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# ELECTRONICS POWER MANAGEMENT


## USING POWER WISELY

### Saving Watts Increases Usage and Saves $

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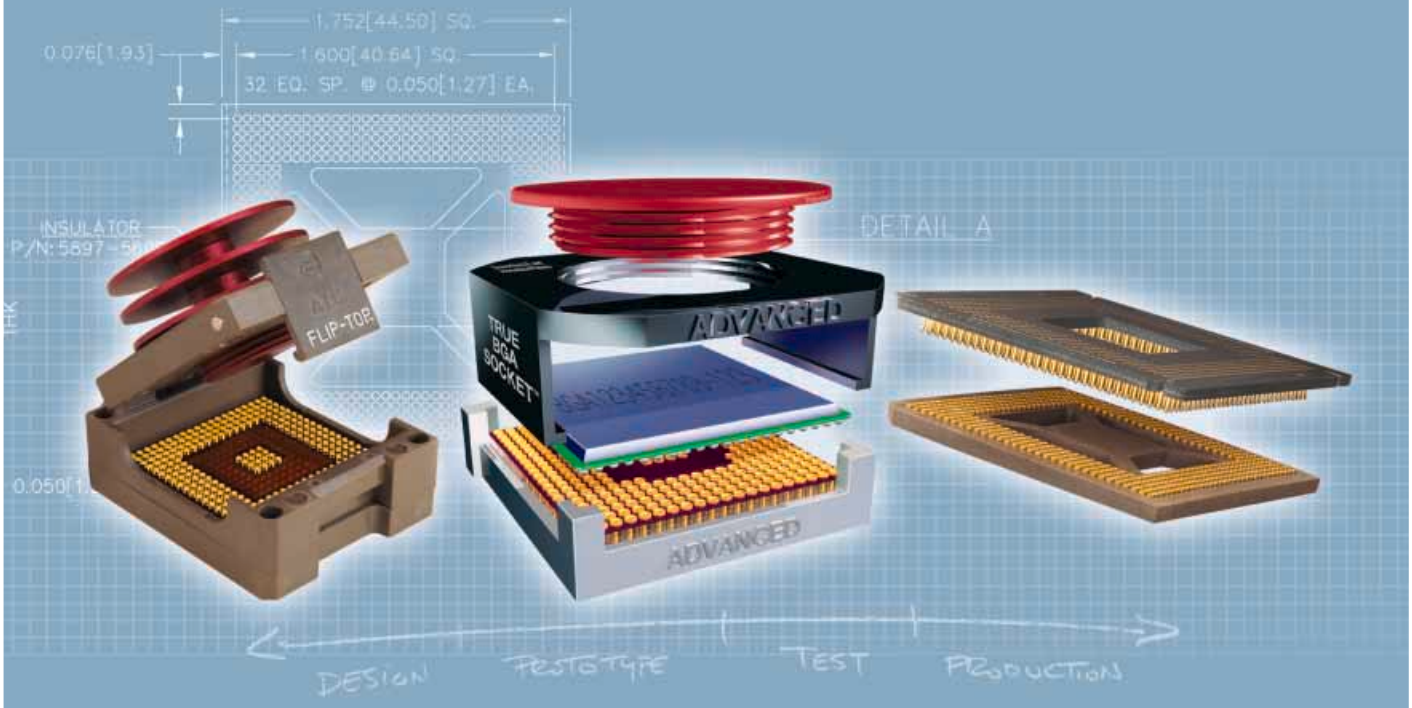


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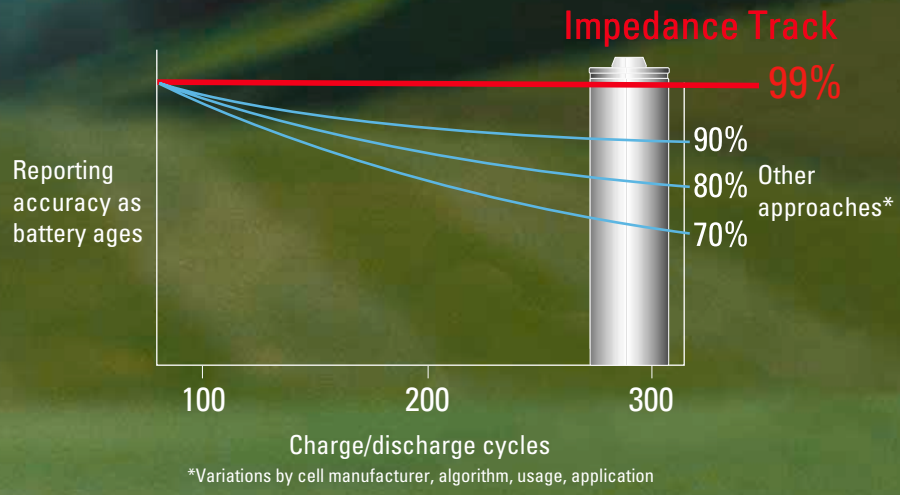


