LM2742,LM2743,LM2744,LM2745,LM2746, LM2747,LM2748

Optimizing Power Controller Designs through Effective Utilization of Performance Features (Adj Frequency & Sync, Ext Ref, Tracking, & Precision Enable)

Literature Number: SNVA601

POWER designer

Expert tips, tricks, and techniques for powerful designs

No. 122

Feature Article 1-7

Synchronous Buck Controllers 2

Optimizing Power Controller Designs through Effective Utilization of Performance Features

— By Ricardo Capetillo, Application Engineer

Introduction

When system design engineers are in search of power for mixed-signal electronics, they must satisfy performance, cost, efficiency, and space requirements. Electronic equipment such as rack mount servers, communication equipment, laptops, and many consumer electronic goods must conserve space in order to maintain the product's form factor. This article will illustrate how the proper features can help satisfy system specifications and enhance the performance of the power supply and the load.

The following key features will be presented: adjustable switching frequency, feedback voltage accuracy, startup tracking, power sequencing, pre-biased startup, utilizing an external reference, and synchronizing to an external clock. When optimized, these features can reduce EMI, transient response times, transient voltage amplitudes, solution size, output capacitance requirements, and overall BOM costs.

User-Adjustable Switching Frequency and External Compensation

A user-adjustable switching frequency allows the power designer to set the oscillator switching frequency to achieve the desired filter component size and consequently, the solution size. A high switching frequency reduces the power solution footprint by decreasing the size of the charge storage components. This includes input/output capacitors, inductors, and other filtering components.

By moving from a 100 kHz to a 1 MHz switching frequency, typical inductance required decreases tenfold while the volume of the inductor decreases fivefold. (The comparison was done with two shielded drum-core inductors of the same series, with saturation levels 15% apart from each other, the inductor current ripple set to 30% of the maximum load current, and with the following application power parameters: V_{IN} = 12V, V_{OUT} = 3.3V, I_{LOAD} = 5A, see ***Figure 1***) Shielded drum-core inductors are a good choice for switch-mode power supplies (SMPSs) that require an inductance value between 0.33 µH and 1 mH. These inductors are appropriate for high-frequency, low-EMI, and low-cost applications.

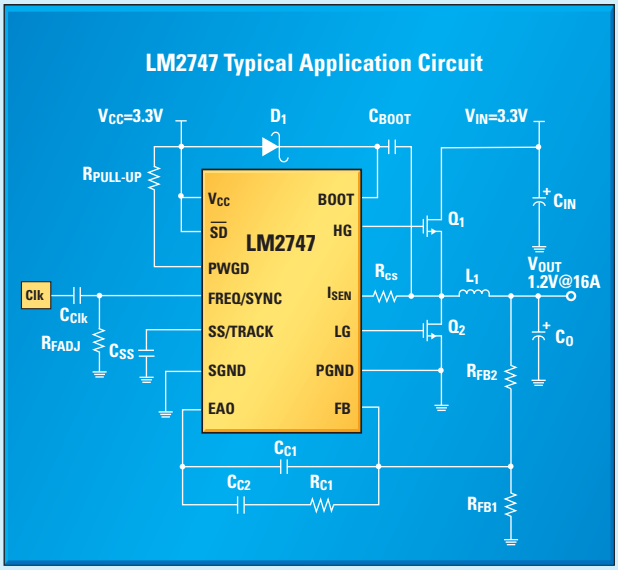
NEXT ISSUE:
Best Voltage Reference for ADCs

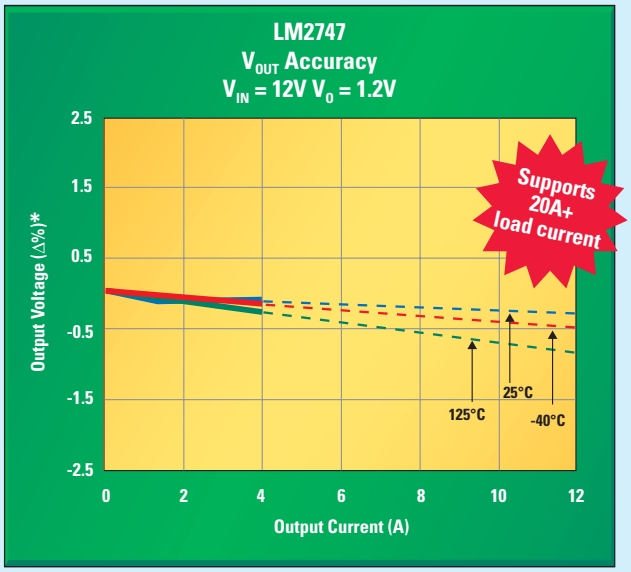
National Semiconductor
The Sight & Sound of Information

Synchronous Buck Controller with 1% Voltage Feedback Accuracy Across -40°C to +125°C

national.com/power

National's LM274x Family of Controllers Provide Down Conversion to Output Voltages as Low as 0.6V





*Includes effects of external components at temperature

AVAILABLE LEAD-FREE

Product ID	Operating Frequency	Product Features	Packaging
LM2742	50 kHz to 2 MHz	40 ns minimum on-time	TSSOP-14
LM2743	50 kHz to 1 MHz	Tracking	TSSOP-14
LM2744	50 kHz to 1 MHz	External reference, tracking	TSSOP-14
LM2745	50 kHz to 1 MHz	Pre-bias operation, ext clock 250 kHz to 1 MHz	TSSOP-14
LM2746	50 kHz to 1 MHz	1% accuracy 0°C to 85°C, startup delay	Thermally-enhanced TSSOP-14
LM2747	50 kHz to 1 MHz	1% accuracy -40°C to +125°C, pre-bias operation, external clock, programmable soft-start	TSSOP-14
LM2748	50 kHz to 1 MHz	Pre-bias operation, 1.5% accuracy	TSSOP-14

Applications

Cable modems, DSL and ADSL, laser and ink jet printers, low-voltage power modules, DSP, ASIC, core, and portable computing.

