

LM2633,LM2657,LM2717,LM3370,LP3906

Implementing Single-Chip FPGA Power Solutions



Literature Number: SNVA597

POWER | *designer*

Expert tips, tricks, and techniques for powerful designs

No. 115

Feature Article.....1-7

Digital Processor Power Management Unit.....2

Power Management Units for Digital Subsystems.....4

Low Output Voltage LDOs6

Power Design Tools.....8

Implementing Single-Chip FPGA Power Solutions

— By Hector F. Arroyo, Sr. Field Applications Engineer

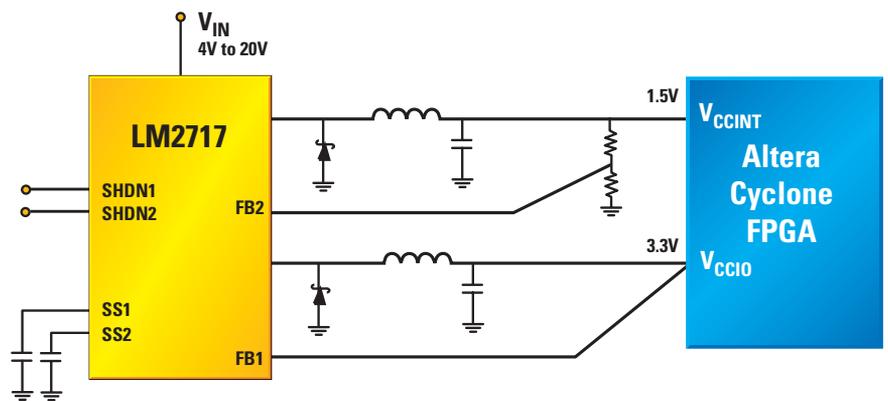


Figure 1.

LM2717 Dual Integrated Switching Supply for 1.5V Core and 3.3V I/O Medium-power FPGA

FPGA-based systems are becoming increasingly common. While many designers favor FPGA-based architectures for the flexibility of adding features or making modifications through code, designing an adequate power supply involves some challenges. First is the multiple power rail issue. FPGAs require, as a minimum, one voltage for powering the core and one (or more) voltages to power the I/O banks. However, FPGA-based systems may require additional rails to power double data rate (DDR) memory, transceivers, Ethernet Physical Layer ICs (PHYs), ADCs or small microcontrollers. Additionally, these voltage rails need to have specific characteristics: sub-1.25V outputs, monotonic ramp-up, sequencing, and controlled rise time etc.

While design engineers and semiconductor manufacturers make continuous efforts to provide integrated, easy-to-use alternatives, many times it is still up to the designer to leverage available features and go beyond the typical datasheet circuit to implement an optimal solution. Through this article, we

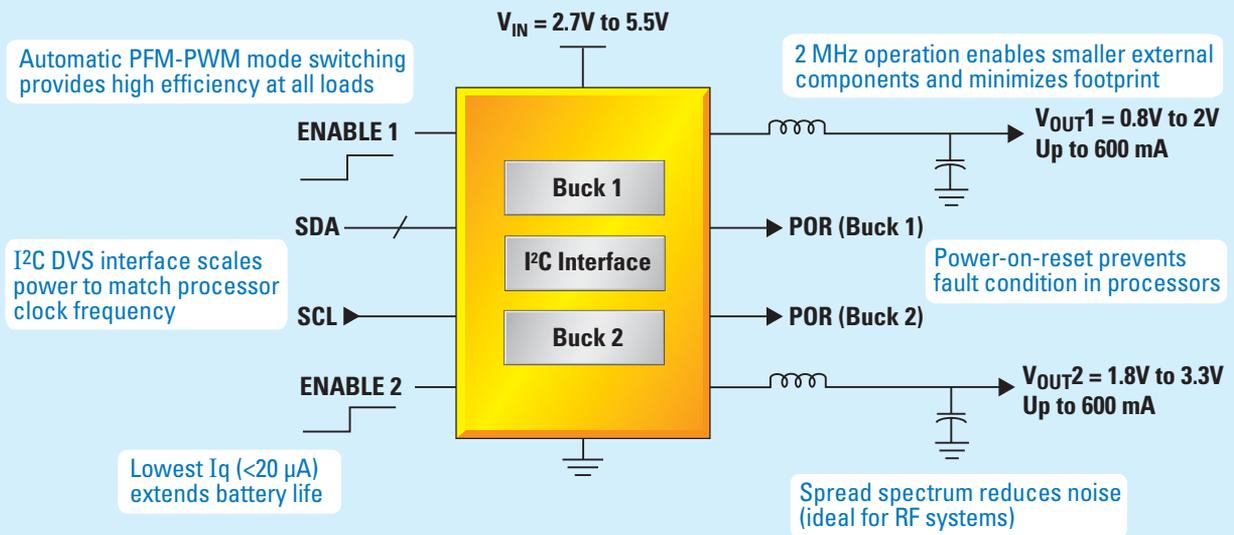
NEXT ISSUE:
Powering High Brightness LEDs

