 EUROPE: 44.1582.650263



International Microwave Symposium IEEE 2-7 June 2013, Seattle, WA MTT-S

THERE ARE SO MANY WAYS TO EXPERIENCE IMS!

ATTEND A WORKSHOP OR SHORT COURSE!

IMS Workshops and Short Courses offer practical, applicationoriented material to advance your career! Whether you're a seasoned professional, recent graduate, or student, IMS will provide a variety of topics that appeal to academia and industry alike. Hear the latest developments in R&D for emerging areas or hone your skills in a specific microwave subject.





MAKE A NEW CONNECTION!

IMS brings together the largest concentration of top engineers and scientists in the RF & Microwave Field. IMS2013 will also be home to over **50 first time exhibitors!** From the exhibition floor, to a variety of social activities, IMS is THE place to network with colleagues and companies both established and new.

VARY YOUR VIEWPOINT!

RF & Microwave technology is always on the cutting edge and that comes with lots of varying opinions. Panel Sessions are a great way to engage with colleagues on the forefront of these hot topics. The open discussion format is perfect for sharing a variety of viewpoints and getting the inside track on future directions!





WHAT WILL YOUR EXPERIENCE BE? REGISTER TODAY AND SAVE UP TO 25%!

f in C SHARE YOUR IMS STORY

COMPLETE CONFERENCE DETAILS ARE AVAILABLE AT: HTTP://IMS2013.MTT.ORG







Measuring The Value of Test Gear

hether by land, sea, or air, defense-electronics systems are designed to use a variety of electrical and optical signals for detection

and protection. Many of these systems feature imaginative use of hardware and software; they often extract high performance levels from the latest available technology. But for all the advanced technologies that may combine for a new radar system or electronic-warfare (EW) platform, those systems and their components must still be tested.

Major suppliers of test equipment design and build solutions for far more than just defense electronics customers, of course; they are often driven by the needs of large markets in commercial communications. But when new test-equipment products provide new levels of performance, their benefits are often far-reaching across a number of different markets—including commercial, military, industrial, automotive electronics, and even medical electronics markets.

Test equipment suppliers do not often receive the credit due to them. Modern RF/microwave test equipment, such as that mentioned in this issue's Cover Story on real-time signal analyzers, or the feature on arbitrary waveform generators, don't just combine hardware and software; they combine different *kinds* of hardware and software. This hardware tackles everything from audio to microwave to digital signals. Impressive coordination and timing is needed among different engineering groups to bring a new test instrument to market. Whether a group is involved in developing control software or is part of a team trying to produce a local oscillator (LO) with slightly lower phase noise, all of the contributions are important and all are vital to the success of the final product.

The instruments featured in this month's issue offer state-ofthe-art capabilities in signal generation and analysis. But they are not quirky. The engineering teams that create test instruments that are vital to electronic product development know that these instruments must provide repeatable performance day after day.

Considering the number of different components and subsystems in some of these instruments, performance variations might be expected under changing environmental conditions. But modern test instruments from major equipment suppliers are stable and dependable. Electronic design engineers working in defense electronics and in those many other industries count on such instruments for reliable results.

Defense electronics systems and test equipment have long been interdependent, relying on each other for a push to the next generation of hardware/software and the next level of performance. The engineering teams that work on both types of products are to be applauded for their efforts. **DE**

Jack Browne Technical Contributor

ADVANCED CIRCUITS

Leading the PCB Industry in Quality & Innovation

NOW Offering

Assembly Services!

Fab+Assembly All Under ONE ROOF... As QUICK as ONE DAY!

Ranked Top 3 in North America

- BEST ON-TIME Shipping Record
- EXPEDITES...a Specialty!
- SAME DAY & WEEKEND TURNS
- 24 Hour "Live" Tech Support
- No Minimum Order

#1 Rated "FREE" PCB Layout Software: www.PCBArtist.com

- Industry's Largest Customer Database
- FREE Tooling on Standard Spec Orders
- Space & Flight Approved Supplier
- INSTANT ONLINE Quotes, Orders, and Status
- Free File Check within minutes at www.FreeDFM.com

Your TOTAL PCB Solution!

Enhanced Capabilities:

- Up to 30 Layers
- .0025" Trace/Space
- Via-in-Pad
- Laser Direct Imaging
- Cavity Boards
- Buried Chip Resistors
- Polarizers
- Heavy Copper (up to 20 oz.)
 Multilayer RF Designs (up to 8 layers)

Microvias (HDI)

Blind & Buried Vias

Oversized Boards (up to 37"x120")

Bonded Heat Sinks & Copper Cores

Microwave Antenna Boards

100% U.S. BASED MANUFACTURING

Certifications & Registrations:

MIL-PRF-31032, MIL-PRF-55110G, ISO 9001:2008, AS9100C, IPC6012 Classes 2-3A, ITAR Registered, & UL Certified MADE IN USA

NEWS SHORTS _____

Lockheed Martin Aids USAF's GEO Satellites

he United States Air Force has awarded Lockheed Martin (www.lockheedmartin.com) a \$284.4 million fixed-price contract for long-lead parts for the fifth and sixth geosynchronous earth orbit (GEO) satellites in the Space Based Infrared System (SBIRS) missile-warning system. The SBIRS system is comprised of GEO satellites, hosted payloads in highly elliptical earth orbit (HEO), and associated ground hardware and software. Lockheed Martin previously received a contract to complete nonrecurring-engineering (NRE) services for the GEO-5 and GEO-6 satellites and procure long-lead spacecraft parts that would enable supplier production lines to deliver the lowest possible price for each component. This contract authorizes the purchase of the remaining long-lead spacecraft components, with a final contract for full production under fixed-price terms to be awarded at a future date.

Jeff Smith, Vice President of Lockheed Martin's Overhead Persistent Infrared (OPIR) mission area, explains: "This contract award is a testament to the importance of the SBIRS program and reinforces the government's confidence in our ability to produce these vital satellites efficiently going forward." He adds: "As we produce follow on SBIRS assets, we aim to continually reduce the cost and cycle time of each space vehicle to ensure we deliver critical and resilient infrared surveillance



Engineers inspect this SBIRS satellite prior to encapsulation into the launch vehicle payload.

capabilities to the nation at the best value to the government." Lockheed Martin's SBIRS contracts include four HEO payloads, four GEO satellites, and ground equipment to receive, process, and disseminate the IR mission data. The SBIRS system is operated by the US Air Force Space Command (www.afspc.af.mil), with Lockheed Martin serving as the prime contractor and Northrop Grumman (www.northropgrumman.com) as the payload integrator.

Satellite Controls Unmanned Vehicle

atellite-based control of battlefield vehicles took one step closer to becoming reality with a recent demonstration at Camp Grayling, MI by Lockheed Martin (www. lockheedmartin.com). During the demonstration, the company's Squad Mission Support System™ (SMSS) was being controlled via satellite from more than 200 miles away. The SMSS unmanned ground vehicle (UGV) conducted several battlefield surveillance operations while being controlled beyond lineof-sight via satellite from the US Army's Tank Automotive Research, Development and Engineering Center (Warren, MI).

The SMSS was equipped with a Gyrocam 9M Tactical Surveillance Sensor and a General Dynamics SATCOM Technologies "SATCOM-On-the-Move" system. The hope for the demonstration was to show that the unmanned system can provide the needed battlefield situational awareness while keeping soldiers out of harm's way. According to Joe Zinecker, Director of Combat Maneuver Systems at Lockheed Martin Missiles and Fire Control, "These demonstrations allow the Army development communities to better understand capabilities available to them with SMSS right now. We are showing our customers innovative ways to employ SMSS vehicles in missions while demonstrating that we are ready to move from technology development to fielding these valuable and mature new capabilities."

The SMSS used an adjustableheight mast with the Gyrocam 9M to acquire a high-resolution electro-optical and thermal video. SMSS movement and sensor functions were controlled at the remote station, through the line-ofsight satellite. In a simulated mission, an operator provided a pre-planned route and SMSS autonomy allowed navigation with minimal operator intervention. Other autonomous functions—such as follow-me, goto-point, and retro-traverse—were also demonstrated.

Zinecker notes that "the concept of an affordable common mobility platform coupled with specialized mission equipment packages is the right answer for UGVs to reduce development, production, and sustainment costs, while providing maximum flexibility for commanders. SMSS continues to demonstrate its readiness to move into the next phase of the Army's UGV roadmap."





A perfect fit for almost any PCB! Our newest fixed surfacemount attenuators are available in nitrogen-filled hermetic LTCC packages for military and industrial applications, as well as plastic cases that meet tight commercial budgets. They're invaluable for both broad- and narrow-band systems, reducing the effects of mismatches, harmonics, and intermodulation, improving isolation, and meeting other circuit level requirements. And to deliver the precise attenuation you need, we're making them available in 1-dB steps from 0 to 10 dB, as well as 12, 15, 20, & 30 dB! The ceramic hermetic *RCAT* family is built from the ground up to deliver reliable, repeatable performance under the harshest conditions. And they're proving it in tough MIL testing, qualifying for gross and fine leak, vibration, PIND, thermal shock, and more, at up to 125°C!

The YAT family utilizes the same dice, with excellent electrical performance and high thermal conductivity, in an even smaller plastic case! For more details, just go to minicircuits.com—place your order today, and you can get them in your hands as soon as tomorrow!

Model	Freq.	P _{MAX}	Atten.	Op. Temp	Size	\$ Price ea.
Family	(GHz)	(W)	(dB)	(°C)	(mm)	(Qty. 20)
RCAT	DC-20	2	0-30	-55 to +125	2.3 x 2.3 x 1.1	4.95
	DC-18	2	0-30	-40 to +85	2.0 x 2.0 x 0.8	2.99
Actual Size					C RoHS	compliant

Keep a few extras on hand! Order Designer Kit K1-YAT+ and get 20 YAT attenuators for only \$59.95! (4 each: 3, 6, 10, 15, & 20 dB)

Mini-Circuits...we're redefining what VALUE is all about!



