

**LMZ10503,LMZ10504,LMZ10505,LMZ12001,  
LMZ12001EXT,LMZ12002,LMZ12002EXT,  
LMZ12003,LMZ12003EXT,LMZ14201,  
LMZ14201EXT,LMZ14201H,LMZ14202,  
LMZ14202EXT,LMZ14202H,LMZ14203,  
LMZ14203EXT,LMZ14203H,LMZ22003,LMZ22005,  
LMZ23603,LMZ23605**

***Application Note 2026 The Effect of PCB Design on the Thermal Performance  
of SIMPLE SWITCHER® Power Modules***



Literature Number: SNVA424

# The Effect of PCB Design on the Thermal Performance of SIMPLE SWITCHER® Power Modules

## Summary

The SIMPLE SWITCHER® Power Modules use a TO-PMOD package similar to a TO-263. This application note focuses on the low current modules which come in a 7 Lead, 10.16 x 4.57 x 9.81 mm package. This package has excellent thermal performance enabled by an exposed pad, which can be soldered to the PCB. The key thermal characteristics are:

- $\theta_{JC} = 1.9^{\circ}\text{C/W}$
- $\theta_{JC} 21.6^{\circ}\text{C/W}$  (On a 4-layer thermal board)

## What Determines $\theta_{JA}$

In order to understand how a PCB's thermal performance determines the thermal resistance ( $\theta_{JA}$ ) of a Power Module mounted on the PCB, a brief analysis for  $\theta_{JA}$  is given as follows. There are two heat dissipation paths, i.e., Junction-PCB-Ambient and Junction-PKG surface-Ambient. Because the two paths are in parallel,  $\theta_{JA}$  can be expressed as

$$\theta_{JA} = (\theta_{JCA} \times \theta_{JTA}) / (\theta_{JCA} + \theta_{JTA})$$

$\theta_{JCA}$  is the thermal resistance from junction to ambient through the PCB and  $\theta_{JTA}$  is the thermal resistance through the package surface to ambient (mainly package top). For the situation where no heat sink is applied on the package top, 95% or more of the power dissipates through the PCB, meaning that  $\theta_{JA}$  is dominated by  $\theta_{JCA}$  (also meaning that  $\theta_{JTA}$  is much bigger than  $\theta_{JCA}$ ). As a result,  $\theta_{JA}$  can be simply expressed as

$$\theta_{JA} = \theta_{JCA} - R_{JTA} = \theta_{JC} + \theta_{CA} - R_{JTA}$$

$\theta_{CA}$  is the thermal resistance from package bottom case to ambient through the PCB. It is mainly dependent on the thermal conductivity of the PCB and the thermal connection between the package and the PCB.  $R_{JTA}$  gives a small reduction of  $\theta_{JA}$  caused by the power dissipation through the package top.

So, it is seen from the equation above that on any given board, the small  $\theta_{JC}$  and large exposed thermal pad should make the

National Semiconductor  
Application Note 2026  
Lianxi Shen  
February 8, 2010



Power Module better in thermal performance than other package types. For example, LGA packages have a  $\theta_{JC}$  of about 5C/W or larger for the similar package size, depending on the copper and thermal vias in its substrate.

## Parametric Study

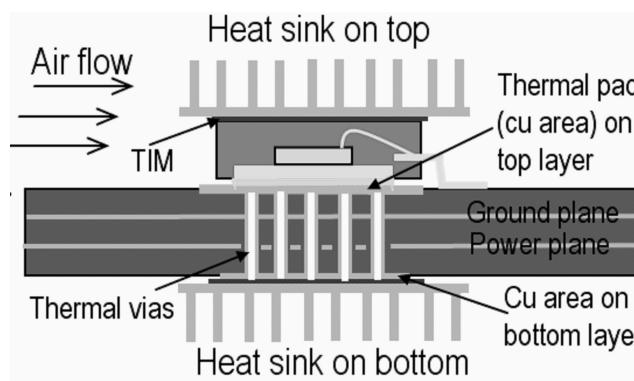
In order to optimize the PCB design to get the best thermal performance out of the SIMPLE SWITCHER® Power Module and to understand the effect of environmental conditions, this application note analyzes how some factors affect the thermal performance of a PCB or the  $\theta_{JA}$  of a package mounted on it. These factors include:

1. Size of direct thermal attachment pad
2. Copper layers (2 or 4 layers)
3. PCB size
4. Air flow
5. Heat sink

Figure 1 shows these factors schematically.