 **National
Semiconductor**
The Sight & Sound of Information

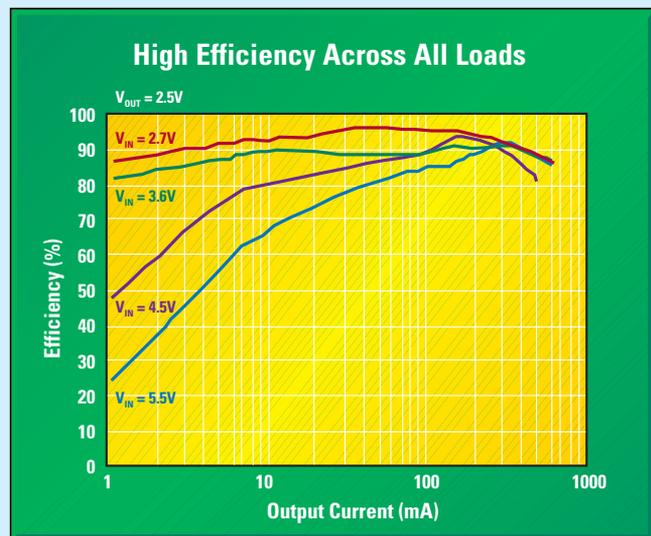


Enhance Digital Processor Power Management with Dynamic Voltage Scaling (DVS)

LM3370 Dual Buck Regulator Provides Highest Efficiency for FPGAs and Multimedia Processors



Ideal for low-power FPGAs, CPLDs, and application processors



For FREE samples, datasheets, and more information, visit

www.national.com/pf/LM/LM3370.html

Implementing Single-Chip FPGA Power Solutions

will explore some available multi-output regulators that can be used as single-chip FPGA power supplies and techniques on how to implement sub-1.25V outputs from readily available bandgap regulators.

Figure 1 shows a simplified diagram of a typical application to power an FPGA (like a Cyclone device from Altera) with a single-chip power supply. National's LM2717, an integrated dual-output switching regulator IC, is set to provide 1.5V at 2A (3.2A peak) to the core and 3.3V at 1.5A (2.2A peak) to the I/Os.

The LM2717 is medium-power, single-chip solution with the simplicity and flexibility needed to implement a compact, greater than 90 percent efficient, supply matching the specifications for many digital multi-rail systems, including FPGAs, from a variety of sources: 5V, 12V or wall warts in the 4V to 20V range. The LM2717 comes with one adjustable output and one fixed output at 3.3V, a very common rail, which helps save space and increase output voltage accuracy by implementing internal output-voltage-setting resistors on this output. The LM2717-ADJ is a variation of the original LM2717 IC that allows both outputs to be adjustable, which is very useful if a different I/O voltage is needed.

Altera's literature on Cyclone and Cyclone II, as well as many other latest generation FPGAs such as Xilinx Spartan 3E, state that those FPGAs do not require any specific sequencing on their voltage rails during power-up. However, individual enable pins (SHDN1 & SHDN2) are still present on the LM2717 to turn on each output at a specific time or in a specific order should this be necessary for the system or when powering other FPGAs. In the same fashion, individual soft-start pins (SS1 and SS2) allow the LM2717 to set different ramp-up times for each output voltage to meet manufacturer specifications for individual FPGAs and other digital cores.