U.S. Patents

P.O. Box 350166, Brooklyn, New York 11235-0003 (718) 934-4500 Fax (718) 332-4661

T2 The Design Engineers Search Engine finds the model you need, Instantly · For detailed performance specs & shopping online see minicipuits.com

IF/RF MICROWAVE COMPONENTS

510 rev A

Secure Mode 5 IFF System Passes Tests

pair of leading United Kingdom defense suppliers recently teamed on the successful over-the-air testing of an upgraded Mode 5 identification friend or foe (IFF) system. The trial involved Raytheon UK (www.raytheon.co.uk) and Thales UK (www.thalesgroup.com/uk). The former is a subsidiary of Raytheon Co. (www.raytheon. com) and a major supplier to the UK Ministry of Defence (MOD), while the latter is a major supplier to aerospace, defense, and security markets. The trials, performed at Raytheon's Matching Green test range (Harlow, UK) in early December, involved Thales' TSA1412 Interrogator and Raytheon UK's IFF4810 Transponder, a standard-fit Successor IFF (SIFF) product with Mode 5-enabled upgrade.

The Mode 5 system is designed to provide a high level of cryptographic security while also featuring excellent resistance to electronic-countermeasures (ECM) efforts. The Raytheon and Thales equipment were fitted with model KIV-77 Mode 5 Cryptocomputers developed by Raytheon in the United States. Raytheon and Thales teamed as part of an agreement signed in July 2012 to pursue the MOD procurement of the next-generation NATO interoperable Mode 5 IFF system. The IFF system, which can be fitted to aircraft, ships, and missile defense systems, allows them to identify friendly and hostile forces.

Richard Daniel, Managing Director for Ravtheon UK's defense business, remarked that "Raytheon has invested in developing the Mode 5 upgrades for existing equipment, and Thales has Mode 5-qualified equipment already in service with French and other NATO armed forces. By teaming, we exploit the complementary strengths of both companies to minimize platform integration risks for Mode 5." He added that "together, we would seek to ensure maximum continuity of operational availability by applying our already successful front-line support model during the transition to Mode 5." Victor Chavez, Chief Executive Officer for Thales UK, elaborates: "IFF Mode 5 is an important program enabling future interoperability for the UK in NATO coalition operations. Both Thales and Raytheon have cutting-edge capability in this area, and by working together we would provide the UK MOD with a world leading IFF solution."

SM-3 Space Sensor Helps Take Out Target

Tracking data from a remote sensor on Space Tracking and Surveillance System-Demonstrator (STSS-D) satellites helped destroy a medium-range ballistic missile (MRBM) target. The test was performed with the Standard Missile 3 (SM-3) space sensor from Raytheon Co. (www.raytheon.com) sending guidance data to a SM-3 Block IA missile fired from the US Navy's USS Lake Erie guided-missile cruiser. For the test, the MRBM target missile was launched from the Navy's Pacific Missile Range Facility (Kauai, HI). Once above the horizon, the target was acquired and tracked by STSS-D satellites, with threat data relayed through the Command, Control, Battle Management, and Communications (C2BMC) system to the ship. Based on the STSS tracking data, the ship's crew fired the SM-3 missile before the ship's radar had acquired the target missile.

The test was performed to prove the "launch on remote" concept, first demonstrated during testing in April 2011 when a US Naval destroyer used tracking data provided by a Raytheon-built AN/TPY-2 radar on Wake Island to engage and destroy an intermediate-range ballistic missile target using an SM-3 Block IA missile. Wes Kremer, Raytheon Missile Systems' Vice President of Air and Missile Defense Systems, notes: "Launching on remote is important because it extends the engagement range of the missile, allowing ships with the SM-3 to expand the battle space and eliminate threats sooner."

Bill Hart, Vice President of Space Systems for Raytheon's Space and Airborne Systems business, adds that "STSS-D's unique vantage point in space allows the sensor payload to see the threat early in its trajectory, and provide launch quality data sooner than nearly any other option. We can give our naval war fighters extra time to analyze and respond by providing target data before the ship can track the threat. That's a tremendous advantage."

Boeing Recognizes Richardson RFPD

B oeing Co. (www.boeing.com) has presented Richardson RFPD (www.richardsonrfpd.com) with the 2012 Boeing Performance Excellent Award. Boeing annually issues the award to suppliers that have provided excellent performance. Richardson RFPD maintained a Silver composite performance rating for each month of the 12-month performance period, from October 1, 2011 to September 30, 2012. Boeing recognized 594 suppliers that have achieved either a Gold or Silver level award; Richardson RFPD was one of 441 suppliers to receive the Silver level award.

Greg Peloquin, President of Richardson RFPD, explains: "We are proud to be recognized by a customer as prestigious as the Boeing Co. for superior supplier performance." He adds that "Richardson RFPD takes great pride in working alongside our customers to provide support, products, and solutions for their design visions, and the Boeing Performance Excellence Award further motivates us to continue striving for operational excellence in all facets of our global business." Richardson RFPD supplies a wide range of RF/microwave, interconnect, and power-conversion products for the aerospace and defense industries. ("News Shorts" continued on p. 31.)



Emerson Network Power Connectivity Solutions has a wide range of cable assemblies and connectors suited for RF, Microwave and Fiber Optic signal transmission. Connectivity Solutions is a vertically integrated supplier of custom, fixed length and semi rigid cable assemblies from DC to 50 GHz. Our product lines deliver custom-engineered products and solutions to satisfy the most demanding and complex requirements.

Emerson Connectivity Solutions products support wire line and wireless communications, data networking, test and measurement, telecomm, broadcast, medical, military, aerospace and industrial applications.



EmersonConnectivity.com Toll free: 800-247-8256 Phone: 507-833-8822

Connectivity Solutions



EMERSON. CONSIDER IT SOLVED.™

CONTRACTS

LGS Innovations Helps Army's MCF

GS Innovations (www. lgsinnovations.com) has been awarded a contract worth slightly more than \$49 million to upgrade the US Army's Main Communications Facility (MCF) in Southwest Asia. LGS, an independent subsidiary of Alcatel-Lucent, was selected as the exclusive contractor to engineer, furnish, install, test, and secure the Army's extensive network, transmission, and voice infrastructure in Southwest Asia. This work falls under the umbrella of the Army's Infrastructure Modernization (IMOD) initiative. The company has also been tasked to execute a critical cutover of transmission circuits, as well as to design, develop, furnish, and install a virtualized infrastructure to accommodate the migration of servers and their applications from

existing facilities to the MCF. The MCF, designed as a state-ofthe-art commercial communications operations center, will serve as the central information systems hub for the region.

LGS Innovations Chief Executive Officer Kevin Kelly explains: "LGS deploys the most advanced, state-ofthe-art communications technologies available to both defense and civilian organizations. This opportunity to upgrade and modernize such a mission critical piece of infrastructure for the US Army will not only support our military and warfighters abroad, but will also help the Federal Government to continue to provide for homeland security and overcome future overseas communications challenges."

TCS Recruited For Marines' WPPL Systems

eleCommunication Systems, Inc. (TCS: www.telecomsvs. com) has been awarded \$16.1 million in incremental funding for communications support to the United States Marine Corps (USMC). The award is for deployed engineering services for the USMC's Wireless Point to Point Link (WPPL) systems. These services, which apply to both satellite communications (satcom) and terrestrial wireless communications systems, will aid USMC vital operations in technical control facilities and data/security centers along with tactical USMC systems. The communications support procurement is being managed by the US Army Project Manager for the Warfighter Information Network-Tactical (PM-WIN-T) Commercial Satellite Terminal

Program—part of the US Army's \$5 billion World-Wide Satellite Systems (WWSS) contract vehicle.

According to Michael Bristol, Senior Vice President and General Manager of TCS Government Solutions, "While it's imperative that the USMC has secure, reliable, and easily deployable communications equipment, that's only half the battle. They also need the expertise backing that equipment, and that's where TCS' knowledgeable and reliable Deployed Engineering Services personnel come in." The WPPL systems provide secure point-to-point and point-to-multipoint; line-of-sight; and non-line-of-sight transmission of voice, video, and data communications as a lowcost alternative to more expensive beyond-line-of-sight satcom approaches.

Wyle Assists Naval Air Systems Command

yle has been awarded a three-year, \$24 million contract to provide unmanned air systems support to the US Naval Air Systems Command. The contract provides reliability improvement, testing, technology insertion, and lifecycle analysis for unmanned air systems and intelligence, surveillance, and reconnaissance projects and programs. Personnel from Wyle (www.wyle.com) will help cost-effectively develop and refine processes and equipment to increase the reliability, maintainability, sustainability, quality, and interoperability of the Naval Air Systems Command's systems. Reducing life-cycle costs while implementing new or updated technologies is an important part of the contract. As Wyle Program Manager Rocky Rauch notes: "We are pleased that Wyle has been awarded this contract, following our successful execution of unmanned aerial system projects ... under a related contract over the past two years."

Work on the contract is being performed primarily at Naval Air Station Patuxent River, MD. The task order was issued under the **Defense Technical Information** Center's Reliability Information Analysis Center contract. As part of the contract, Wyle is performing acquisition planning; system interoperability assessments; integrated reliability test planning and management; affordability and life cycle cost analysis; logistics management; and various management tasks associated with the data collection and testing of electrical, mechanical, and avionics systems.



Two-way 90° power splitters (hybrids) are critical building blocks in a wide array of RF design solutions. That's why Mini-Circuits offers extra-tight phase and amplitude balance, to ensure your expected high-performance design results. Plus, our robust, rugged units deliver repeatable performance and are available in over 70 different SMT models, in the widest range of frequencies in the industry (from 5 MHz to 8 GHz), and in package sizes as small as 0.08" x 0.05".

LTCC models now available in small-quantity reels, with standard counts of 20, 50, 100, 200, 500, 1000, or 2000 at no extra cost! For full performance O RoHs compliant details and product availability, visit our web site www.minicircuits.com. You can order online and have units in-hand as soon as next-day.

Mini-Circuits...we're redefining what VALUE is all about!