*Variations by cell manufacturer, algorithm, usage, application



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# USING POWER WISELY

## Saving Watts Increases Usage and Saves $

*Power is never appreciated as a precious commodity until it's not available. When a battery in any portable product is fully discharged, the product becomes a paperweight even if it only weighs a few ounces. When excessive power demand shuts down the power grid during hot summer months, air conditioners, televisions, computers, and all non-battery-powered electrical/electronic appliances sit idle.*

*Using the latest technology, engineers are putting more complex power management strategies in place to reduce power consumption. Reduced power consumption can impact consumers' purchases by providing longer time between charges for products including portable cell phones, cameras, computers, and PDAs. Products with advanced power management features provide consumers, as well as commercial and industrial organizations, the means to reduce electricity cost. The importance of power conservation is addressed at the national level by efforts such as the U.S. Department of Energy's Energy Star Program and the International Energy Agency's "1-Watt Initiative." This special power management report addresses all of these areas, highlighting both analog and digital approaches for power management in both battery and grid-powered applications, as well as how industry's insiders are addressing these issues:*

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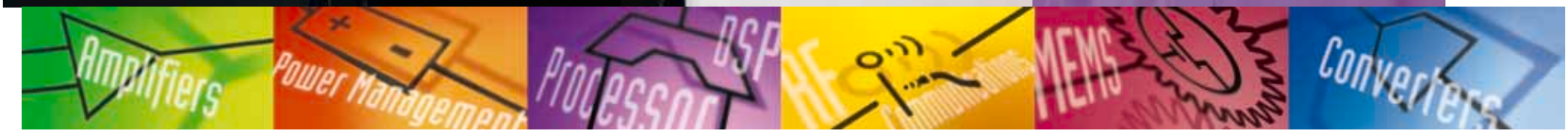
- Amplifiers with the low noise, low distortion, and power efficiency required for sophisticated signal conditioning
- High performance linear and mixed-signal ICs, PLLs, digital isolation ICs, switches, multiplexers, plus other analog ICs, all at the leading edge of performance

The bottom line: When industry leaders National Instruments and Analog Devices partnered, engineers got powerful measurement tools that increased total system value—like never before.


**"ADI's high performance converter and amplifier technology makes possible the high speed and high precision needed in National Instruments' new designs, which provide our customers with a wide range of leading-edge test and measurement equipment."**

Tim Dehne, VP of Engineering
National Instruments

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## SILICON SOLUTIONS

Semiconductor companies have put significant effort into expanding analog power management integrated circuits (ICs) as well as developing digital solutions for managing power. These solutions include controllers and regulators, the distinction being the power function is included with those products classified as regulators. One of the easiest strategies for advanced power management is simply taking advantage of the improvements that the newest circuits offer as off-the-shelf solutions. For established products, custom ICs or application-specific integrated circuits (ASICs) can provide a highly integrated answer for reducing board space and overall system cost. These ICs and more efficient power semiconductors are being designed by several established and numerous start-up companies for dc-to-dc converters and ac-to-dc power supplies.

## STRATEGIES FOR PORTABLE AND WIRED APPLICATIONS

- Disintegrate to improve time to market
- Use scalable multiphase for high-current computing applications
- Reduce the power consumption in the standby mode
- Reduce switching losses and use an integrated power stage for high-frequency applications
- Bring digital technology inside point of load control
- Use digital technology for various aspects of power management
- Use highly integrated power management ICs for increased value

## POWER MANAGEMENT SEMICONDUCTOR AND IC PRODUCTS

**Analog Power Management**

- Battery management (i.e., protection ICs, fuel gauges, charge controllers)
- DC-DC converters/controller
- AC-DC converters/controller
- Off-line SMPS control
- Power factor controller
- Voltage reference
- Linear voltage, low drop-out regulator
- Switching Regulator
- Dedicated driver IC (i.e., LED drivers, flash strobe, control, display interface, display) control, audio,
- Dedicated power management control
- Supervisor circuit (reset and temperature sensors, undervoltage and overvoltage circuits)
- DC motor control
- Optocouplers

**Discrete Semiconductors**

- Power (FETs, IGBTs, bipolar, rectifiers)
- LEDs

**Digital**

- Digital power control
- Digital management IC
- Digital supervisory circuit
- Digital PWM converter
- Digital multi phase controller

**Hybrid Power Management**

- (Digital & analog) controller

| LEVEL OF DIGITAL CONTROL | POWER CONTROL LOOP | TYPICAL DIGITAL CONTROLLER | PROGRAM MEMORY | EXAMPLE FUNCTION |
|---|---|---|---|---|
| Augmenting existing analog design | Analog | Small microcontroller | 0.5-2 kbytes | Softstart or power-sequenced point-of-load converter |
| Actively manage analog control power | Analog | Small to midsize microcontroller | 1-8 kbytes | Programmable voltage/current level |
| Integrated digital and analog power loop control | Analog and digital | Speciallized microcontroller | 2-16 kbytes | Adaptable multiphase converter |
| Pure digital loop control | Digital | Microcontroller with DSP functionality | 8-64 kbytes | High-power ac/dc converter |

***The long-established world of analog power management is becoming part of the digital invasion. Digital control is being implemented in four different levels with the highest level appreciate only for very high-end power supplies. See Microchip executive's commentary on page S12 for more details.***

## 1 AUDIO/VIDEO JUKEBOXRCA

### RCA Lyra

**Portable Hard Drive Player**

Almost half of the area of the palm-sized Lyra is a liquid crystal display for video and still pictures. It has a built in 20-Gbyte hard drive that stores 5,000 MP3 songs or 25 hrs of video.