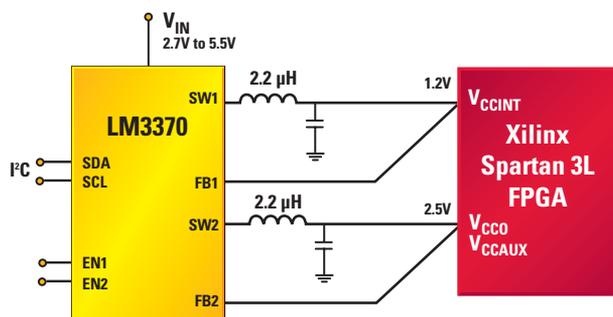


Figure 2.
LM3370 Dual Integrated Synchronous Switching Supply for 1.2V Core and 2.5V I/O and VCCAUX Low-power FPGA

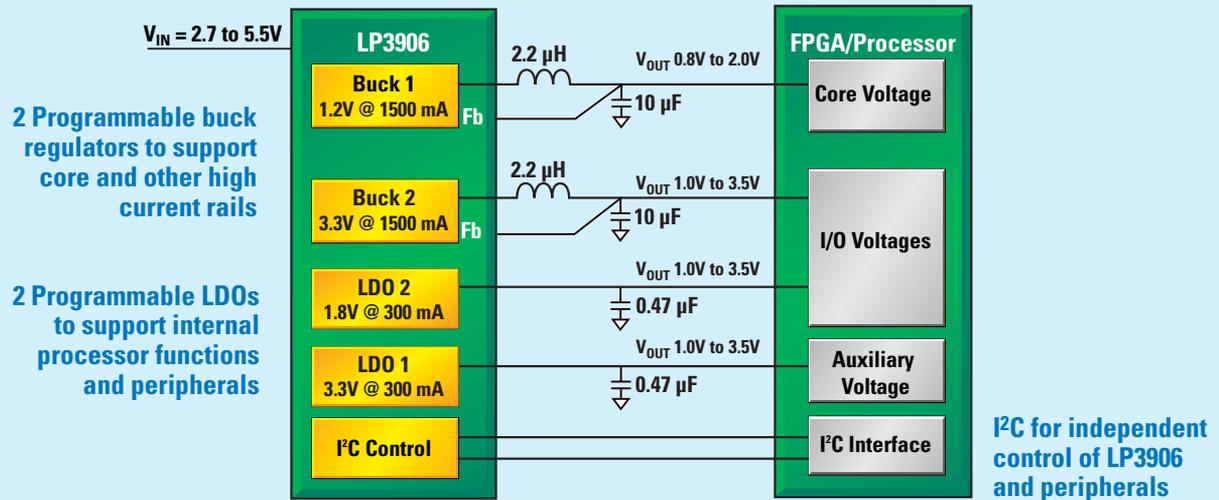
Figure 2 shows a low-power 1.2V, 90 nm FPGA (Spartan 3L from Xilinx) powered by the LM3370, a dual 600 mA per channel integrated synchronous buck regulator.

Voltage for one channel can be adjusted from 1V to 2V in 50 mV steps (ideal for core power) while the other channel can be programmed for an output of 1.8V to 3.3V in 100 mV steps (ideal for I/O power). Individual enable pins, internal soft-start, fast transient response, and power-on-reset flags for each output make this IC a single-chip minimum-external-components solution optimized to power low-power FPGAs and other multi-rail digital cores.

While the LM3370 can be used off-the-shelf because pre-programmed output voltages and individual enable pins are available. An on-board I²C-compatible interface allows the user to optionally modify various parameters of the IC, even dynamically, for added flexibility. These parameters include output voltage setting (per channel), output enable (per channel), switching mode selection (auto PWM-PFM for high efficiency under light-loads or fixed PWM for fixed frequency operation), spread spectrum feature enable, and spread spectrum frequency range selection.

Easy-to-Use Power Management Units for Digital ICs

96% Efficient LP3906 Provides Flexibility with Digital Programmability



AVAILABLE
LEAD-FREE

| Product ID | Digitally Programmable | Efficiency | Regulator Output Current | LDO Output Current | Packaging | Solution Size |
|------------|------------------------|------------|--------------------------|--------------------|-----------|---------------|
| LP3906 | I ² C | Up to 96% | 1.5 A | 300 mA | LLP-24 | 20 mm x 20 mm |
| LP3905 | N/A | Up to 90% | 600 mA | 150 mA (low noise) | LLP-14 | 15 mm x 10 mm |

Ideal for powering application processors, FPGAs, and DSPs where size and efficiency are important