For the parametric study, the above factors were varied as follows:

1. The sizes of copper area on top and bottom layers include:  
Copper Area = DAP size (8.5x5.4mm)  
Copper Area = Package body size (10x10mm)  
Copper Area = 2 X package body size (20x20mm)  
Copper Area = Full copper layer (4 solid copper layers)
2. 2 layer and 4 layer boards
3. The PCB size varies from 4"x3" (102x76mm) to 1.5"x1.5" (38x38mm)
4. The air flow includes Natural Convection, 200LFPM, and 400LFPM
5. The heat sink may be on the package top or on the PCB bottom side



30112901

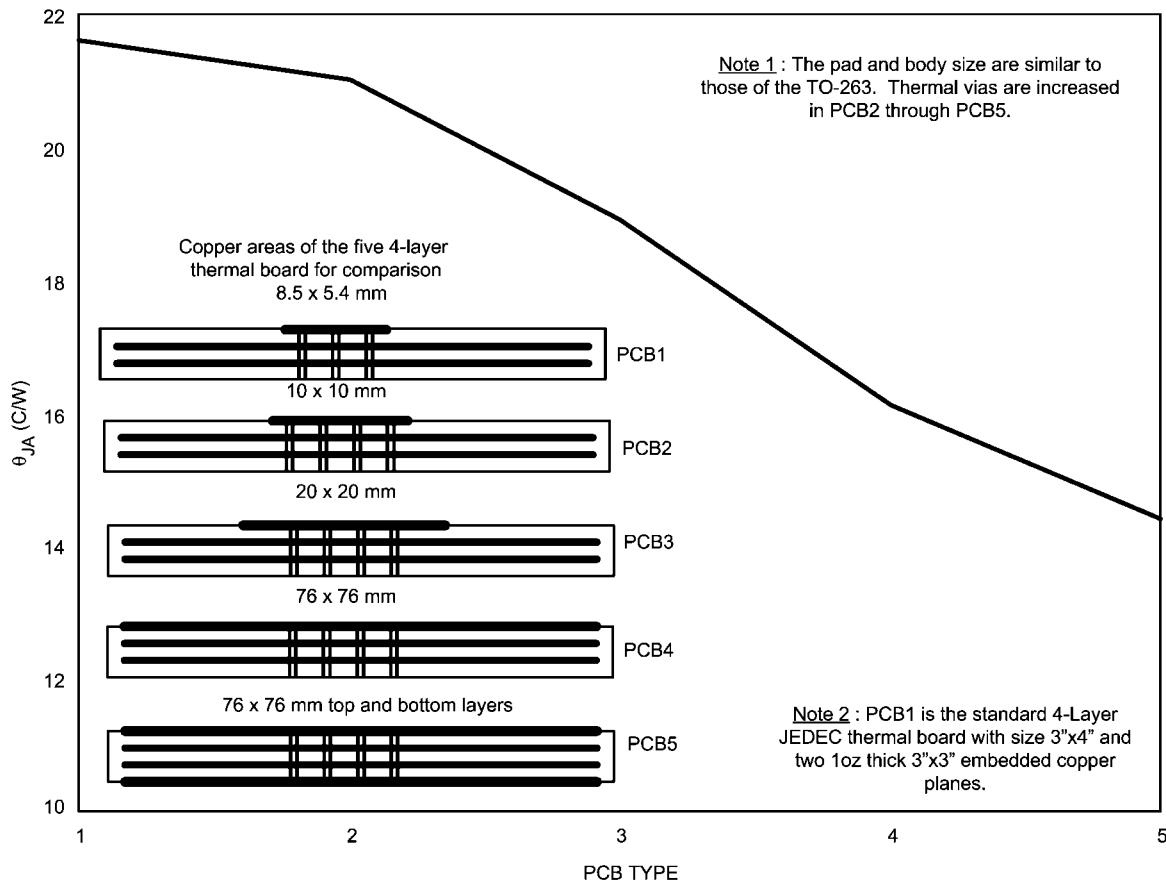
FIGURE 1. Thermal Management of the SIMPLE SWITCHER® Power Module on a 4-Layer PCB