P.O. Box 350166, Brooklyn, New York 11235-0003 (718) 934-4500 Fax (718) 332-4661 2 The Design Engineers Search Engine finds the model you need, Instantly • For detailed performance specs & shopping online see minicipuits.com

IF/RF MICROWAVE COMPONENTS

463 rev G

DESIGN & TECHNOLOGY

RICHARD OVERDORF / AEROSPACE DEFENSE PLANNING WALT SCHULTE / AEROSPACE DEFENSE APPLICATION ENGINEER Agilent Technologies, Microwave Communications Division, 1400 Fountaingrove Pkwy., Santa Rosa, CA 95403-1738; (707) 577-5131, e-mail: richard_overdorf@agilent.com, www.agilent.com.

Reviewing Phase Noise Measurement Methods

Different approaches have different strengths and weaknesses, and each is best for characterizing different types of RF/microwave signal sources.



1. The three main contributors to source noise create a theoretical lower limit for phase noise measurements.



2. Contributions to the phase-noise performance of a signal generator can be traced to the major sections of its internal architecture.

xtracting signals from noise is a task that has challenged RF and microwave engineers since the earliest days of electronic communications systems. Engineers involved with cutting-edge radar and communication systems often use extreme amounts of signal processing to extract maximum information from faint or impaired signals. A major obstacle these engineers must often overcome is phase noise, which can severely limit the performance of a receiving system.

Phase noise is often the nemesis that limits the performance of a receiving system. For example, it can degrade the capability of a pulsed-based radar system to process Doppler information, and impair the error-vector-magnitude (EVM) performance of a digitally modulated communications system. Measuring phase noise is consequently vital to improving the performance of these and other RF or microwave electronic systems used in military and commercial applications.

Phase-noise measurements may seem difficult to some—more like a puzzle, with many oddly shaped pieces that are difficult to connect. Even with today's advanced hardware and improved techniques, the process of making measurements and interpreting the results may still contain a certain amount of mystery. To help clear things up, it may be useful to first review some fundamental details about phase noise. Next, we will detail the three most common phase-noise measurement techniques and to which applications they are best suited.

Phase noise is essentially a measure of an electronic signal's frequency stability. The long-term frequency stability of—for example—an oscillator, can be characterized in terms of hours, days, months, or even years. Short-term stability refers to frequency changes that occur over a period of a few seconds or less. These short-cycle variations can have deleterious effects on electronic systems that rely on extensive processing to extract information from a signal. Thus, this discussion will focus on short-term stability.

Short-term stability can be described in many ways, but the most common is single-sideband (SSB) phase noise. The United States National Institute of Stan-

UITRA-REL CERANC MIXERS 300 MHz to 12 GHz

MAC



from only ea. qty. 10

- Hermetically Sealed, 100% Tested
- Rugged LTCC Construction
- Easy Visual Solder Inspection, gold-plated terminals
- Low Profile, only 0.06"/1.5 mm thick

Mini-Circuits new MAC mixer family combines rugged ceramic construction with monolithic quad semiconductor technology to produce the most reliable mixers available in the marketplace today—the only mixers anywhere backed by a *3-year guarantee!* Top to bottom, inside and out, they're designed and built for long-term reliability under hostile conditions such as high moisture, vibration, acceleration, and thermal shock from -55 to +125°C.

- Highly Repeatable Performance
- Flat Conversion Loss & High Isolation across the whole band
- Outstanding Thermal Stability, -55 to +125°C

Excellent electrical performance across the entire frequency range makes them ideal not only for aerospace and military ground applications, but anywhere long-term reliability adds bottom-line value: instrumentation, heavy industry, high-speed production, and unmanned facilities, to name just a few. So why wait? Go to minicircuits.com for performance data, technical specifications, and **remarkably low prices**, and see what MAC mixers can do for your applications today!

Mini-Circuits...we're redefining what VALUE is all about!



P.O. Box 350166, Brooklyn, New York 11235-0003 (718) 934-4500 Fax (718) 332-4661

212 The Design Engineers Search Engine finds the model you need, Instantly · For detailed performance specs & shopping online see minicipatis.com

U.S. Patents

IF/RF MICROWAVE COMPONENTS

498 rev.B

Design & Technology

dards and Technology (NIST; www.nist.gov) defines SSB phase noise as the ratio of two power quantities: the power density at a specific frequency offset from a signal carrier and the total power of the carrier signal. This is most commonly measured in a 1-Hz bandwidth at some frequency "f" away from the carrier. The units of measure are in decibels relative to the carrier per Hertz (dBc/Hz) over a 1-Hz bandwidth.

The level of phase noise is deterministically related to the



3. This basic phase-detector concept has been implemented in many ways.



4. This method uses a reference source and a double-balanced mixer as the basis of the phase detector.



5. Splitting the SUT and manipulating it with a delay line and phase shifter eliminates the need for reference source.

carrier frequency, increasing by 6 dB for every doubling in frequency. As a result, when characterizing the performance of components integrated into advanced radar and communication systems, measurements of phase noise for a 1-GHz carrier signal may extend from roughly -40 dBc/Hz at offsets "close to the carrier" (such as 1 kHz or less) to as low as -150 dBc/Hz or less at offsets "far from the carrier" (such as 10 MHz or more). At such low levels, the measurement noise floor is affected by two microscopic electronic effects: thermal noise from passive devices, which is broad and flat (white noise), and flicker noise from active devices, which has a shape akin to the inverse of frequency, 1/f (such as pink noise), that emerges from the thermal noise at lower offsets. Both of these contributors are unavoidable because they are present all along the signal chain—in the measuring instrument, in the device that produces the signal-under-test (SUT), and even in the cables used to connect the measuring instrument to the device under test (DUT).

Any type of amplifier in the test signal chain will also serve as a source of noise. While the main purpose of the amplifier is to increase the power level of a weak carrier signal, it also adds its own noise to the signal and boosts any input noise. The net result is that the amplifier, thermal noise, and flicker noise continue to give any phase-noise plot a characteristic shape and, more significantly, reduce the theoretical lower limit of sensitivity for any phasenoise measurement (**Fig. 1**). These effects appear in the phasenoise characteristics of any high-performance signal generator.

The underlying sources of noise can be traced back to the major sections of the block diagram for such an instrument (Fig.

2). For offsets below 1 kHz, the noise is dominated by the performance of the reference oscillator, which is multiplied to the carrier frequency. In this particular signal-generator design, the other major contributors include the synthesizer circuitry at offsets of 1 kHz to roughly 100 kHz, the yttrium-irongarnet (YIG) oscillator for offsets from 100 kHz to 2 MHz, and the output amplifier for offsets above 2 MHz. When these effects on phase noise are well understood, they can be minimized and optimized within a system design to ensure maximum performance.

Phase-noise measurement techniques have evolved along with advances in analyzer technology. Three phase-noise measurement methods (ranging in complexity from basic to intermediate) are direct spectrum measurements, phasedetector-based measurements, and twochannel cross-correlation techniques. The direct-spectrum approach is the oldest and perhaps simplest way to measure phase noise. In this approach, the SUT or DUT is simply connected to the input port of a spectrum or signal analyzer and then tuned to the carrier frequency of in-

Elusive signals can hide, but not for long.





Understand what's happening in the most signal-rich environments or systems. Detect transients or interference, even small signals in the presence of large ones. And achieve the best probability of intercepting signals – all with the real-time PXA signal analyzer. Go after the most elusive signal and know you've got it.

Real-Time Spectrum AnalyzerIndustry-best POI: > 3.57 μs160 MHz BW across 50 GHz frequency rangeUp to 75 dB of spurious-free dynamic rangeLicense-key upgrade to Agilent N9030APXA signal analyzer

Learn more: *Measuring Agile Signals and Dynamic Signal Environments* app note www.agilent.com/find/elusive-signals

u.s. 1-800-829-4444 canada: 1-877-894-4414







© Agilent Technologies, Inc. 2013



We have specialized in Low Phase Noise Fixed Frequency Sources since 1998.

A plot of our new quieter FRDRO line.



- Crystal reference phase noise to -130 dBc/Hz @ 100 Hz @ 100 MHz
- Dual loop output frequency resolution +/- 0.001 Hz
- Internal reference stability to +/- 10 ppb
- 5 1000 MHz External reference
- Frequency: 10 MHz to 35 GHz
- Power output: +10 to +24 dBm
- Wide operating temperature range: -55° to +85°
- Spurious: < -90 dBc

We welcome your custom requirements.



Nexyn offers the best performance and reliability on the market.

1287 Forgewood Ave. Sunnyvale, CA 94089 Tel: (408) 962-0895 Fax: (408) 743-5354 sales@nexyn.com

www.nexyn.com

Design & Technology *(*

terest. Two measurements are then made: First, the power level of the carrier is measured. Next, the power spectral density (PSD) of the signal source noise, at a specified offset frequency, is measured and referenced to the level measured for the carrier power.

As is often the case when using a simple measurement approach, a variety of corrections must be made to ensure an accurate result. For example, it may be necessary to correct for the noise bandwidth of the signal or spectrum analyzer's resolution-bandwidth (RBW) filters. In addition, it may also be necessary to correct for the behavior of the analyzer's peak detector, which may under-report the actual noise power. It was once necessary to perform these corrections manually (Agilent Technologies' Application Note No. 150 provides guidance in this process). But these extra steps are no longer necessary when using a signal analyzer equipped with either an interval-band/ interval-density marker function (for the PSD measurement) or a built-in phase noise measurement application.

Time and experience have revealed the limitations of the direct-spectrum phasenoise measurement method. Most of these limitations are related to shortcomings in the quality or performance of the signal or spectrum analyzer: the residual frequency modulation (FM) of the instrument's local oscillator (LO), the noise sidebands or phase noise of the analyzer's







7. The two-channel cross-correlation technique utilizes two phase detectors.

Design & Technology <u>/</u>}

LO, and the analyzer's noise floor can all impact the phase-noise measurement results. In addition, most spectrum analyzers measure only the scalar magnitude of the SUT noise sidebands. As a result, the analyzer cannot differentiate between amplitude noise and phase noise. Finally, the process is complicated by the need to make a noise measurement at every frequency offset of interest—potentially, a very time-consuming task.