For FREE samples, datasheets, and more information, visit

www.national.com/pf/LP/LP3905.html

www.national.com/pf/LP/LP3906.html

Implementing Single-Chip FPGA Power Solutions

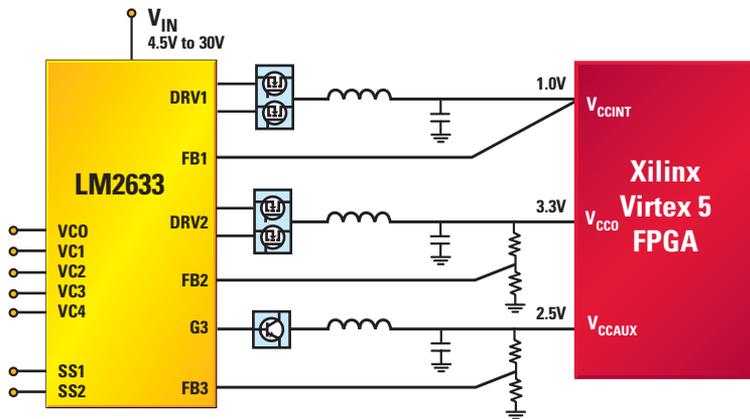


Figure 3.
LM2633 Triple Switching/Linear Controller Supply for 1.0V Core, 3.3V I/O and 2.5V V_{CCAUX} High-power FPGAs

The simplified diagram in *Figure 3* shows the implementation of a three-rail, higher power FPGA supply. In this case, an LM2633 controller is providing 1.0V to a Xilinx Virtex 5 core, 3.3V to the I/Os and 2.5V for V_{CCAUX} . The LM2633 is a triple output IC, and is a perfect example of how existing technology can be leveraged for new purposes, taking it out of its original context. Two of the three LM2633 outputs utilize a synchronous rectification buck architecture to provide maximum efficiency to medium and high current loads (5A to 15A per channel) while it also integrates an LDO controller for a third low-power output. One of the switching outputs has a voltage range between 0.900 and 2.000, making it a perfect fit for powering the core of digital devices. The second switching output has a range of 1.25V to 6V, adequate for I/Os, memory, and other loads. For higher accuracy and flexibility, the low voltage output is programmable through a 5-bit parallel digital word that can be either hard-wired or tied to a processor for dynamic voltage scaling if desired.

For applications where only a dual synchronous buck controller with sub-1.25V outputs is needed, the LM2657 provides a good alternative in a fewer pin-count package. For lower power applications where three or four rails are needed, the LP3906 is also an excellent alternative, providing two fully integrated 1.5A synchronous switching outputs and two 300 mA LDO outputs, all in a single package.

As seen from the previous examples, most of today's FPGAs require 1.50V,

1.20V and sometimes even a lower core voltage (as Xilinx's newest Virtex 5 series of FPGAs which have a 1.0V 65 nm core). Many regulators in the market have a regular 1.25V bandgap reference. *Figures 4* and *5* show simplified diagram examples of how to use regular bandgap ICs (like the LM2717) to power such sub-bandgap digital loads. Fundamental operation of the voltage converter remains the same, but the way in which the resistive voltage divider is referenced to program the regulator's output voltage is different.

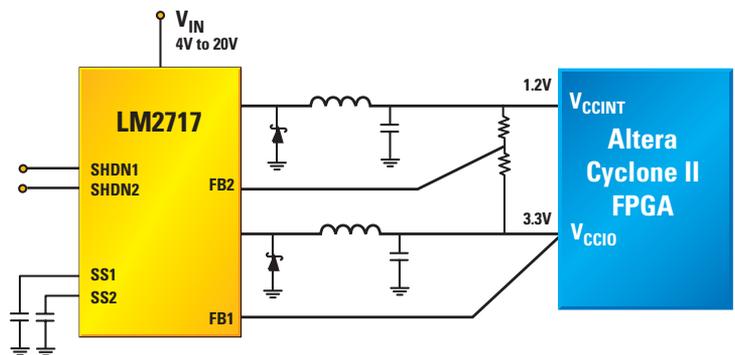
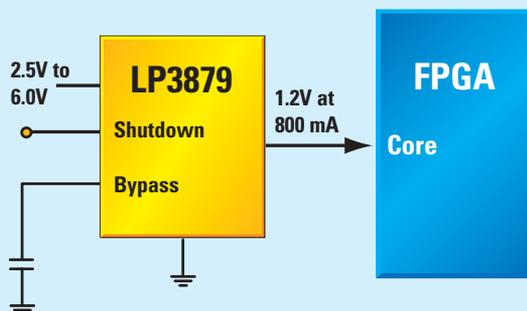
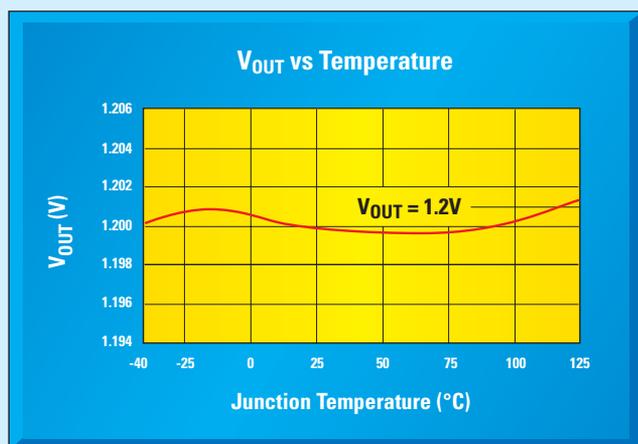