- Total watts: About 2.5W consumption
- Battery type: Lithium ion, 2,200 mA-h, 3.7V
- Battery run time: Video playback 4 hrs; audio, 12 hrs
- Battery recharge time: 3 to 4 hrs
- Power up time: Under 10 sec


**Power Management Strategies**

More than 10 Texas Instruments power management ICs are used to control functions such as the white LED driver for backlighting the display, Li-Ion battery charger, dc-to-dc switch mode boost converters, low drop out regulators, and a step down dc-to-dc converter.

http://rbi.ims.ca/3880-500

## 2 HP707

### Hewlett Packard

**Digital Camera**

The HP707 has 5.1 megapixels with 24x zoom, 2,612 x 1,968 resolution, and 32-Mbyte internal memory. Image sensor is a diagonal 9.075 mm (1/1.8-inch, 4:3 format) charge coupled device (CCD). The display is a backlit, 1.5-inch color active matrix TFT LCD with 119,548 pixels (494 by 242).

- Typical power usage: 2.3W with LCD on. Maximum power usage of 4W.
- Battery type: Lithium ion or option to use one disposable Duracell CP1 battery.
- Battery recharge time: 5-7 hrs (average)

**Power Management Strategies**

The digital camera has several Texas Instruments power devices to manage various voltage levels including, two dc-dc boost converters and a dedicated power management IC.

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## Create Analog and Digital Harmony

*Lou Pechi, Marketing Director, Power-One*

On-board power conversion can be fairly simple until there is a need to control and manage a number of different voltages on the circuit board. Adding external control and management to the conversion devices complicates and makes the power system complex. One solution is using digital conversion inside the point-of-load (POL) converters that creates harmony between simple conversion and the complex digital control and management, and results in overall system simplicity. For example, the Z-One Digital IBA™ board-level power management and conversion system, developed by Power-One, consists of just a single ZM7000 digital power manager (DPM) that interfaces with up to 32 identical ZY7000 digitally controlled non-isolated Z-POLTM converters. The whole system can be programmed, controlled, and monitored through the industry-de-facto standard I2C bus. In the Z-One Digital IBA™ the conflict between the simple and the complex is resolved with the resulting harmony, providing numerous benefits such as: overall cost savings; reduction of component count, different part numbers, and different vendors; decrease in the number of circuit board traces; and overall savings of circuit board space.

## Time to Market Strategy

*David Carey, President, Portelligent*

There is no doubt about priorities in portable products. Clearly battery life reigns supreme as an important parameter. With the addition of cameras and color screens, richer operating systems, and applications processors, handsets are dripping with electronics and there is a significant need to provide careful attention to power management. The handset world has probably advanced the art of power management better than any other product category. Portelligent recently performed a teardown analysis of one of the first 3G W-CDMA phones that demonstrates a first to market strategy for power management. This cell phone is the first to use i-motion, video-clip, and music transmission service with a videophone. To be first to market and incorporate a number of new features, several off-the-shelf power management chips were used in the design. More than ten integrated circuits and at least three power MOSFETs were identified that address various voltage requirements and manage the power in this handset. When there is significant time pressure to get to market before your competitor, it is very typical to implement what could be called a relatively disintegrated solution. In the disintegrated system, there is still a relatively high level of integration. But with a new design when the volumes are low and future feature sets are uncertain, putting all the pieces together into one power management ASIC may not be practical.

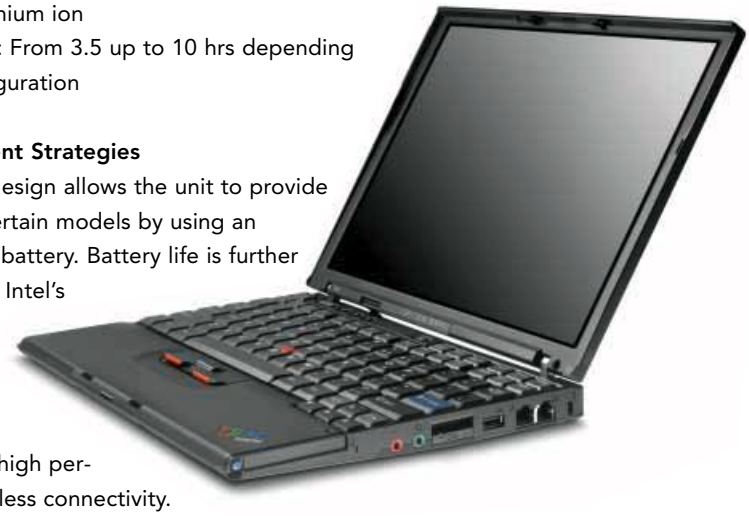
## ❸ THINKPAD X40

IBM

**Ultraportable Notebook Computer**

Weighing only 2.7 lbs for the lightest unit, the ThinkPad X40 provides up to 3.5 hrs of battery life with a gamut of wireless connectivity options. Unique battery options allow users to obtain up to 10 hrs of battery life while increasing the total weight to less than 4 lbs.