## Thermal Measurement and Simulation

The thermal performance of the module on a 4-layer evaluation board is measured. This is used to validate our thermal model for the parametric study. The 4-layer evaluation board is 3"x1.75" with a thickness of 1.6mm and 4 solid copper layers.

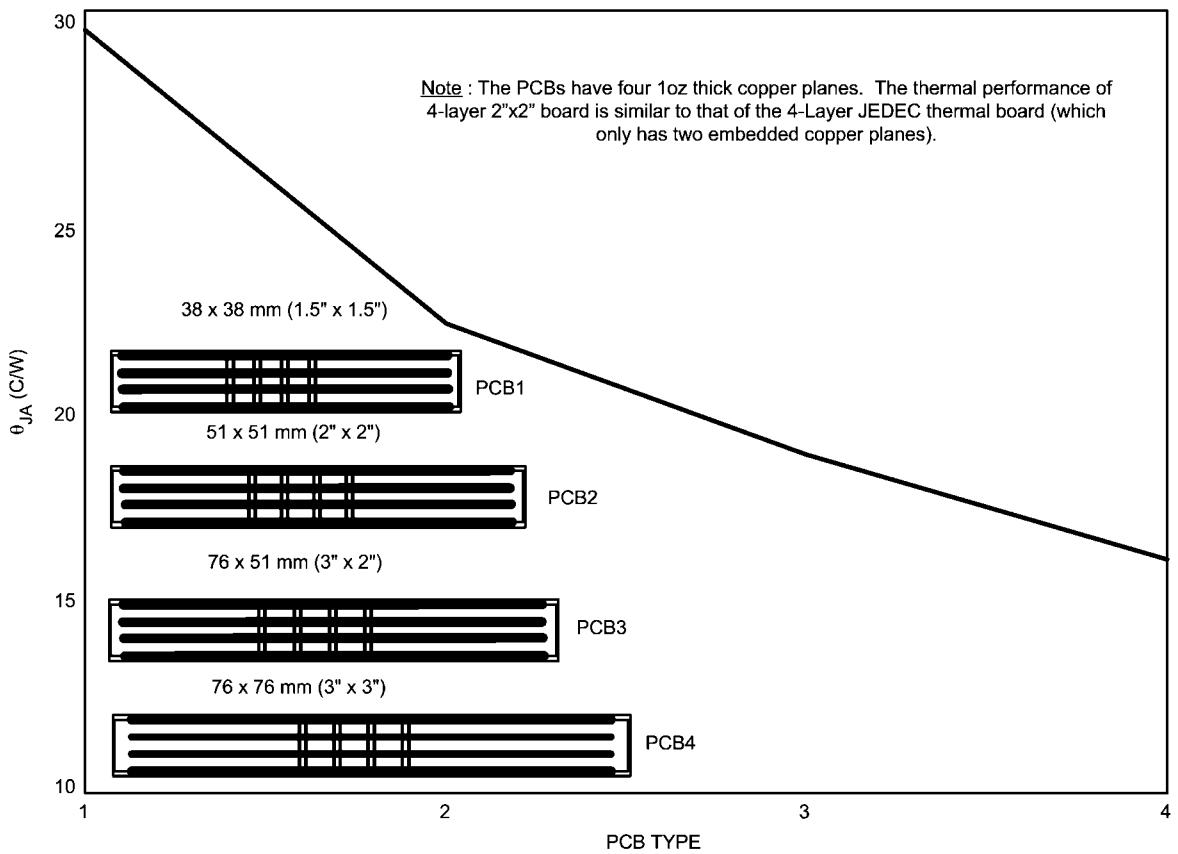
Note:  $\theta_{JC}$  is the junction-to-case thermal resistance, which characterizes the thermal performance of package itself, and can be used to rate different packages.