In the phase-detector measurement approach, a phase detector is used to separate the phase noise from the amplitude noise. Figure 3 shows how the phase detector converts the phase difference of two signals into a voltage available at the output of the phase detector. When this phase difference is set to quadrature, the voltage is zero. Any phase fluctuation from quadrature will result in a corresponding voltage fluctuation at the output and a value other than zero. The phase-detector approach is the basis for several commonly used phase-noise measurement techniques, including the reference-source/ phase-locked loop (PLL) method, the frequency-discriminator method, and the heterodyne digital discriminator method.

The reference-source/PLL method uses a double-balanced mixer as the detector, with the reference frequency source and the SUT serving as the inputs to the mixer (Fig. 4). The reference source is controlled such that it follows the SUT at the same carrier frequency, but with a 90-deg. phase offset. To ensure accurate measurements of the SUT, the phase noise of the reference source should be as low as possible, with behavior that is wellcharacterized. The sum frequency from the mixer is removed by means of a lowpass filter, while the difference frequency is 0 Hz with an average output voltage of 0 VDC. Any AC voltage fluctuations will rise on top of the DC voltage, and be proportional to the combined noise contributions of the two input signals. In this phase-noise measurement approach, the baseband signal from the mixer is often boosted by a low-noise amplifier (LNA) before being connected to the input port of a baseband analyzer.

The reference-source/PLL phase-noise measurement method yields the overall best sensitivity and the widest measurement coverage, with a frequency-offset



8. This uniform test signal can be used to verify the performance of a phase noise measurement solution.

www.SignalAntenna.com

DC-20 GHz! CUSTOM DESIGNS HI POWER HELIX

B'BAND ANTENNAS LOG PERIODIC OMNI EMC TEST MAN-WORN OTH HF RADAR



SAS antennas at work protecting our forces:

Signal Antenna Systems, Inc.

8-B Hangar Way Watsonville, CA 95076 **Phone: (831) 722-9842 Email: info@signalantenna.com**



Signal Antenna Systems, Inc.



In the 21st century battlefield, cyber security is the front line. The National Defense Authorization Bill, H.R 1540, recognized this and requires protection against any EMP assault. The Equipto R6 is a major shield in that battle, defending against EMP weapons and geomagnetic storms that can "take out" communication centers, power plants, electronically-controlled infrastructure, surveillance systems and more.

The R6 far exceeds Tempest (NSA 94-106) requirements, the most stringent in the fields of intelligence and security. Its design



is cost-effective, compact and mobile, while providing shielding effectiveness comparable to an anechoic chamber. Each is custom-sized and fitted with an array of exclusive features to keep your signals in and potentially damaging electromagnetic disturbances out.

Learn more now at EquiptoElec.com or call us.



800-204-7225 Ext. 9 630-859-7840 email: sales@equiptoelec.com www.equiptoelec.com ISO 9001:2008 • RoHs Compliant **Jesign & Technolog**y

range that spans 0.1 Hz to 100 MHz. It is also insensitive to AM noise and is capable of tracking drifting sources. However, it requires a reference source with low phase noise and with the capability of being tuned electronically. In addition, if the SUT has a high frequency drift rate, the reference source must be tunable over a very wide frequency range.

The frequency-discriminator phase-noise measurement method simplifies the equipment configuration and measurement process by substituting an analog delay line for the reference oscillator. In this approach (Fig. 5), the SUT is split into two channels. One path is delayed relative to the other, and the delay line converts frequency variations into phase fluctuations. Adjusting the delay time will determine the phase quadrature of the two inputs to the mixer. The phase detector converts the phase fluctuations into voltage variations that are measured as frequency noise by the analyzer. The frequency noise is then converted to a phase noise reading for the SUT or DUT.

Unfortunately, this method sacrifices some measurement sensitivity, especially at offsets close to the carrier. Longer delay lines can improve sensitivity, but while also reducing the signalto-noise ratio (SNR) of the measurement setup and limiting the maximum measurable offset frequency. The insertion loss of the delay line can also be a concern when trying to produce measurable test signal levels when analyzing low-level signals. As a result, this method works best with free-running sources such as inductor/capacitor (LC) oscillators and cavity oscillators. These tend to produce noisy signals that have high-level, low-rate phase noise or high close-in spurious sideband conditions that can limit the performance of the PLL technique.

In the heterodyne digital discriminator method, a heterodyne digital discriminator replaces the analog delay line of the frequency-discriminator phase-noise measurement method. In this approach (**Fig. 6**), the SUT is downconverted to an intermediate frequency (IF) by means of a mixer and a frequencylocked LO. The IF signal is amplified and digitized and then split and delayed using digital-signal-processing (DSP) techniques. As in the frequency-discriminator method, the delayed version of the signal is compared to the non-delayed version using a digital mixer and the delay is adjusted to achieve quadrature. The mixer output is filtered to remove the sum component, leaving a baseband component that is processed to produce a phase-noise value.

This method is suited to measurements of the high levels of phase noise that are typically present in unstable signal sources, such as some high-frequency VCOs. It provides a wider measurement range than the reference-source/PLL method and eliminates the need to reconnect the analog delay lines used in the frequency-discriminator method. By setting the delay time to zero, the heterodyne digital discriminator method also enables easy and accurate measurements of AM noise with the same setup and RF connections. On the downside, the total dynamic range of this measurement method is limited by the performance of the LNA and the analog-to-digital converters (ADCs).

The two-channel cross-correlation phase-measurement approach provides improved dynamic range compared to the heterodyne digital discriminator method. It employs two duplicate reference-source/PLL channels with the measuring instrument and calculates the cross-correlation between the two resulting Design & Technology <u>/</u>|_

VALIDATING A TEST SETUP

Once a measurement approach has been selected and a test solution assembled, how is it possible to know if the results provided by a particular test system are accurate? The answer: by using a calibrated, precisely characterized phase-noise signal. For example, a known-good reference is valuable when developing a direct-spectrum solution that includes self-written software that applies the necessary corrections. Such a reference source can be created by using uniform noise as the FM input to a signal generator. The slope of the noise sidebands will be constant at -20 dB/decade, and the desired sideband level can be reached by varying the deviation of the FM signal. Figure 8 shows a phase-noise-measurement calibration example produced with this FM-driven signal-generator approach. It was produced with a uniform noise signal frequency modulated at 500 Hz. This calibration signal yielded a measured phasenoise value of -100 dBc/Hz offset 10 kHz from the carrier.

Phase noise is one of the most important figures of merit for an RF/ microwave signal source. The phasenoise performance of the source can impact the effectiveness of a wide range of electronic systems, from commercial communications to military radars. The type of measurement method used to measure the phase noise of a given source should be guided by the nature of the signal source, such as whether it is relatively stable or is a free-running source with frequency that tends to vary over time. The measurement methods and solutions presented here are among the easiest and most cost-effective to implement. And while these approaches can provide excellent results for engineers who are not specialists in phase noise, an expert can help interpret results that may sometimes be quite puzzling.

outputs (Fig. 7). Because any SUT noise present in both channels is coherent, it is not affected by the cross-correlation computation. In contrast, any internal noise generated by either channel is noncoherent and is diminished in the crosscorrelation operation by the square root of the number of correlations. For the two-channel cross-correlation method, the number of correlation operations is a key factor in determining the total measurement time. In a typical instrument, the number of correlation operations is a user-selected value. Increasing the num-



«Excellence under extreme conditions»





HUBER+SUHNER solutions support your land-based, naval and airborne defence systems.

- SUCOFLEX 400 ultra low loss flexible micro-wave cable
- EACON Field terminating, waterproof cable and connector family up to 18 GHz
- KX Series Field terminating for Aerospace up to 6 Ghz
- Multiport Solutions our 18 GHz
 BMA contact family incorporated into MIL-C-38999

USA and Canada: Toll free 1866 HUBER SUHNER (1-866-482-3778)

hubersuhner.com

Increasing the number of cross-correlation ope	erations
will reduce the level of non-coherent nois	e.

Number of correlations	10	100	1000	10,000
Noise reduction	–5 dB	–10 dB	–15 dB	–20 dB



KRY IAR, Inc., founded in 1975, specializes in the design and manufacturing of ultra-broadband microwave components and test equipment for both commercial and military applications.

Products cover the DC to 67 GHz frequency range and are designed for a wide range of applications including:

- Test Equipment
- Simulation Systems
- □ SATCOM & SOTM
- □ Jammers for Radar & IEDs
- Radar Systems
- EW: ECM, ECCM & ESM

KRYTAR has a commitment to technical excellence and customer satisfaction.

These principles form the basis for the steady growth that has earned KRYTAR an enviable reputation in the microwave community.

Cover your bases. Contact KRYTAR today for more information.

MIL-Qualified RF, Microwave & mmW Components

- □ 3 dB 90° Hybrid Couplers to 40 GHz
- □ 3 dB 180° Hybrid Couplers to 26.5 GHz
- Beamforming Networks to 18 GHz
- Power Dividers to 45 GHz
- Detectors to 40 GHz
- Custom Applications



www.krytar.com 1288 Anvilwood Avenue • Sunnyvale, CA 94089 Toll FREE: +1.877.734.5999 • FAX: +1.408.734.3017 • E-mail: sales@krytar.com ber of correlation operations reduces the noise contribution from both channels (**see table**) but extends the time required to complete the measurement.

Because it reduces measurement noise, the two-channel cross-correlation technique is capable of achieving excellent measurement sensitivity. Since it relies on DSP techniques rather than analog signal processing, the measurement sensitivity is enhanced without requiring exceptional performance from the measurement hardware. The two-channel cross-correlation technique also provides greater dynamic range than possible with the digital discriminator method. The two-channel cross-correlation approach is a good choice when measuring the phase noise of free-running oscillators, although it can be used effectively for phase-noise mea-

Left unchecked, short-term stability can have deleterious effects on electronics systems that rely on extensive processing to extract information from a signal.

surements on many types of synthesized and stabilized high-frequency sources and oscillators.