- Battery type: Lithium ion
- Battery run time: From 3.5 up to 10 hrs depending on battery configuration



**Power Management Strategies**

A unique battery design allows the unit to provide up to 7.5 hrs on certain models by using an optional eight-cell battery. Battery life is further extended by using Intel's Centrino mobile technology, designed to provide lower power consumption with high performance and wireless connectivity.

http://rbi.ims.ca/3880-502

## Use Highly Integrated Power Management ICs for Increased Value

*Rich Valley, Vice President of System Power Management, Texas Instruments*

Successful power conditioning for today's portable designs and complex telecom systems can be a daunting task. In the eyes of the designer, the power supply is practically invisible to a system's performance. A power supply is expected to take up very little space, supply no heat, add no extra cost and maintain perfect system reliability. But as electronics become more prevalent in every day life, there is a growing need to tightly couple the power supply with system operation, making power system design ever more vital. Power management semiconductor suppliers continue the quest to build greater value into higher-performing products. An increasing number of OEMs rely on their semiconductor suppliers to provide a much higher level of application support, including complete hardware examples of design applications–often tailored to meet specific system requirements. Improved semiconductor process techniques with tighter resolution reduce die sizes for controller chips, and newer process technologies are set to provide greater power integration and design flexibility. The end result provides engineers with easy to use, higher functionality, and lower cost-per-function power management solutions.

## Flexible Power Strategy for Computing

*Gene Sheridan, Vice President, International Rectifier*

When designing a 150A voltage regulator for EVRD and voltage regulator module (VRM) 10.x designs, it is critical to enable engineers to design for the "sweet spot" where both efficiency and transient performance reach maximum levels. A scalable multiphase synchronous buck converter is one of the best solutions for the low-voltage, high-current requirements (1V and up to 150A) of next-generation microprocessors. Flexibility in the number of phases ( from 1 to 16 phases) and selection of operating frequency allows the designer to achieve the optimal balance in performance parameters. In addition, the ability to expand to other converter voltages using VRMs via an average current sharing bus is an advantage. The distributed control IC architecture enables local phase current signal processing, which minimizes induced noise and facilitates layout while reducing the gate driver to power stage impedance. For example, IR's multiphase XPhase™ architecture, together with benchmark DirectFET™ MOSFETs, offer the architect of EVRD and VRM10.x designs the flexibility of selecting desired phase count and frequency to deliver very fast transients and 88 percent full-load efficiency.

## 4 PD-42WX84

JVC

**42-inch XGA Plasma Display Television**

The plasma TV offers a 3000:1 contrast ratio, 770p Digital Image Scaling Technology for all video sources, 4-Point Color Management Circuitry, and supports TV scan lines of 480i, 480p, 720p, and 1,080i.

- Input voltage: 100-120V @ 50-60 Hz
- Power: 36W total audio output (audio portion only)

**Power Management Strategies**

JVC engineers designed the TV to meet the U.S. EPA's Energy Star rating. Extensive use of digital technology is made for items such as noise clear circuitry and image scaling technology, and high-end edge correction circuitry.

http://rbi.ims.ca/3880-503

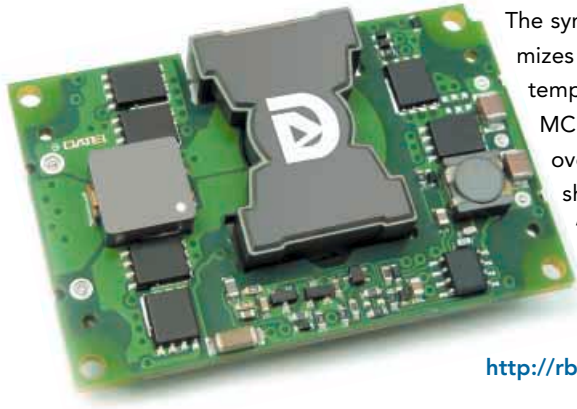
## 5 QBC-12/22-L48

Datel

**Isolated, Intermediate Bus Converter**

Targeting telecom power, the fully isolated open-frame dc/dc converter achieves low, 80 mVp-p ripple/noise, and is available in a standard quarter-brick package.

- Total power output: 264W
- Efficiency @ full load: 96 percent
- Voltage input 48V input (40.5 to 57V range)
- Output: 12V/22A for intermediate bus



**Power Management Strategies**

The synchronous-rectifier topology allows ultra-high efficiency, minimizes power losses, and enables full-power operation to ambient temperatures up to +70C with minimal air flow. Using a Microchip MCU PIC, the unit provides full I/O fault protection including input overvoltage and undervoltage shutdown, output overvoltage shutdown, output current limiting, and "hiccup" and optional "latch-up" short-circuit protection. The microcontroller-based approach reduced the number of components to provide all these functions from 60-plus components down to 12.