Note:  $\theta_{JA}$  is the junction-to-ambient thermal resistance, which is used to evaluate the thermal performance of a package in an application environment.



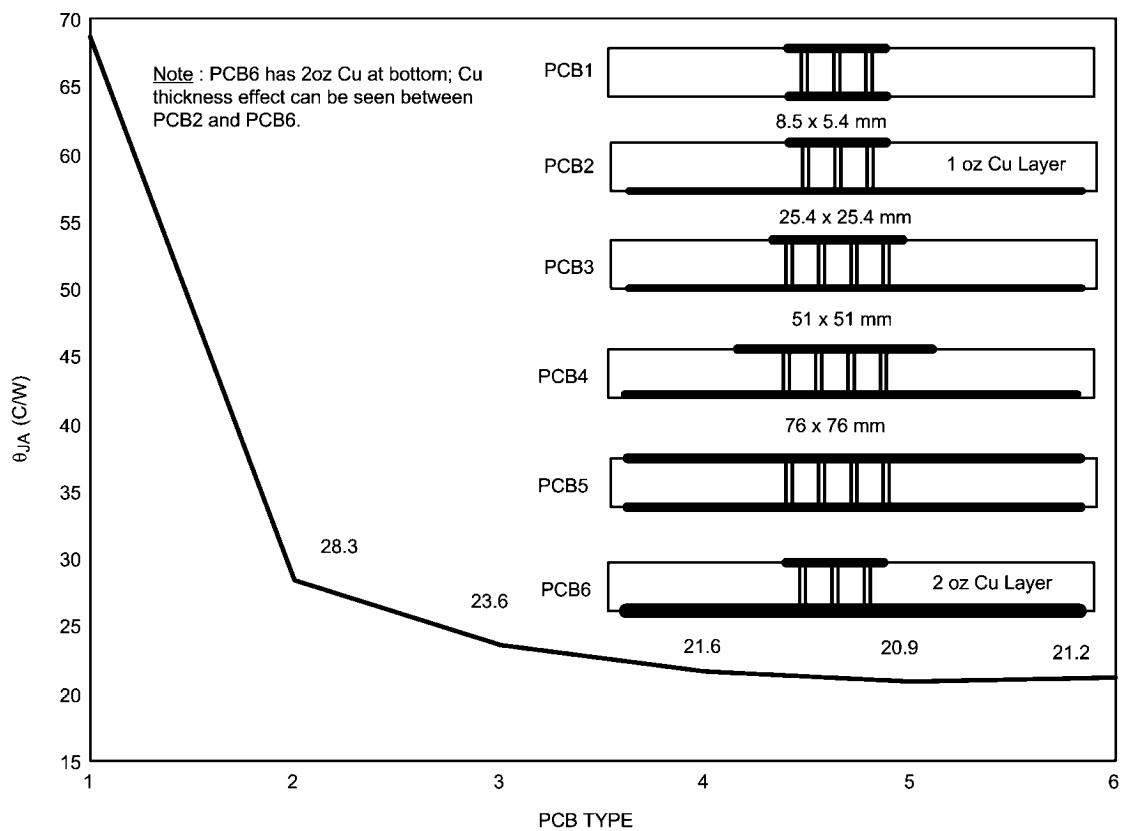
**FIGURE 2. Effect of Cu Area on Top and Bottom Layers of 4-Layer PCB**