COMPARING APPROACHES

Phase-noise measurements rely on a variety of different instrumentation choices, including general-purpose spectrum analyzers, specialized instruments, and personal-computer (PC) -based modular systems. The key differences in these hardware options center on capabilities, flexibility, and performance, which determines the overall performance possible from a given test setup, including such parameters as frequency range, dynamic range, and minimum and maximum offset frequencies that a solution can achieve. For example, the direct-spectrum approach can be implemented with a general-purpose spectrum analyzer or signal analyzer equipped with an optional phase-noise measurement application or
Design & Technology <u>/</u>-

personality. In most cases, the measurement application automatically performs the required carrier and noise measurements and then applies the necessary correction factors. The results may be presented as both a logarithmic phasenoise plot (in dBc/Hz versus logarithmic frequency) and a table of phase-noise values at specific offset frequencies from a desired carrier frequency. This solution typically works well when making phasenoise measurements at offsets as close as 10 Hz or 100 Hz from the carrier and at offsets as far as 10 MHz from the carrier, which is a typical offset range used throughout the RF/microwave industry to characterize the phase noise of highfrequency signal sources.

A benefit of performing phase-noise measurements with a software application or test personality and a general-purpose instrument such as a spectrum analyzer is the availability of the analyzer for test requirements other than phase-noise measurements. In addition, the cost of the measurement setup is essentially spread across any additional number of test applications possible with the spectrum or signal analyzer.

For the more complex phase-detector or cross-correlation methods, a dedicated standalone or modular test solution is typically needed and such a test system may not be suitable for the variety of measurements possible with a spectrum analyzer. For example, an instrument known as a signal-source analyzer (SSA) has been developed as a standalone solution for measurements of phase noise and other signal source characteristics. At least one commercially available SSA includes low-noise reference sources, an extremely low noise floor, and the DSP capabilities necessary to implement the heterodyne digital discriminator method and the two-channel cross-correlation technique. Such instruments are well-suited to measurement offsets as close as 1 Hz and as distant as 1 GHz. The dedicated functionality of an instrument like an SSA often means easy operation, as well as simplified setup and calibration.

Some PC-based modular solutions can be configured with an analog delay line to implement phase-detector techniques such as the reference-source/PLL method or the frequency-discriminator method. In the reference-source/PLL configuration, this type of solution often has the performance and capabilities needed to measure very low phase noise at offsets as close as 0.01 Hz when used with a highperformance LO. In frequency-discriminator mode, a system configured with an analog delay line can measure very low phase-noise levels at offsets far from the carrier. The downside of the versatility provided by this approach is that setup and calibration are more complicated than with the SSA- or signal-analyzer-based solutions. **DE**



ignal creation is critical to the design and analysis of a wide range of military electronics systems, including for electronic-warfare (EW), radar, and signal-intelligence (SIGINT) systems. Traditional methods of creating signals have relied on analog sources, which can require additional hardware and software to create advanced modulated signals. With

the new AWG70000 Series of arbitrary waveform generators from Tektronix (www.tektronix. com), however, an almost unlimited variety of highly accurate signals can be created right from the front panels of these highspeed instruments. They provide enough processing power and waveform memory to generate output waveforms up to 20 GHz for defense electronics, serial communications systems analycommunication research.

The AWG70000 Series consists of the single-channel model respectively. AWG70001A (Fig. 1, top) and

the dual-channel model AWG70002A (Fig. 1, bottom). Both create signal waveforms with 10-b resolution, with as much as 16 GSamples of waveform memory available to produce long signal sequences when necessary. Model AWG70001A features sample rates to 50 GSamples/s with 16 GSamples memory on its one channel. The model AWG70002A divides that sampling capability across its two channels for sample rates as high as 25 GSamples/s and 8 GSamples memory on each of its channels.

These arbitrary waveform generators can essentially generate any signal with-

Waveform Generators Run To 50 GSamples/s

This pair of high-speed arbitrary waveform generators provides the performance needed to create complex signals for analog, digital, and optical testing to 20 GHz.

in their ranges that can be captured or defined. The extended high-frequency performance of the generators is made possible by a 25-GSamples/s digitalto-analog converter (DAC) developed by the Tektronix Component Solutions group (www.component-solutions.tek. com). The DAC application-specificintegrated-circuit (ASIC) design was fabricated using the 8HP silicon-germanium (SiGe) BiCMOS device process

JACK BROWNE / TECHNICAL CONTRIBUTOR



sis, and even for coherent optical **1. The single-channel AWG70001A (top) and dual-channel** AWG70002A (bottom) arbitrary waveform generators operate at sampling rates to 50 and 25 GSamples/s,

from IBM (www.ibm.com). The 10-b vertical resolution translates into outstanding signal dynamic-range performance, with both generators offering a spurious-free dynamic range (SFDR) of -80 dBc or better (Fig. 2).

For either generator, second-harmonic levels are better than -60 dBc for output signals below 2 GHz. Second-harmonic levels are less than 50 dBc from 2 to 6 GHz, and less than -42 dBc for signals above 6 GHz. Third harmonic levels are less than -60 dBc for outputs below 1 GHz, less than -50 dBc for output signals from 1 to 2 GHz, and less than -40 dBc for output signals above 2

GHz. Random jitter for either generator is 250 fs root mean square (RMS), with total typical jitter of 10 ps at 125 Gb/s.

The generous amounts of memory available with these signal sources enable the creation of advanced, long-running signal formats. For example, in the single-channel model AWG70001A arbitrary waveform generator, 16 GSamples of waveform memory supports 320 ms of waveform data at the full sam-

pling rate of 50 GSamples/s. The AWG70001A is equipped with 2 GSamples of memory as a standard feature and 16 GSamples of memory as an option, while the AWG70002A provides 2 GSamples of memory as a standard feature and 8 GSamples of memory per channel as an option.

At the maximum sample rates of 50 and 25 GSamples/s for the AWG70001A and AWG70002A generators, the sin(x)/x 3-dB rolloff point occurs at 11.1 GHz, with higher-frequency signals produced at lower amplitude levels. For instance, the amplitude flatness for both generators is

within ± 1.8 dB to 10 GHz, $\pm 1.8/-3.0$ dB from 10 to 15 GHz. The single-channel model AWG70001A arbitrary waveform generator operates at sample rates of 1.5 kSamples/s to 50 GSamples/s. It can generate a maximum frequency of 20 GHz with an output amplitude range of -8 to -2 dBm. It provides amplitude resolution of 0.35 dB with amplitude accuracy of 0.17 dB.

The VSWR is 1.32:1 from DC to 5 GHz, 1.52:1 from 5 to 10 GHz, and 1.73:1 from 10 to 20 GHz. The model AWG70001A arbitrary waveform generator has an analog bandwidth of 15 GHz and operates at bit rates to 12.5

SUPER ULTRA WIDEBAND AMPLIFIERS

up to +27 dBm output... 0.1 to 21 GHz from \$845 ea.

Ultra wide coverage and super flat gain make our ZVA family ideal for ECM, instrumentation, and test systems. With an output power up to 0.5 Watts, they're simply some of the most usable amplifiers you'll find, for a wide range of applications and architectures!

All of our ZVA models are unconditionally stable, ruggedly constructed, and able to withstand open or short circuits at full output. For more details, from data sheets to environmental ratings, pricing, and real-time availability, just go to minicircuits.com! C RoHS compliant All models IN STOCK!

Mini-Circuits...we're redefining what VALUE is all about!

JMini-Circuits

Electrical Specifications (-55 to +85°C base plate temperature)						
Model	Frequency	Gain	P1dB	IP3	NF	Price \$ *
NEW	(GHz)	(dB)	(dBm)	(dBm)	(dB)	(Qty. 1-9)
ZVA-183WX+	0.1-18	28±3	27	35	4.0	1345.00
ZVA-183X+	0.7-18	26±1	24	33	3.0	845.00
ZVA-213X+	0.8-21	25±2	24	33	3.0	945.00
						·

Heat sink must be provided to limit base plate temperature. To order with heat sink, remove "X" from model number and add \$50 to price.







P.O. Box 350166, Brooklyn, New York 11235-0003 (718) 934-4500 Fax (718) 332-4661

The Design Engineers Search Engine finds the model you need, Instantly · For detailed performance specs & shopping online see minicircuits.com



Gb/s. It delivers a rise/fall time of better than 23 ps for a sampling rate of 25 GSamples/s and better than 27 ps for a sampling rate of 50 GSamples/s.

The dual-channel model AW-G70002A provides a maximum frequency of 10 GHz with an amplitude range of -8 to -2 dBm. It offers 0.35dB amplitude resolution with 0.17 dB amplitude accuracy and amplitude flatness of +0.8/-1.5 dB to 10 GHz. The AWG70002A exhibits VSWR of 1.61:1 from DC to 5 GHz and 1.61:1 from 5 to 10 GHz, with an analog bandwidth of

An Uncompromising Approach to Ultimate Mission Success High Efficiency & Light Weight & Small Size



Employing multipurpose payloads including EO/IR, EW, SAR and others, UAVs can now transmit complex information directly to troops in the field while simultaneously sending the information halfway around the world for analysis.

CTT, Inc. continues its expansion of GaAs- and GaN-based solid-state amplifier products and subassemblies designed to accommodate these ever evolving requirements.

CTT's UAV experience includes participation in data and video communication links on programs including Shadow, Hunter, Predator/Reaper, Pioneer, Global Hawk and others.

Building on this experience, CTT is well positioned to offer engineering and production technology solutions — including high-rel manufacturing — in support of your complete UAV system requirements.

More than twenty-five years ago CTT, Inc. made a strong commitment to serve the defense electronics market with a simple goal: quality, performance, reliability, service and on-time delivery of our products. Give us a call to find out how our commitment can support your mission success. It's that simple.

Uplink and Downlink Amplifiers

- C, X, Ku, and Ka-Band
- Power Amplifiers Up to 100 Watts
- Low-Noise Amplifiers 1–18 GHz
- Power and Driver Amplifiers for SAR
 X thru Ka-Band
 - Up to 100 Watts
- Up Converters and Transceivers
 C thru Ka-Band
 - Compact, Space-Saving Designs
- Surface Terminal Amplifiers
 C thru Ku-Band
 - Up to 100 Watts
- CDL and TCDL Subassemblies
 - IF and RF
 - Digitally Controlled





Phone: 408-541-0596 • Fax: 408-541-0794 • www.cttinc.com • E-mail: sales@cttinc.com



2. Both the AWG70001A and AWG70002A generators offer a spurious-free dynamic range (SFDR) of -80 dBc or better.

13.5 GHz and bit rates to 6.25 Gb/s. It offers a rise/fall time of better than 22 ps for a sampling rate of 25 GSamples/s. The skew between the AWG70002A's two channels is within \pm 5 ps. It provides channel-to-channel output skew control from -100 to +100 ps with 500 fs resolution and \pm 5 ps accuracy and less than 5 ps intrachannel skew.