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## 6 Z-POL™

### Power-One

**Point-of-Load (POL) Converter**

The Z-POL provides power densities up to 39 A/inch² and integrates a digital PWM controller, digital current sharing, and power-system communication functions for intermediate bus architectures. The vertical mounting achieves a 1.25 x 0.3-inch footprint and is only 0.55-inch high.

- Voltage input: 3.0 to 13.2V dc
- Output: 0.5 to 5.5V dc (programmable) up to 15A

**Power Management Strategies**

The unit makes maximum use of digital technology with a patented digital PWM to reduce the number of external active and passive components while increasing the reliability and providing extremely high current densities. High power density is achieved by using vertical mounting in surface mount technology.

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## Reduce Switching Losses and Integrate Power Stage

*Serge Jaunay, Vice President of Marketing Development, Vishay Siliconix*

Designer challenges for today's systems are similar in many different applications requiring higher efficiency products in spite of increasingly lower voltages due to device thermal limitations in advanced semiconductor processes. This has resulted in a drastic increase in output current, which in turn increases the need for improved power management for dc-dc converters. Overall, what this creates is a need for even higher efficiency. Examples of application trends include 200A, 1V output CPU road maps in desktop computers, 10-hr notebook usage by 2008, and PDA-phone convergence with notebook power predicted to include additional features such as camera, multi band-mobile, and wireless access. These trends have created a new power train paradigm requiring higher frequency. Obtaining high efficiency at higher switching speeds requires a new MOSFET structure to reduce switching losses without compromising the conduction losses. Products such as Siliconix FabuFET are designed for switching applications. In addition, an integrated MOSFET and driver function is required for the power stage. This integration can be at the silicon or packaging level, and targeted at either high-frequency (1 to 2 MHz and up to 20A output) or high-current (up to 40A output switching up to 300 kHz) applications, but in any case provides an optimized, efficient subsystem. Using this methodology provides system designers better optimization and easy interface for traditional analog power management and as they transition to digital power control.

## Lower the Standby Power

*Seth Prentice, Strategic Marketing Engineer, Fairchild Semiconductor*

Recognizing the importance of electrical energy, many governments and organizations have created stringent power regulations for switch mode power supplies (SMPSs), such as the International Energy Agency's (IEA) "1-Watt Initiative," which requires that the standby power is less than 1W for specific electronic products. Semiconductor suppliers have responded with products such as Fairchild's Green FPS™ ICs that have an integrated PWM and current sensing MOSFET. This product can address power supplies with ratings up to 200W to help systems meet these regulations in cell phones and several other applications. During standby, the SMPS's load current drops and, at the same time, the GreenFPS provides a burst of energy to align with the required power, meeting the 1W initiative. Cell phones provide an excellent example of the impact provided by using these kind of power management ICs. In the U.S.A. there are 309 million cell phone adapters in operation. An adapter without burst mode consumes 1.84W while not charging the phone. Integrating GreenFPS in the power supply design would reduce the power consumption to 0.29W. For this single application, if one third of the adapters remained in standby for half the time the U.S.A. would recognize a 79.8-MW savings per year. Some of the newest GreenFPS ICS are designed with frequency modulation operating over a range of frequencies to reduce electromagnetic interference. Other Green FPS ICs are designed for systems that require a quasi-resonant input. In the quasi-resonant products, the PWM cycles with the horizontal and vertical inputs to avoid distortion. By providing a quasi-resonant input for color TVs and CRT monitors, even more power can be saved.

## Use Digital Techniques for Expanded Power Management

*Fani Duvenhage, Marketing Manager, Microchip*

To cope with the increasing voltage complexity in high-performance computing ICs, the traditional analog switching power supply is getting considerable help from digital technology. However, digital control in power supplies is a very broad topic. To make it easier to understand, digitally controlled power supplies can be subdivided into four different levels. The first level is simply a digital controller to provide a secondary function or to complement an existing power supply with a feature that was difficult to do with analog, such as soft start or sequencing. This level does not involve the power loop. The second level gets more involved with actively managing the power loop. A small cost-effective MCU can make some smart decisions such as checking for overvoltage and undervoltage conditions, performing calibrations, and doing temperature compensation. At this time, this could be the most popular level for using digital control. In level three, the control loop is still primarily analog, but the analog portion can be integrated with the MCU to actively adjust the feedback loop. This level is just emerging. The last step is a completely digitally controlled power supply. The A to D is sampled very fast, and the MCU or even a DSP directly controls the PWM. At this point, this would only be appropriate in very high-end power supplies. The main driver is telecom power supply systems with an intermediate power bus.