30112902



**FIGURE 3. Effect of PCB Size of 4-Layer PCB**

30112903



**FIGURE 4. Effect of Cu Area on Top and Bottom Layers of 2-Layer PCB**

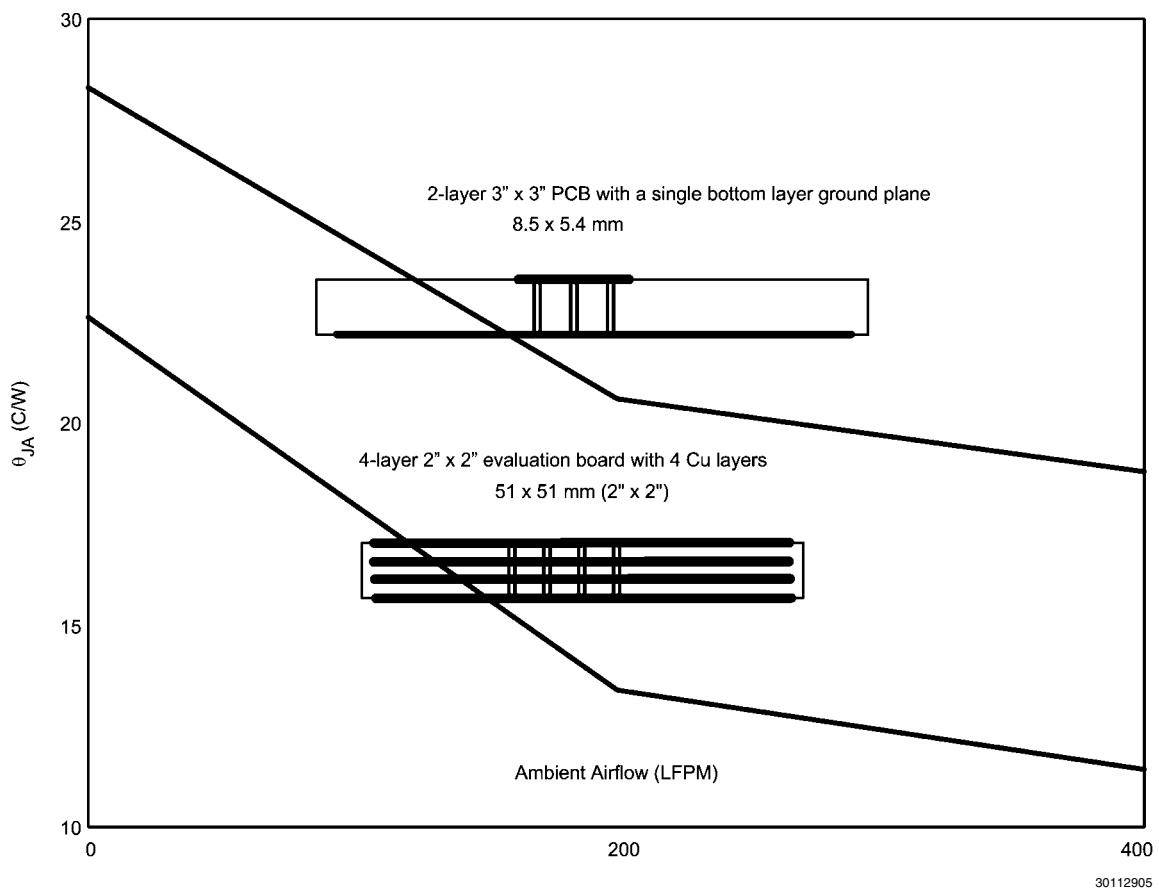
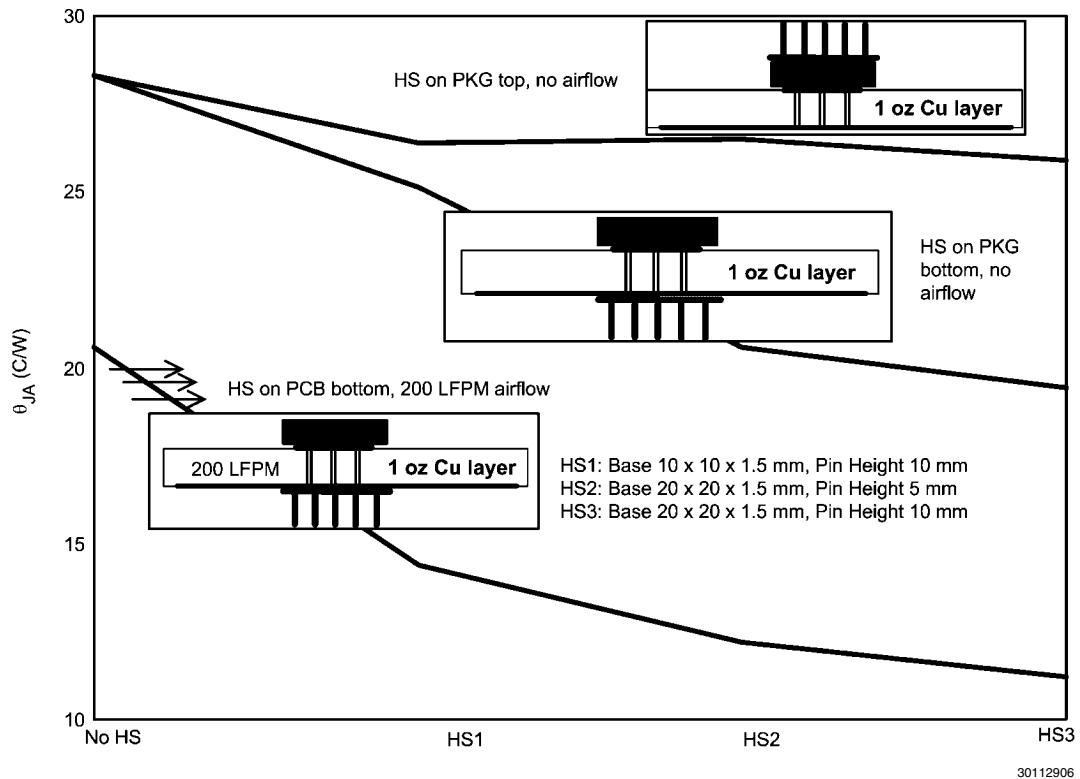