The generators can be used to create and simulate real-world signal environments in a number of ways. Both arbitrary waveform generators are fully operational with or without an external personal computer (PC), and can take advantage of the company's powerful and flexible RFXpress[®] software.

In addition, the AWG70001A and AWG70002A generators can use waveform vectors imported from third-party software simulation tools to create and playback complex waveforms. Signals captured on Tektronix oscilloscopes or real-time spectrum analyzers can also be transferred to the AWG70001A and AWG70002A generators and played back. With the aid of the company's RFXpress software (**Fig. 3**), captured signals can be edited and modified to meet a wide range of requirements.

Either of the AWG70000A generators teamed with the RFXpress software can produce RF, baseband, and intermediate-frequency (IF) signals for system test and analysis. The software helps digitize and synthesis signals, providing full modulation capabilities over the 20-GHz bandwidth of the AWG70001A source and the 10-GHz bandwidth of the AWG70002A. For fashioning pulsed and modulated waveforms, the software can command all the parameters needed to precisely generate a pulsed waveform; these include start time, rise time, off time, fall time, pulse width, droop, overshoot, and ripple.

The RFXpress software simplifies



3. This screen shows the graphical user interface for the RFXpress software, which can be used with the AWG70001A and AWG70002A generators to create a wide range of analog and digitally modulated waveforms.

the creation of complex radar signals, including with step and nonlinear frequency modulation (FM); linear frequency modulation (LFM); and Barker and polyphase codes. By teaming with one of the arbitrary waveform generators, the RFXpress software can be used to generate pulse trains with staggered pulse repetition interval (PRI) to resolve range and Doppler ambiguity, frequency hopping for electronic-countermeasures (ECM) and electronic-counter-counter-measures (ECCM) applications. It can also support a wide range of intra-modulation formats.

To simplify signal generation for radar designs, the RFXpress software can be used with one of the generators and the Radar Signal Creation software module. This module enables operators to build custom radar pulse suites starting from pulse-to-pulse trains though complete groups of pulsed waveforms. A number of other modules are available for use with the RFXpress software and the arbitrary waveform generators, including the Environmental Signal Creation module, which makes it possible to emulate a complete RF environment, to evaluate the performance of radar receivers in the presence of other signals.

For truly complex signal emulation, two or more of the AWG70000A arbitrary waveform generators can be synchronized for linking multiple units to increase the channel count, as might be needed for testing some phased-array radar systems. In addition to their RF/microwave capabilities, the AWG70001A and AWG70002A arbitrary waveform generators can provide serial data signals to 12.5 Gb/s and can generate highspeed I/Q signals for testing optical systems. The instruments can be controlled via front panel and remotely by Universal Serial Bus (USB), Ethernet, and GPIB. P&A: \$120,000 (AWG70002A with 25 GSamples/s sampling rate on each channel) and up. **DE**

Tektronix, Inc., 14150 SW Karl Braun Dr., P.O. Box 500, Beaverton, OR 97077; (503) (800) 833-9200, (503) 627-6497, www.tektronix.com.



© 2013 dB Control Corp. All rights reserved. Photos provided courtesy U.S. Air Force, U.S. Army and U.S. Navy.

contact us today.

JACK BROWNE / TECHNICAL CONTRIBUTOR

Simulator Assists Infantry Training

With its high-resolution head-mounted display, this wearable simulation system allows trainees to be fully immersed in virtual scenarios.

nfantry training is critical to ultimate mission success in the field, and modern electronic tools have made it possible to elevate the education to a new level. One of the better training simulators available is ExpeditionDI® from Quantum3D (www.quantum3d.com), a wearable turnkey simulation solution for US Army infantry simulation and training. The simulator's open software architecture enables integration of simulation and game software to create realistic battle scenarios in which those wearing the simulator can freely act as individuals, but learn to behave as part of a team.

The ExpeditionDI system is based on research performed by CG² (www. cg2.com), a wholly owned subsidiary of Quantum3D. Research has shown that the most dangerous time for new warfighters is when they are in a new environment learning how to handle weapons and different combat situations. The ExpeditionDI system is designed to provide practical training in almost any environment (**Fig. 1**), using a hardware "weapon" in a virtual environment presented on a highresolution display screen. The weapon has a realistic shape, weight, and feel.

The uniform employs a 1280 × 1024 pixel organic-light-emitting-diode (OLED) head-mounted display (HMD) to provide realistic images. The simulator uses wireless connectivity to provide a collective training environment for any number of participants (**Fig. 2**).

Participants do not simply look at a video screen but are immersed in a simulated world, with senses responding to audio and video information. With the high-resolution HMD, when a participant moves his head, the world he is viewing moves



1. The ExpeditionDI system is a fully worn simulator that immerses a user in a virtual world with audio and video information.

accordingly. Because posture sensors are built into the leg strap, when a trainee drops to a knee, his perspective on the virtual world changes. The tightly coupled HMD presents a 360deg. field of view with the participant in the middle. The flexible simulator, with an open architecture that allows a variety of different simulation and game software to be integrated into the controller, can be networked for largerscale exercises for joint forces training. The uniform/system includes an audio headset with microphone for realistic tactical communications and recording.

Each ExpeditionDI is powered by a hot-swappable battery for full mobility.

The system's computer is contained within a wearable pack on the back of the uniform, and the platform features an integrated cable-management system that can withstand hard use in any training field. The ExpeditionDI also employs a patent-pending hand-grip/ controller unit that provides an intuitive interface for locomotion within the virtual environment. Those wearing the system hear the sounds of the environment as well.

The ExpeditionDI simulator is an effective tool not only for military trainees, but also for special security forces and civilian law-enforcement personnel. Among other programs, it is currently part of the Dismounted Soldier Training System led by the Army's Program Executive Office for Simulation, Training, and Instrumentation (PEO STRI). Because the training system is portable and uses wireless communications and can be operated with a variety of different software tools, it can be used almost anywhere and at any time. It can host a number of different simulation software programs, including SVS from Advanced Interactive Systems (www. ais-sim.com), VBS2 from Bohemia Interactive (www.bistudio.com), and RealWorld from Total Immersion Software (now Intific: www.totimm. com). In addition, Squad Kits are available for group training and mission rehearsal. DE

Quantum3D, 5400 Hellyer Ave., San Jose, CA 95138; (408) 600-2500, FAX: (408) 600-2604, e-mail: sales@quantum3d.com, *www. quantum3d.com*.



2. The ExpeditionDI simulation system can be used in groups with wireless connectivity, allowing coordinated exercises.





Improve the efficiency of your test setup!

DC to 18 GHz from \$385

Test multiple parameters or multiple DUTs in a single pass. Quit constantly stopping to connect/disconnect cables! It sounds simple, but you'll quickly appreciate all the "smarts" we built into our new switch matrices. The user-friendly GUI gets you up and running in minutes right out of the box, for step-by-step control, full automation, or remote operation via the internet. They're fully compatible with almost any PC and most third-party lab software,* adding capabilities to existing setups with ease! And the rugged aluminum cases house our patented mechanical switches, the only ones available anywhere, at any price, that offer up to 10 years/100 million cycles of guaranteed performance.[†] Just go to minicircuits.com for technical specifications, performance data, pricing, and real-time availability—or give us a call to discuss any custom programming needs—and think how much time and money you can save!

Mini-Circuits...we're redefining what VALUE is all about!

Model	# Switches (SPDT)	IL (dB)	VSWR (:1)	Isolation (dB)	RF P _{MAX} (W)	Price \$ (Qty. 1-9)
USB-1SPDT-A18	1	0.25	1.2	80	10	385.00
USB-2SPDT-A18	2	0.25	1.2	80	10	685.00
USB-3SPDT-A18	3	0.25	1.2	80	10	980.00
USB-4SPDT-A18	4	0.25	1.2	80	10	1180.00
NEW USB-8SPDT-A18	8	0.25	1.2	80	10	2495.00

* See data sheet for an extensive list of compatible software.
†The mechanical switches internal to each model are offered with an optional 10 year extended warranty. Agreement required, see data sheets on our website for terms and conditions. Switches protected by patents 5,272,458 6,650,210 6,414,577 7,633,361 7,843,289 and additional patents pending.





P.O. Box 350166, Brooklyn, New York 11235-0003 (718) 934-4500 Fax (718) 332-4661

The Design Engineers Search Engine finds the model you need, Instantly · For detailed performance specs & shopping online see minicircuits.com

JACK BROWNE / TECHNICAL CONTRIBUTOR

Switch Matrices Reconfigure To 40 GHz

These 5 x 5 and 10 x 10 offerings bring flexibility and performance to measurement applications that require fast switching speeds and high reliability.

F

F

witch matrices can greatly enhance the productivity of a test-and-measurement system, reliably routing input signals to different output ports as needed. In terms of flexibility, the 5×5 switch matrices in the FX500 series and the 10 × 10 matrices in the FX1000 seriesboth from SenarioTek (www.senariotek. com)-offer a variety of different configurations for testing commercial and military applications. In addition, the firm recently announced the extension of these FlexMatrix reconfigurable switch matrices to incorporate signal conditioning when needed.

The rack-mountable FX500 and FX1000 switch matrices (see figure) are available in models that provide frequency coverage of DC to 6 GHz, DC to 26.5 GHz, and DC to 40 GHz (see table). The FlexMatrix expansion ports on these reconfigurable units make it possible to

expand them to a greater number of ports, as needed. In addition, the company recently announced that the flexibility of these expansion ports also makes it possible to add signal conditioning, such as an amplifier or filter, between a FlexMatrix input and output port without adding external switching. This can help simplify testing of consumer wireless components as well as military communications and radar equipment.

All FX500 series units are 5×5 switch matrices with 1 W powerhandling capability and 10-ms switching speed, housed in a 2U-high rack-mountable chassis. The FX500 series consists of the DC-to-6-GHz model FX506, the DC-to-26.5-GHz



The FX500 series 5 x 5 switch matrices and the FX1000 series 10 x 10 switch matrices are available in rack-mount enclosures for applications from DC through 40 GHz.