## 7 G7NC-C5A

### Bel Power

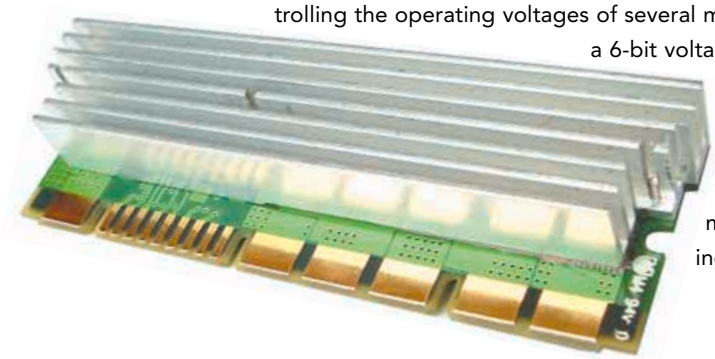
**Non-Isolated Converter**

The G7NC-C5A converter is a non-isolated step-down dc/dc converter designed to be compatible with both the Intel VRM10.2 and AMD Opteron requirements.

- Total power output: 120A
- Voltage input: Nominal 12V
- Output: Options for several microprocessor operating voltages

**Power Management Strategies**

A PIC16F72 microcontroller was used in conjunction with a four-phase power control IC. The analog to digital converter channels are used to monitor various parameters such as input voltage, output voltage, an optional analog trim signal, a temperature sensor, and internal operating points. The converter provides options for controlling the operating voltages of several microprocessor loads. Using a 6-bit voltage identification (VID) bus, the MCU identifies the unique ID of different microprocessors and tells the voltage regulation module (VRM) what operating voltage is required.



## 8 PX3536 AND PX3520 REFERENCE DESIGN

### Primarion Digital Power Products

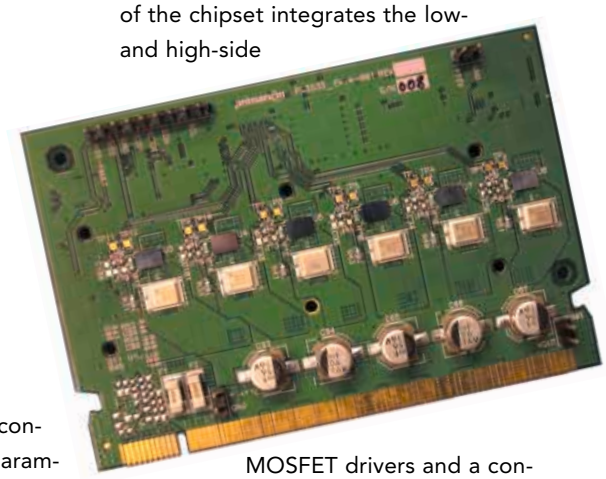
**VRM Reference Design**

The reference design demonstrates the capability of Primarion's PX3536 digital multiphase controller and PX3520 power stage. The reference design is packaged for a 1U (1 × 4 inches) voltage regulator module (VRM).

- Output current: 120A (four-phase)
- Output voltages: Between 1.1V and 1.3V
- Efficiency: 85 percent

**Power Management Strategies**

The PX3536 manages from two to four phases to achieve supply regulation of 40 mV. Operating at frequencies up to 1 MHz, the PX3520 power stage portion of the chipset integrates the low- and high-side



MOSFET drivers and a control (P-Channel) MOSFET into a chip scale package delivering up to 30A per phase. Internal registers for the digital controller are accessible through an industry standard I2C serial bus for customizing the protection features.

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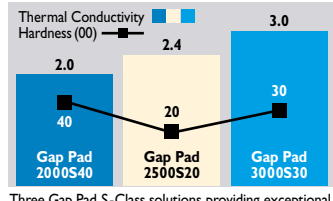

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## POWER—MORE CHALLENGING THAN EVER

In an effort to spur development of more efficient ac-dc power supplies, two U.S. regulatory agencies have collaborated and thrown down the gauntlet with the **Efficiency Challenge 2004**, a power supply design competition. The U.S. Environmental Protection Agency (EPA) and the California Energy Commission announced the international design competition for power supply efficiency, dubbed the Efficiency Challenge 2004, at the IEEE Applied Power Electronics Conference and Exposition (APEC), Feb. 23, 2004. More efficient ac-dc power supplies have been identified as a major opportunity for reducing global energy consumption and greenhouse gas emissions.

To provide real-world targets for development, Intel, Sony, and Pace Micro subsequently provided internal power supply specifications for desktop computers, LCD televisions, and set-top boxes. The specifications can be found at: **www.efficientpowersupplies.org/competition.html**.

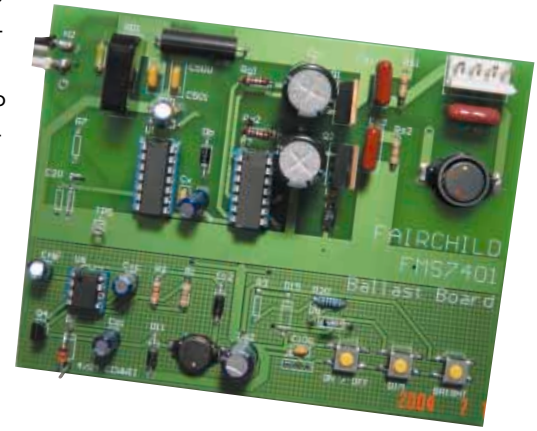
Winners of the competition will be announced at APEC 2005, which will be held in Austin, TX, March 6-10, 2005.