FIGURE 5. Effect of Airflow for Two PCBs



**FIGURE 6. Effect of Heatsink**

## Conclusion

The TO-PMOD package has excellent thermal performance, as demonstrated by its low  $\theta_{JA}$  and  $\theta_{JC}$ . The thermal performance of any package strongly depends on its application environment. But how well a package can take advantage of a high thermal conductivity PCB is determined by the package itself, that is, its  $\theta_{JC}$  and its exposed pad size. The TO-PMOD package module has been optimized on both sides, giving excellent thermal performance. For a specific application,

users of the SIMPLE SWITCHER® Power Module can refer to the results of the parametric study plotted in [Figure 2](#) - [Figure 6](#) to quickly estimate the real  $\theta_{JA}$  and evaluate the maximum power dissipation that the device can handle. Note that the effect of other heating sources on the same PCB is not considered in this thermal analysis. So, a system level simulation may be needed when other complicated factors are involved. For this purpose, a Flotherm model is available upon request.



## Notes

For more National Semiconductor product information and proven design tools, visit the following Web sites at:  
[www.national.com](http://www.national.com)

Products		Design Support	
Amplifiers	<a href="http://www.national.com/amplifiers">www.national.com/amplifiers</a>	WEBENCH® Tools	<a href="http://www.national.com/webench">www.national.com/webench</a>
Audio	<a href="http://www.national.com/audio">www.national.com/audio</a>	App Notes	<a href="http://www.national.com/appnotes">www.national.com/appnotes</a>
Clock and Timing	<a href="http://www.national.com/timing">www.national.com/timing</a>	Reference Designs	<a href="http://www.national.com/refdesigns">www.national.com/refdesigns</a>
Data Converters	<a href="http://www.national.com/adc">www.national.com/adc</a>	Samples	<a href="http://www.national.com/samples">www.national.com/samples</a>
Interface	<a href="http://www.national.com/interface">www.national.com/interface</a>	Eval Boards	<a href="http://www.national.com/evalboards">www.national.com/evalboards</a>
LVDS	<a href="http://www.national.com/lvds">www.national.com/lvds</a>	Packaging	<a href="http://www.national.com/packaging">www.national.com/packaging</a>
Power Management	<a href="http://www.national.com/power">www.national.com/power</a>	Green Compliance	<a href="http://www.national.com/quality/green">www.national.com/quality/green</a>
Switching Regulators	<a href="http://www.national.com/switchers">www.national.com/switchers</a>	Distributors	<a href="http://www.national.com/contacts">www.national.com/contacts</a>
LDOs	<a href="http://www.national.com/ldo">www.national.com/ldo</a>	Quality and Reliability	<a href="http://www.national.com/quality">www.national.com/quality</a>
LED Lighting	<a href="http://www.national.com/led">www.national.com/led</a>	Feedback/Support	<a href="http://www.national.com/feedback">www.national.com/feedback</a>
Voltage References	<a href="http://www.national.com/vref">www.national.com/vref</a>	Design Made Easy	<a href="http://www.national.com/easy">www.national.com/easy</a>
PowerWise® Solutions	<a href="http://www.national.com/powerwise">www.national.com/powerwise</a>	Applications & Markets	<a href="http://www.national.com/solutions">www.national.com/solutions</a>
Serial Digital Interface (SDI)	<a href="http://www.national.com/sdi">www.national.com/sdi</a>	Mil/Aero	<a href="http://www.national.com/milaero">www.national.com/milaero</a>
Temperature Sensors	<a href="http://www.national.com/tempssensors">www.national.com/tempssensors</a>	SolarMagic™	<a href="http://www.national.com/solarmagic">www.national.com/solarmagic</a>
PLL/VCO	<a href="http://www.national.com/wireless">www.national.com/wireless</a>	PowerWise® Design University	<a href="http://www.national.com/training">www.national.com/training</a>

THE CONTENTS OF THIS DOCUMENT ARE PROVIDED IN CONNECTION WITH NATIONAL SEMICONDUCTOR CORPORATION ("NATIONAL") PRODUCTS. NATIONAL MAKES NO REPRESENTATIONS OR WARRANTIES WITH RESPECT TO THE ACCURACY OR COMPLETENESS OF THE CONTENTS OF THIS PUBLICATION AND RESERVES THE RIGHT TO MAKE CHANGES TO SPECIFICATIONS AND PRODUCT DESCRIPTIONS AT ANY TIME WITHOUT NOTICE. NO LICENSE, WHETHER EXPRESS, IMPLIED, ARISING BY ESTOPPEL OR OTHERWISE, TO ANY INTELLECTUAL PROPERTY RIGHTS IS GRANTED BY THIS DOCUMENT.

TESTING AND OTHER QUALITY CONTROLS ARE USED TO THE EXTENT NATIONAL DEEMS NECESSARY TO SUPPORT NATIONAL'S PRODUCT WARRANTY. EXCEPT WHERE MANDATED BY GOVERNMENT REQUIREMENTS, TESTING OF ALL PARAMETERS OF EACH PRODUCT IS NOT NECESSARILY PERFORMED. NATIONAL ASSUMES NO LIABILITY FOR APPLICATIONS ASSISTANCE OR BUYER PRODUCT DESIGN. BUYERS ARE RESPONSIBLE FOR THEIR PRODUCTS AND APPLICATIONS USING NATIONAL COMPONENTS. PRIOR TO USING OR DISTRIBUTING ANY PRODUCTS THAT INCLUDE NATIONAL COMPONENTS, BUYERS SHOULD PROVIDE ADEQUATE DESIGN, TESTING AND OPERATING SAFEGUARDS.