The FlexMatrix FX500 and FX1000

switch matrices at a glance.						
Model	Configuration	Frequency range				
X506	5 x 5	DC to 6 GHz				
X526	5 x 5	DC to 26.5 GHz				
X540	5 x 5	DC to 40 GHz				
X1006	10 x 10	DC to 6 GHz				
X1026	10 x 10	DC to 26.5 GHz				
X1040	10 x 10	DC to 40 GHz				

model FX526, and the DC-to-40-GHz model FX540. Typical performance for the lowest-frequency switch matrix includes insertion loss of 1.5 dB, VSWR of 1.50:1, and isolation between ports of 80 dB across the full frequency range. The FX526 switch matrix has typical insertion loss of 1.5 dB from DC to 6 GHz, 2.5 dB from 6 to 18 GHz, and 3.5 dB from 18 to 26.5 GHz. The VSWR is 1.50:1 from DC to 6 GHz, 2.0:1 from 6 to 18 GHz, and 2.5:1 from 18 to 26.5 GHz. The isolation is typically 80 dB from DC to 6 GHz, 70 dB from 6 to 18 GHz, and 60 dB from 18 to 26.5 GHz.

The highest-frequency 5×5 switch matrix, model FX540, exhibits insertion loss of 1.5 dB from DC to 6 GHz, 2.5 dB from 6 to 18 GHz, 3.5 dB from 18

to 26.5 GHz, 4.5 dB from 26.5 to 32.0 GHz, and 6.0 dB from 32 to 40 GHz. The VSWR is typically 1.50:1 from DC to 6 GHz, 2.0:1 from 6 to 18 GHz, and 2.5:1 from 18 to 40 GHz. The typical isolation is 80 dB from DC to 6 GHz, 70 dB from 6 to 18 GHz, 60 dB from 18 to 32 GHz, and 55 dB from 32 to 40 GHz.

The FX1000 series consists of 10 x 10 switch matrices in 4U rack-mount chassis, also with 1-W input rating and 10-ms switching speed. The series includes models FX1006 for use from DC to 6 GHz, FX1026 for applications from DC to 26.5 GHz, and FX1040 for use from DC to 40 GHz. As might be expected, the electrical performance is somewhat degraded compared to the smaller FX500 units, but still quite good. The DC-to-40-GHz model FX1040 exhibits insertion loss of 3 dB from DC to 6 GHz, 4 dB from 6 to 18 GHz, 6 dB from 18.0 to 26.5 GHz, 8 dB from 26.5 to 32.0 GHz, and 10 dB from 32 to 40

GHz. It has VSWR of 1.60:1 from DC to 6 GHz, 2.10:1 from 6 to 18 GHz, 2.60:1 from 18.0 to 26.5 GHz, and 2.70:1 from 26.5 to 40.0 GHz, with typical isolation of 80 dB from DC to 6 GHz, 70 dB from 6 to 18 GHz, 60 dB from 18 to 32 GHz, and 55 dB from 32 to 40 GHz. For the other models, performance over the common frequency bands is quite similar.

The 6- and 26.5-GHz FX500 and FX1000 switch matrices are outfitted with precision SMA connectors, while the 40-GHz models have precision 2.92-mm connectors. The 40-GHz models are rated for operating lifetimes of 2×10^6 switching operations while the 6- and 26.5-GHz models are rated for lifetimes of $10 \times$ 10^6 switching operations. The switch matrices offer front-panel lightemitting-diode (LED) position indicators and standard three-year warranties, and are available with LAN, GPIB, or USB interfaces. **DE**

SenarioTek, 3636 North Laughlin Rd., Ste. 150, Santa Rosa, CA 95403; (707) 544-2770, FAX: (866) 409-7626, sales@ senariotek.com, www.senariotek.com.

NEWS SHORTS _/>

High-Speed DAC Drives EW Systems

ektronix Component Solutions (www.tektronix.com) has developed a highly accurate, 10-b digital-to-analog converter (DAC) capable of operating at sampling rates to 25 Gsamples/s. This high-performance component is key to the success of the arbitrary waveform generators featured in this issue's Cover Story (see p. 24). The DAC is now available apart from the firm's instrument products for use in defense, medical, commercial aerospace, and coherent optical applications.

The high-speed DAC (model TDAC-25), which is ideal for electronic-warfare (EW) applications, features a dynamic range exceeding -60 dBc across its operating range. The application-specific integrated circuit (ASIC) supports direct generation of wideband signals at bandwidths of 12 GHz and more. The DAC has already been designed into two next-generation systems under development, including the CHAMP-WB-DRFM, a VPX module designed by the Defense Solutions group of Curtiss-Wright Controls Defense Solutions (www. cwcdefense.com).

Tom Buzak, President of Tektronix Component Solutions, notes that "this new DAC offering showcases the effectiveness of our development model. Our organization brings the expertise in ASIC design, chip packaging, and RF/microwave data converters needed to power new Tektronix instrumentation. At the same time, we're able to make these advanced capabilities and technologies available to customers in noncompeting industry segments, helping to solve their signal generation challenges and lower the cost of their systems."

IR Satellite Joins SBIRS Configuration

The second Space Based Infrared System (SBIRS) Geosynchronous Earth Orbit (GEO-2) spacecraft was encapsulated into its payload in preparation for its launch and addition to the SBIRS missile-defense configuration. As mentioned on p. 22, this advanced infrared (IR) surveillance satellite, developed by Lockheed Martin (www.lockheedmartin.com), will enhance the United States' missile warning capabilities while improving missile defense, intelligence, and battlespace awareness.

The satellite **(see figure)** includes highly sophisticated scanning and staring sensors with improved IR sensitivity. Its scanning sensor will provide a wide area surveillance of missile launches and natural phenomena across the earth, while the staring sensor will be used to observe smaller areas of interest with superior sensitivity.

The SBIRS includes a mix of satellites in geosynchronous orbit, hosted payloads in highly elliptical earth (HEO) orbit, and ground hardware and



software. Lockheed Martin's SBIRS contracts include four HEO payloads, four GEO satellites, and ground assets to receive, process, and disseminate the infrared mission data. The firm has also begun procuring long lead parts for the fifth and sixth GEO satellites. The SBIRS team is led by the Infrared Space Systems Directorate at the US Air Force Space and Missile Systems Center. Lockheed Martin is the SBIRS prime contractor and Northrop Grumman is the payload integrator. The US Air Force Space Command operates the SBIRS system.

Armored Vehicles Require Costly Upgrades

coording to market research performed by industry analysis Visiongain (www.visiongain.com), the global market for upgrades and retrofits to armored vehicles will be worth \$4.97 billion (USD). Annual spending on systems retrofitted to armored vehicles is expected to rise by 17.7% based on their 2012 levels. The report "Global Armored Vehicle Upgrade & Retrofit Market 2013-2023," points to the need to improve vehicular performance in Afghanistan and other locations. In spite of expected cuts in US defense spending, the nation is committed to programs worth more than 45% of the global armored vehicle upgrade market in 2013.

The Visiongain report provides a detailed breakdown of the sources of growth and areas of contraction in the armored vehicle upgrade and retrofit market, including detailed 10-year budget forecasts for the 20 largest national countries. The financial research is backed by interviews with representatives from four key locations, including AmSafe (www.amsafe.com), Plasan (www. plasan.com), and Navistar Defense (www.navistardefense.com). The 185-page report details trends and market projections within the armored vehicle upgrade and retrofit market.

NEW PRODUCTS (

Power Sensor Spans DC To 110 GHz

odel R&S NRP-Z58 is a broadband power sensor that enables power measurements over the continuous frequency range of DC to 110 GHz. The thermal sensor supports a dynamic range from –35 to +20 dBm (55 dB)

and is capable of more than 300 measurements



dB and includes a ball-bearing 1-mm coaxial plug connector for ease of connection to other test equipment. The sensor's high frequency range makes it a suitable tool for analyzing commercial automotive applications—such as cruise-control and collision-

warning systems—at 77 GHz, as well as industrial and military radar systems at 94 GHz.

Rohde & Schwarz USA, Inc.

8661A Robert Fulton Dr., Columbia, MD 21046-2265; (410) 910-7800, FAX: (410) 910-7801; e-mail: info@rsa.rohde-schwarz.com, www.rohde-schwarz.com.

Phase Shifter Runs 18 To 40 GHz

odel 7929 is a digitally programmable phase shifter suitable for military airborne systems operating from 18 to 40 GHz. Over that frequency range, it provides a full 360-deg. phase shift with accuracy of ±15 deg. and maximum switching

per second for production testing. With its integral Universal Serial Bus (USB) connector, the sensor can be connected di-

rectly to a personal computer (PC). It is also designed for use

with any of the company's signal generators, spectrum analyzers, or network analyzers. The sensor offers linearity of 0.01

time of better than 500 ns. It uses 10-b transistor-transistorlogic (TTL) control to adjust phase, boasting resolution as fine as 0.35 deg. with guaranteed monotonic phase control. The phase shifter handles signals to +20 dBm without performance degradation, with insertion loss specified at 15 dB but more typically at 13



dB across the wide frequency range. The component achieves typical input second-order and third-order intercept points of +60 and +35 dBm, respectively. The phase shifter is supplied in a hermetic package measuring 1.95 × 1.67 × 0.52 in. and designed for an operating temperature range of –54 to +95°C. **Herley General Microwave**

227A Michael Dr. Syosset, NY 11791; (516) 802-0900, FAX: (516) 802-0897, e-mail: sales.newyork@herley.com, www. herley.com.