## 9 FMS7401L REFERENCE DESIGN

### Fairchild Semiconductor

**Ballast Board**

The FM7401L is a hybrid, digital with analog power controller, designed with an 8-bit microcontroller core. Integrated functions include 1K on-board code EEPROM, 64 bytes of data ROM, 64 bytes of SRAM, and a fast 12-bit PWM timer with deadtime control. The reference design uses this capability in a ballast board for powering a fluorescent light that requires only three ICs and provides medium to high performance with programmability and a high degree of flexibility.




- Power output: Sufficient for two S32T8 bulbs (64W)
- Voltage input: 90 to 250Vac at 50/60 Hz
- Output: 600V peak for start-up and up to 20Vrms for running

**Power Management Strategies**

Digital phase lock loop allows for higher frequency PWM operation for reduced power consumption. The unit provides flexibility of full digital control and cost savings of pure analog approaches allowing designers to meet time to market, customization, and digital communication requirements very effectively.

http://rbi.ims.ca/3880-507

### VISIT THESE LINKS FOR MORE INFORMATION ON POWER MANAGEMENT SEMICONDUCTOR AND IC COMPANIES

| | |
|---|---|
| Advanced Power Technology | http://rbi.ims.ca/3880-576 |
| Allegro Microsystems | http://rbi.ims.ca/3880-577 |
| AMI Semiconductor | http://rbi.ims.ca/3880-578 |
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| Bay Linear | http://rbi.ims.ca/3880-584 |
| Fairchild Semiconductor | http://rbi.ims.ca/3880-585 |
| Freescale (formerly Motorola) | http://rbi.ims.ca/3880-586 |
| Infineon Technologies | http://rbi.ims.ca/3880-587 |
| Intersil | http://rbi.ims.ca/3880-588 |
| International Rectifier | http://rbi.ims.ca/3880-589 |
| IXYS | http://rbi.ims.ca/3880-590 |

*More on page S16*

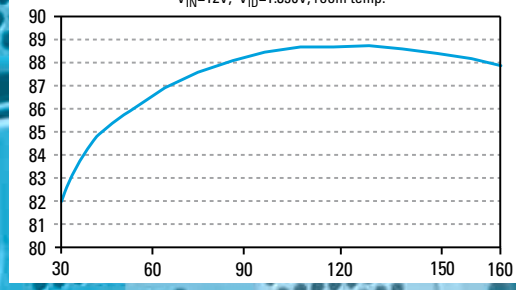
# DESIGNING A 150A VOLTAGE REGULATOR?

***Scaleable XPhase Architecture and DirectFET MOSFETs Achieve 88% Efficiency with a 2.5 sq-in Powertrain***

**7-Phase XPhase-DirectFET Design**


**EVRD10.x: Efficiency vs. Load Current**

$V_{IN}$=12V, $V_{ID}$=1.350V, room temp.




| Part Number | $BV_{DSS}$ (V) | $R_{DS(on)}$max @10V (mΩ) | $R_{DS(on)}$max @4.5V (mΩ) | DirectFet Package | $V_{GS}$ (V) | $I_D$@25°C (A) | $Q_G$ Typ. (nC) | $Q_{GD}$ Typ. (nC) |
|---|---|---|---|---|---|---|---|---|
| IRF6691 | 20 | 1.6 | 2.4 | Med Can | ±12 | 160 | 49 | 16 |
| IRF6617 | 30 | 8.0 | 10.5 | Small Can | ±20 | 52 | 13 | 3.0 |

| Part # | Function | Package | Applications |
|---|---|---|---|
| IR3081 | VR 10.X Control IC | 28-Lead MLPQ | Controller for EVRD 10.x and VRM 10.x for Servers |
| IR3086 | Phase IC | 20-Lead MLPQ | Phase ICs with fault detect and integrated VR-HOT |

IR's new XPhase™ architecture, together with benchmark DirectFET™ MOSFETs, offer the architect of EVRD and VRM10.x designs the flexibility of multiple phases for the highest efficiency power management. A 7-phase EVRD 10.x design using IR's award winning products is capable of delivering 150A, 88% efficiency, and runs so cool it doesn't need a heatsink.

The higher phase count enables a compact design by reducing the size of output filters, saving cost and valuable board real estate, in servers and workstations.

**Features**

- Uses the IR3081 and IR3086 XPhase chipset and the IRF6617 and IRF6691 DirectFET MOSFETs
- Eliminates the need to parallel MOSFETs
- Low profile, small size ceramic and POS caps
- Smaller solution footprint saves board space

**The IR Advantage**

- Only 150A EVRD 10.x solution exceeding 88% in efficiency
- Flexible, scaleable solution enables more than 4 phases for higher efficiency and small size as EVRD and VRM current requirements increase
- 2.5 sq. in powertrain

Achieve the highest efficiency, compact designs with award-winning solutions from the power management leader. Contact your local IR sales representative today.