Figure 4.
LM2717 1.2V Core, 3.3V I/O Dual Integrated Switching FPGA Supply Using the 3.3V Rail as Auxiliary Voltage for Sub-1.25V Core Voltage Generation

1.2V Output LDO Enables Powering of Latest Generation Digital Cores

LP3879 800 mA LDO Provides $\pm 1\%$ Initial Output Accuracy



LP3879 Features

- 1% initial output accuracy
- Input voltage: 2.5V to 6.0V
- Custom voltages available from 1.0V to 1.2V
- $<10 \mu\text{A}$ quiescent current in shutdown
- Low 18 μV output noise reduces noise
- Available in PSOP-8 and LLP-8 surface mount packages

| LDOs for Powering FPGAs | | | | |
|-------------------------|------------------------|-----------------------|------------------|--|
| Product ID | V _{OUT} Range | V _{IN} Range | I _{OUT} | Features |
| LP38856 | 0.8V to 1.2V | 1.3V to 5.5V* | 3A | Enable Pin |
| LP38859 | 0.8V to 1.2V | 1.3V to 5.5V* | 3A | Soft Start Pin |
| LP3879 | 1V to 2V | 2.5V to 6V | 800 mA | Shutdown Pin |
| LP3878 | 1V to 5.5V | 2.5V to 16V | 800 mA | Adjustable Output |
| LP5951 | 1.3V to 3.3V | 1.8V to 5.5V | 150 mA | Low 29 μA quiescent current |

* 3V to 5.5V input bias rail required

For FREE samples, datasheets and more go to

www.national.com/pf/LP/LP3879.html

Implementing Single-Chip FPGA Power Solutions

In any closed-loop regulator circuit, the output voltage, after being scaled down by a resistor divider, is compared to an internal reference. If this reference is 1.25V, then the scaled-down sample of the output voltage, which is injected to the regulator IC through the FB pin, needs to be set to match this value to maintain regulation. In a typical system, this FB voltage divider is placed between the output (highest potential) and ground (lowest potential) since the FB voltage (1.25V) falls within this range. In a system that requires the output voltage to be below the internal reference value, we still need to provide a matching voltage (1.25V) to the FB pin, however this value won't fall now between V_{OUT} (which is now lower) and ground. The way to achieve it is by placing the voltage divider between V_{OUT} (now becoming the lowest potential and the lower end of the divider) and any auxiliary voltage above 1.25V (to serve as the higher potential).

The example in *Figure 4* uses Altera's Cyclone II 1.20V FPGA and National's LM2717 to show the simplest implementation for this configuration, with the higher voltage being the 3.3V rail itself. Adequate filtering and layout for this rail is important (a decoupling ceramic capacitor close to where the resistive divider lower end meets the 3.3V rail is recommended) because regulation on the sub-bandgap output will depend on the stability of this rail. Sequencing is also important, because 3.3V rail needs to be present for proper regulation before the core voltage output is turned on.

In most FPGAs, the nominal 1.20V or 1.0V core supply voltage needs to be stable within ± 50 mV or ± 60 mV, so all transients, ripple and tolerance variations need to be kept within that limit.