EXCEPT AS PROVIDED IN NATIONAL'S TERMS AND CONDITIONS OF SALE FOR SUCH PRODUCTS, NATIONAL ASSUMES NO LIABILITY WHATSOEVER, AND NATIONAL DISCLAIMS ANY EXPRESS OR IMPLIED WARRANTY RELATING TO THE SALE AND/OR USE OF NATIONAL PRODUCTS INCLUDING LIABILITY OR WARRANTIES RELATING TO FITNESS FOR A PARTICULAR PURPOSE, MERCHANTABILITY, OR INFRINGEMENT OF ANY PATENT, COPYRIGHT OR OTHER INTELLECTUAL PROPERTY RIGHT.

### LIFE SUPPORT POLICY

**NATIONAL'S PRODUCTS ARE NOT AUTHORIZED FOR USE AS CRITICAL COMPONENTS IN LIFE SUPPORT DEVICES OR SYSTEMS WITHOUT THE EXPRESS PRIOR WRITTEN APPROVAL OF THE CHIEF EXECUTIVE OFFICER AND GENERAL COUNSEL OF NATIONAL SEMICONDUCTOR CORPORATION.** As used herein:

Life support devices or systems are devices which (a) are intended for surgical implant into the body, or (b) support or sustain life and whose failure to perform when properly used in accordance with instructions for use provided in the labeling can be reasonably expected to result in a significant injury to the user. A critical component is any component in a life support device or system whose failure to perform can be reasonably expected to cause the failure of the life support device or system or to affect its safety or effectiveness.

National Semiconductor and the National Semiconductor logo are registered trademarks of National Semiconductor Corporation. All other brand or product names may be trademarks or registered trademarks of their respective holders.

Copyright© 2010 National Semiconductor Corporation

For the most current product information visit us at [www.national.com](http://www.national.com)



National Semiconductor  
 Americas Technical  
 Support Center  
 Email: [support@nsc.com](mailto:support@nsc.com)  
 Tel: 1-800-272-9959

National Semiconductor Europe  
 Technical Support Center  
 Email: [europe.support@nsc.com](mailto:europe.support@nsc.com)

National Semiconductor Asia  
 Pacific Technical Support Center  
 Email: [ap.support@nsc.com](mailto:ap.support@nsc.com)

National Semiconductor Japan  
 Technical Support Center  
 Email: [jpn.feedback@nsc.com](mailto:jpn.feedback@nsc.com)

## 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	<a href="http://www.ti.com/audio">www.ti.com/audio</a>
Amplifiers	<a href="http://amplifier.ti.com">amplifier.ti.com</a>
Data Converters	<a href="http://dataconverter.ti.com">dataconverter.ti.com</a>
DLP® Products	<a href="http://www.dlp.com">www.dlp.com</a>
DSP	<a href="http://dsp.ti.com">dsp.ti.com</a>
Clocks and Timers	<a href="http://www.ti.com/clocks">www.ti.com/clocks</a>
Interface	<a href="http://interface.ti.com">interface.ti.com</a>
Logic	<a href="http://logic.ti.com">logic.ti.com</a>
Power Mgmt	<a href="http://power.ti.com">power.ti.com</a>
Microcontrollers	<a href="http://microcontroller.ti.com">microcontroller.ti.com</a>
RFID	<a href="http://www.ti-rfid.com">www.ti-rfid.com</a>
OMAP Mobile Processors	<a href="http://www.ti.com/omap">www.ti.com/omap</a>
Wireless Connectivity	<a href="http://www.ti.com/wirelessconnectivity">www.ti.com/wirelessconnectivity</a>

### Applications

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

[TI E2E Community Home Page](#)

[e2e.ti.com](#)

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