Power Amplifier Drives 6 To 18 GHz

odel BHE69189-20 is a solid-state Class AB linear power amplifier that provides output levels in excess of 20 W from 6 to 18 GHz. Designed to work into a 2.0:1 load VSWR, this rugged amplifier offers 25-W typical saturated output power; it boasts better than 41 dB (and typically 45-dB) gain with an output level of 20 W. The RF input overdrive level occurs at +10 dBm. Second harmonics are -15 dBc, while thirdharmonic levels are at -30 dBc. Spurious output levels are at -60 dBc or less. Using a 5-V transistor-transistor-logic (TTL) Amplifier Cuts Noise From 5 To 11 GHz

odel CMD132P3 is a low-noise amplifier (LNA) that provides outstanding RF/microwave performance from 5 to 11 GHz. This offering is suitable for C- and X-band pointto-point and point-to-multipoint radios, as well as in military and space equipment. The LNA exhibits a low noise figure

of 1.3 dB across its frequency range, with better than 20-dB gain and an output 1-dB compression point of +10 dBm. It provides +13-dBm saturated output power and a third-order intercept point of +22 dBm. Input return loss is typically 10 dB and output return loss is



typically 15 dB. Housed in a RoHS-compliant, $3 \times 3 \text{ mm QFN}$ plastic surface-mount package, the amplifier operates with a single voltage supply of +3.6 VDC and only 30 mA current. The 50- Ω matched design does not require external DC blocks or matching components, and can be installed with a minimal number of external components other than bypass capacitors. **Custom MMIC**

1 Park Dr., Unit 12, Westford, MA 01886; (978) 467-4290, FAX: (978) 467-4294, e-mail: davef@custommmic.com, www. custommmic.com.

signal, the amplifier can be enabled or disabled in 2 microseconds or less. The rack-mountable amplifier measures 19 \times 22 \times 3.5 in. and weighs 40 lbs. Ilt is supplied with Type-N female coaxial connectors, but available with SMA orTNC connectors as options.

Comtech PST

105 Baylis Rd., Melville, NY 11747; (631) 777-8900, FAX: (631) 777-8877, e-mail: sales@comtechpst.com, www. comtechpst.com.



NEW **ULTRA-REL** CERAMICAMPLIFIERS \$**4**95 ea. (qty 20)

10 MHz to 6 GHz High IP3 up to 38 dBm Low DC current 80 mA

When failure is not an option. Our new CMA amplifiers deliver incredible performance, in an incredibly rugged, nitrogen-filled hermetic LTCC design, just 0.045" high, that can only be found at Mini-Circuits! These models are so tough, they've qualified for use under every test condition we've thrown at them:

MIL Standard Qualifications (see website for complete list and details)

Gross and Fine Leak Mechanical Shock Vibration Acceleration PIND

HTOL (1700 hours + @ +105°C) Thermal Shock Steam Aging Solder Heat Resistance Autoclave (and more)

Electrical Specifications (-55 to +105°C)

Chouter	Model	Freq. (GHz)	Gain (dB)	Р _{ОUT} (dBm)	IP3 (dBm)	NF (dB)	DC (V)	Price \$ea (qty 20)
	CMA-62+	0.01-6	15	19	33	5	5	4.95
	CMA-63+	0.01-6	20	18	32	4	5	4.95
1.14 mm	CMA-545+	0.05-6 ïant	15	20	37	1	3	4.95

Robust performance across wide bandwidths make them

ideal for instrumentation, or anywhere long-term reliability

adds bottom-line value, in outdoor, industrial & commercial

applications. Go to minicircuits.com for all the details today,

and get them in your hands as soon as tomorrow!

Mini-Circuits...we're redefining what VALUE is all about!

3 x 3 >



P.O. Box 350166, Brooklyn, New York 11235-0003 (718) 934-4500 Fax (718) 332-4661

The Design Engineers Search Engine finds the model you need, Instantly · For detailed performance specs & shopping online see minicipations.com

0. 7761442

IF/RF MICROWAVE COMPONENTS

503 Rev Oria

GaN Amp Drives Satcom Systems

odel XTSLIN-100X-B1 is a power amplifier with block upconverter (BUC) based on gallium-nitride (GaN)

device technology. The amplifier delivers 100 W linear out-

put power from a compact housing measuring just $6.8 \times 10.5 \times 17.0$ in. The amplifier provides efficient operation for single- or multicarrier tactical satcom systems. With its BUC, it handles input signals from 950 to 1450 MHz and provides output signals from 7.9 to 8.4



GHz, using a 6950-MHz local-oscillator (LO) signal. The unit is available with 60 to 68 dB factoryconfigurable smallsignal gain with ±0.5dB or better gain varia-

tion over any 400-MHz operating

frequency segment. **Comtech Xicom Technology, Inc.** 3550 Bassett St., Santa Clara, CA 95054; (408) 213-3000, FAX: (408) 213-3001, e-mail: sales@xicomtech.com, www. xicomtech.com.

Amplifiers Power Systems To 20 GHz

A pair of transistor amplifiers fromTriQuint Semiconductor serve commercial and military communications applications through 20 GHz. ModelTGA2579-FL is a high-gain amplifier supplied in a 14-pin flange package. It delivers 32-dB small-signal gain with +44-dBm saturated output power from 13.75 to 15.35 GHz. It features a typical third-order intercept point of +48 dBm and 30% power-added efficiency.

The amplifier incorporates low-loss groundsignal-ground (GSG) transitions and is supplied in a lead-free and RoHS-compliant housing. Designed for operating temperatures from -40to $+85^{\circ}$ C, it runs on drain voltage of +25 VDC, quiescent drain current of 1 A, and typical gate voltage of -3.4 VDC. The more broadband model TGM2543-SM is a combination limiting amplifier and low-noise amplifier (LNA) that can survive



CW input levels to 4 W from 4 to 20 GHz. This GaAs device varies gain by means of its two gates, with typical electrical requirements that include drain voltage of +5 VDC, drain current of 100 mA, and voltage of -0.6 and +1.3 VDC at the two gates.

TriQuint Semiconductor, Inc.

2300 NE Brookwood Pkwy., Hillsboro, OR 97124; (503) 615-9000, FAX: (503) 615-8902, e-mail: info-sales@tqs.com, www.triquint.com.

ADVERTISERS' INDEX

Advanced Circuits	S7
Agilent Technologies	S17
AWR	IBC
Coilcraft	IFC
СТТ	S26
Emerson Network Power	S11
Equipto Manufacturing	S20
Huber & Suhner	S21
IMS 2013	S6
Krytar	S22
Microlambda	S2
Mini-Circuits/SCI Components	S9

Mini Circuits/Sci Components	S13
Mini Circuits/Sci Components	S15
Mini Circuits/Sci Components	S25
Mini Circuits/Sci Components	S29
Mini Circuits/Sci Components	S33
Nexyn Corporation	S18
Phase Matrix	S23
PIC Wire & Cable	S5
Signal Antenna Systems	S19
TRM Microwave	BC
dB Controls	S27

Pads Program Levels From DC To 18 GHz

rogrammable attenuators in the PA series from RLC Electronics are available in coaxial housings for applications from DC to 18 GHz. Two basic models provide total attenuation ranges of 0 to 15 dB in 1-dB steps (model PA124) and 0 to 70 dB in 10-dB steps (model PA-125). For example, PA-125 models can be specified for frequency ranges as wide as DC to 18 GHz with maximum insertion loss of 0.5 dB from DC to 5 GHz: 0.8 dB from 5.0 to 12.4 GHz; and 1.0 dB from 12.4 to 18.0 GHz. These attenuators exhibit maximum VSWR of 1.50:1 from DC to 5 GHz: 1.70:1 from 5.0 to 12.4 GHz: and 1.80:1 from 12.4 to 18.0 GHz. The rugged PA-125 attenuators are supplied with SMA female connectors. They use attenuation cells of 10, 20, and 40 dB to achieve the values of 10, 20, 30, 40, 50, 60, and 70 dB, with accuracy of at least ±1 dB per cell. Both types are available with TTL drivers, failsafe or latching operation, and +12- or +28-VDC coils, and in a choice of frequency ranges.

RLC Electronics, Inc.

83 Radio Circle, Mount Kisco, NY 10549; (914) 241-1334, (FAX: (914) 241-1753, email: sales@rlcelectronics.com, www. rlcelectronics.com.

Combiner/Divider Goes Eight Ways

odel D5829 is an eight-way power combiner/divider rated for 400 W CW power from 20 to 500 MHz. It features at least 20-dB isolation between ports, with maximum VSWR of 1.40:1. The insertion loss is 0.75 dB or less across the full frequency range. Phase balance is ± 5 deg. or better, while amplitude balance is ± 0.3 dB or better. The rugged power combiner/divider measures 12.00 × 7.75 × 2.25 in. with choice of Type-N female connectors, SMA connectors, or a combination of the two connector types.

Werlatone, Inc.

17 Jon Barrett Rd., Patterson, NY 12563; (845) 278-2220, FAX: (845) 278-3440, email: sales@werlatone.com, www.werlatone.com.





The AWR mmWave design flow. Often MMIC'd. Never duplicated.

When you're racing toward important targets, design performance is paramount. Don't let yourself be duped. Nobody does more for mmWave MMIC design than AWR. You can do circuit, system, and EM simulations faster, easier, and more accurately. What's more, with schematic and layout in the same UI, you're more efficient and avoid the manual mistakes associated with running multiple tools. Tackle today's high-end, mission-critical mmWave MMIC designs with ease. Grab a test copy at www.awrcorp.com/mwo.



MICROWAVE OFFICE®



Custom component military · space · commercial

Custom Design Manufacturer

DC through 40 GHz • High-Mix/Low Volume • Multi-Technology Expertise

thinking



Beamformers - Power Dividers - Directional Couplers - Hybrids

TRM is a recognized leader in the design and manufacture of custom RF and microwave components, integrated assemblies and subsystems for defense, space and commercial applications.

Over its 42 year history, TRM Microwave has built its solid reputation by engineering innovative solutions for mission critical systems using the most suitable combination of stripline, coaxial, microstrip, ferrite and air-strip technology. From sourcing of quality materials to optimized manufacturing processes and equipment, TRM is committed to delivering the best solution to our customers. Our catalog of power dividers, couplers and hybrids provides a cost-effective starting point for upgrading to high-reliability, space-qualified components.

Email us at info@trmmicrowave.com or call us at 603.627.6000 to learn more about our custom capabilities. We are growing... Apply today!



TRM is ISO 9001:2008 certified and is an ITAR compliant facility.

603.627.6000 info@trmmicrowave.com Bedford, NH 03110