Figure 5 shows an alternate method for achieving a sub-bandgap output using an independent source

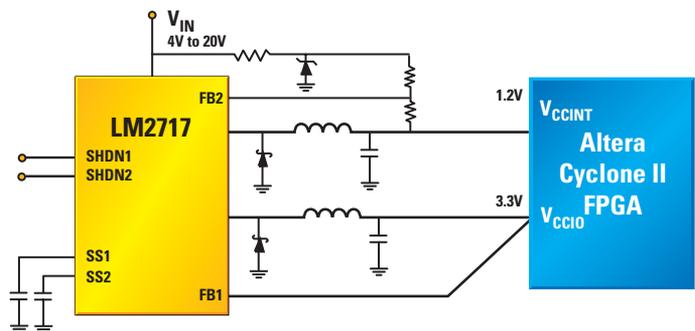


Figure 5.
LM2717 1.2V Core, 3.3V I/O Dual Integrated Switching FPGA Supply
Using an LM4040 Shunt Reference for Sub-1.25V Core Voltage Generation

for the auxiliary rail, in this case a small, low-cost shunt reference (precision Zener), such as National's LM4040CIM3-2.5 (0.5%) or LM4040DIM3-2.5 (1%). This approach allows potential transients seen in the 3.3V output not to be cross-coupled to the regulation of the 1.20V output. It also allows the 3.3V rail to be powered up after the 1.2V rail, or be turned off at any time without disturbing the 1.2V output regulation. Accuracy of this output is dependent on the line regulation of the selected voltage reference. Because core voltage accuracy is important in the application, selection of the right voltage reference is key.

Multiple resources are available today to assist designers craft the optimal power supply for their application. For example, National's Power Expert software tool, easily guides the user through selecting the FPGA of their choice, picking up the supply rails and operating conditions and finally recommending the power IC solution that matches the designers top requirements, whether these are maximum efficiency or design simplicity. It also connects to National's WEBENCH® design environment for component selection around the selected regulator IC and circuit simulation (if these features are available for the selected regulator). ■

For additional information on these tools, visit altera.national.com and xilinx.national.com.

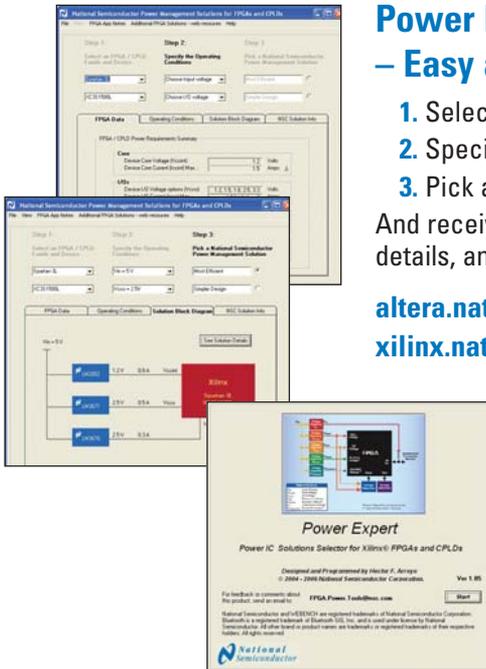
Power Design Tools

Power Expert Design Tools for Altera and Xilinx FPGAs – Easy as 1-2-3

1. Select an FPGA/CPLD family and device
2. Specify the operating conditions
3. Pick a National Semiconductor power management solution

And receive an instant **Solution Block Diagram** complete with solution details, and go directly into the WEBENCH® online design environment

altera.national.com
xilinx.national.com



WEBENCH® Online Tools



Design, build, and test analog circuits in this FREE online design and prototyping environment.

webench.national.com

Powering Digital ICs

National's powering digital ICs web page includes: Altera and Xilinx reference designs, application notes, articles, design guides, selection guides and tools.

power.national.com

National Semiconductor
2900 Semiconductor Drive
Santa Clara, CA 95051
1 800 272 9959

Mailing address:
PO Box 58090
Santa Clara, CA 95052

Visit our website at:
www.national.com

For more information, send email to:
new.feedback@nsc.com

Don't miss a single issue!

Subscribe now to receive email alerts when new issues of Power Designer are available:

power.national.com/designer

Read our Signal Path Designer® online today at:

signalpath.national.com/designer



 **National Semiconductor**
The Sight & Sound of Information

©2006, National Semiconductor Corporation. National Semiconductor, N, LLP, WEBENCH, SIMPLE SWITCHER, and Signal Path Designer are registered trademarks of National Semiconductor. All other brand or product names are trademarks or registered trademarks of their respective holders. All rights reserved.