**for more information call 1.800.981.8699 or visit us at**

**http://dc2dc.irf.com/evrd**

International IOR Rectifier

THE POWER MANAGEMENT LEADER

# USING POWER WISELY

## LINKS FOR MORE INFORMATION ON POWER MANAGEMENT SEMICONDUCTOR AND IC COMPANIES *(continued from page S14)*

| | |
|---|---|
| Linear Technology | http://rbi.ims.ca/3880-591 |
| Maxim | http://rbi.ims.ca/3880-592 |
| Micrel | http://rbi.ims.ca/3880-593 |
| Micro Linear | http://rbi.ims.ca/3880-594 |
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| Microchip Technology | http://rbi.ims.ca/3880-596 |
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| Power-One | http://rbi.ims.ca/3880-604 |
| PowerX | http://rbi.ims.ca/3880-605 |
| Primarion | http://rbi.ims.ca/3880-606 |
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| Semtech | http://rbi.ims.ca/3880-608 |
| Silicon Power Corp. | http://rbi.ims.ca/3880-609 |
| Silicon Semiconductor | http://rbi.ims.ca/3880-610 |
| Siliconix (Vishay) | http://rbi.ims.ca/3880-611 |
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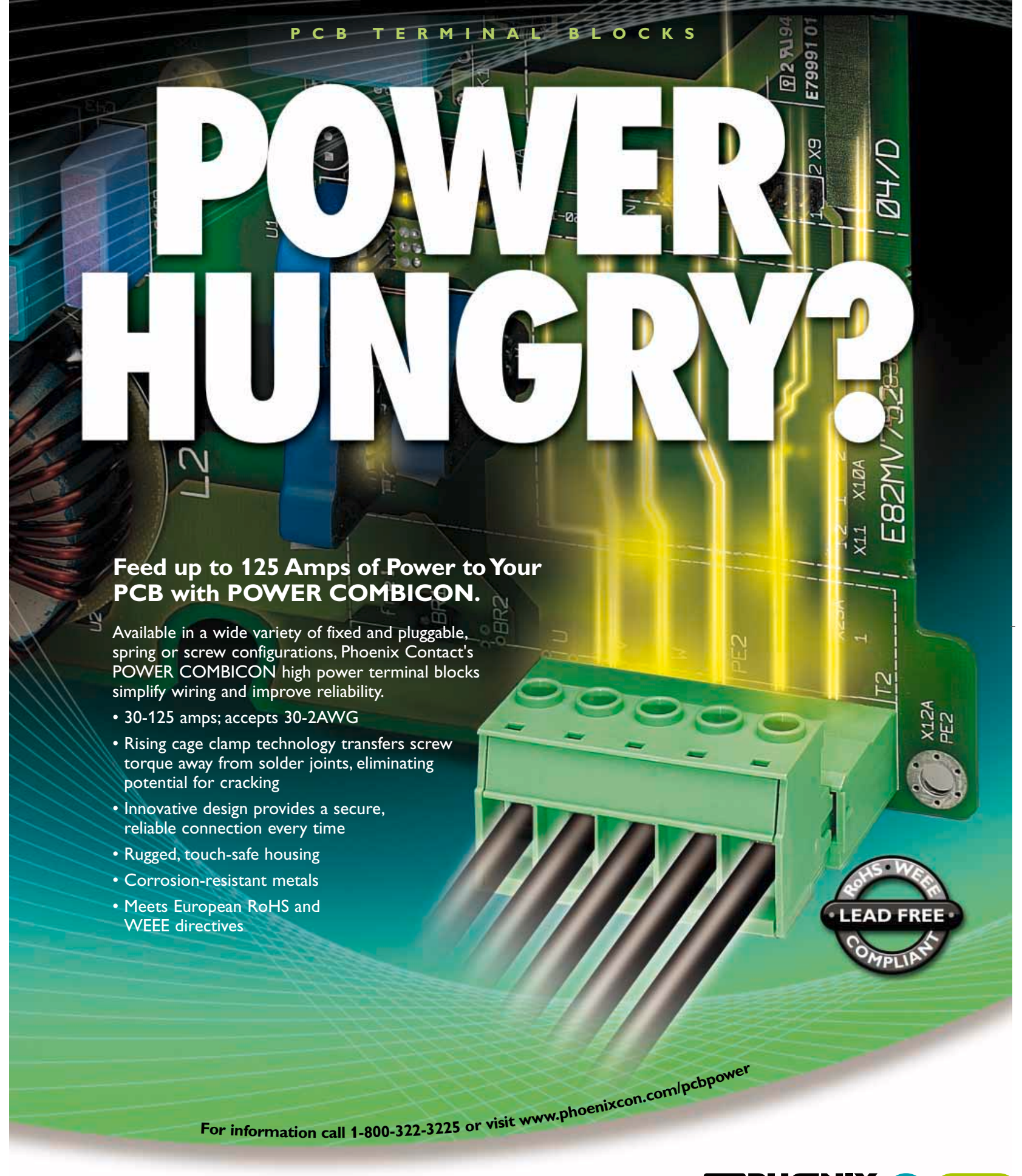
PCB TERMINAL BLOCKS

# POWER HUNGRY?



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