550263-015

IMPORTANT NOTICE

Texas Instruments Incorporated and its subsidiaries (TI) reserve the right to make corrections, modifications, enhancements, improvements, and other changes to its products and services at any time and to discontinue any product or service without notice. Customers should obtain the latest relevant information before placing orders and should verify that such information is current and complete. All products are sold subject to TI's terms and conditions of sale supplied at the time of order acknowledgment.

TI warrants performance of its hardware products to the specifications applicable at the time of sale in accordance with TI's standard warranty. Testing and other quality control techniques are used to the extent TI deems necessary to support this warranty. Except where mandated by government requirements, testing of all parameters of each product is not necessarily performed.

TI assumes no liability for applications assistance or customer product design. Customers are responsible for their products and applications using TI components. To minimize the risks associated with customer products and applications, customers should provide adequate design and operating safeguards.

TI does not warrant or represent that any license, either express or implied, is granted under any TI patent right, copyright, mask work right, or other TI intellectual property right relating to any combination, machine, or process in which TI products or services are used. Information published by TI regarding third-party products or services does not constitute a license from TI to use such products or services or a warranty or endorsement thereof. Use of such information may require a license from a third party under the patents or other intellectual property of the third party, or a license from TI under the patents or other intellectual property of TI.

Reproduction of TI information in TI data books or data sheets is permissible only if reproduction is without alteration and is accompanied by all associated warranties, conditions, limitations, and notices. Reproduction of this information with alteration is an unfair and deceptive business practice. TI is not responsible or liable for such altered documentation. Information of third parties may be subject to additional restrictions.

Resale of TI products or services with statements different from or beyond the parameters stated by TI for that product or service voids all express and any implied warranties for the associated TI product or service and is an unfair and deceptive business practice. TI is not responsible or liable for any such statements.

TI products are not authorized for use in safety-critical applications (such as life support) where a failure of the TI product would reasonably be expected to cause severe personal injury or death, unless officers of the parties have executed an agreement specifically governing such use. Buyers represent that they have all necessary expertise in the safety and regulatory ramifications of their applications, and acknowledge and agree that they are solely responsible for all legal, regulatory and safety-related requirements concerning their products and any use of TI products in such safety-critical applications, notwithstanding any applications-related information or support that may be provided by TI. Further, Buyers must fully indemnify TI and its representatives against any damages arising out of the use of TI products in such safety-critical applications.

TI products are neither designed nor intended for use in military/aerospace applications or environments unless the TI products are specifically designated by TI as military-grade or "enhanced plastic." Only products designated by TI as military-grade meet military specifications. Buyers acknowledge and agree that any such use of TI products which TI has not designated as military-grade is solely at the Buyer's risk, and that they are solely responsible for compliance with all legal and regulatory requirements in connection with such use.

TI products are neither designed nor intended for use in automotive applications or environments unless the specific TI products are designated by TI as compliant with ISO/TS 16949 requirements. Buyers acknowledge and agree that, if they use any non-designated products in automotive applications, TI will not be responsible for any failure to meet such requirements.

Following are URLs where you can obtain information on other Texas Instruments products and application solutions:

Products

| | |
|------------------------|--|
| Audio | www.ti.com/audio |
| Amplifiers | amplifier.ti.com |
| Data Converters | dataconverter.ti.com |
| DLP® Products | www.dlp.com |
| DSP | dsp.ti.com |
| Clocks and Timers | www.ti.com/clocks |
| Interface | interface.ti.com |
| Logic | logic.ti.com |
| Power Mgmt | power.ti.com |
| Microcontrollers | microcontroller.ti.com |
| RFID | www.ti-rfid.com |
| OMAP Mobile Processors | www.ti.com/omap |
| Wireless Connectivity | www.ti.com/wirelessconnectivity |

Applications

| | |
|-------------------------------|--|
| Communications and Telecom | www.ti.com/communications |
| Computers and Peripherals | www.ti.com/computers |
| Consumer Electronics | www.ti.com/consumer-apps |
| Energy and Lighting | www.ti.com/energy |
| Industrial | www.ti.com/industrial |
| Medical | www.ti.com/medical |
| Security | www.ti.com/security |
| Space, Avionics and Defense | www.ti.com/space-avionics-defense |
| Transportation and Automotive | www.ti.com/automotive |
| Video and Imaging | www.ti.com/video |

TI E2E Community Home Page

e2e.ti.com

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265
Copyright © 2011, Texas Instruments Incorporated