For samples, datasheets, and more, visit:

national.com/power

Or call: 1-800-272-9959

National Semiconductor

The Sight & Sound of Information

© National Semiconductor Corporation, 2008. National Semiconductor and N are registered trademarks of National Semiconductor Corporation. All rights reserved.

Optimizing Power Controller Designs through Effective Utilization of Performance Features

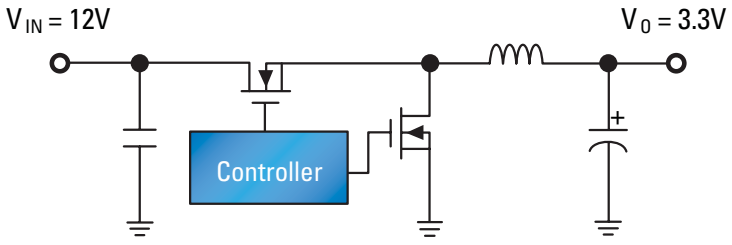


Figure 1. Simplified Buck Controller Circuit

The output capacitor also decreases in size as the switching frequency increases. Assume that multilayer ceramic capacitors (MLCCs) for the output filter have been selected and that the equivalent series resistance (ESR) is low enough that the output voltage ripple is capacitive. An SMPS design with a 100 kHz switching frequency, 1.5A peak-to-peak AC current, and a 50 mV output voltage ripple, requires 37.5 µF capacitance. The typical capacitance requirement decreases tenfold when operating at a 1 MHz switching frequency and the case size transitions from a 1210 MLCC to a 0603 case representing almost a 20x reduction in volume.

In this example, design for the output filter components only considered voltage and current ripple without examination of load and line transients. The availability of external compensation gives the power supply designer the flexibility to optimize the feedback loop without oversizing the output capacitance. For example, to decrease the output voltage transient, one can take advantage of the wide gain bandwidth product of the error amplifier. A high closed-loop bandwidth frequency decreases the time required for the error amplifier to react to load and line transients. As a typical rule of thumb, a bandwidth designed at one-tenth to one-fifth of the switching frequency results in a high-performance loop response. ***Figures 2*** and ***3*** show the result of increasing the bandwidth. The SMPSs underwent the same test conditions: equal slew rates, 350 mA to 8A load transient step, 440 µF output capacitance, and equal feedback-loop-gain phase margin (48°).

In the example, the output voltage transient decreased by approximately ±80 mV. The external compensation provides the flexibility to fine-tune the speed of the loop response while maintaining the same output capacitance.

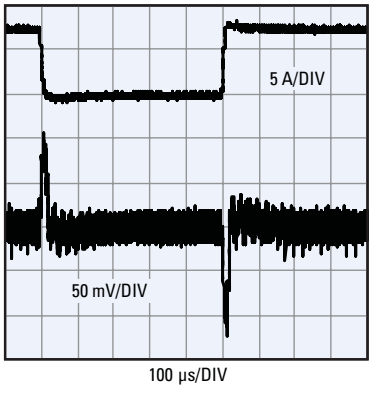


Figure 2. 26 kHz Bandwidth

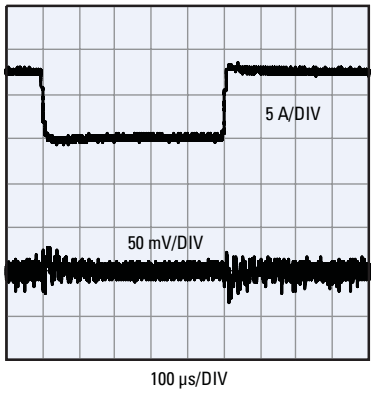


Figure 3. 119 kHz Bandwidth

Optimizing Power Controller Designs through Effective Utilization of Performance Features

Feedback Voltage Accuracy

The demand for faster processing speeds, conservation of battery life, and thermal considerations have driven digital processors to decrease their operating voltage. To maintain predictable logic level states, it is particularly significant for the SMPS to have tight feedback voltage accuracy across an extended die temperature range of -40ºC to +125ºC. Capacitance reduction is also feasible when using a ±1% feedback accuracy device over ±2% devices. According to FPGA power requirements, an output voltage response to a line or load transient must not exceed ±5% of the nominal 1.2V supply voltage.

With a ± 2% DC accuracy device, this leaves the output voltage supply with only ±36 mV of allowable voltage swing. With a device DC accuracy of ±1%, the allowable output voltage budget is now wider at ±48 mV.

In a typical example as shown in ***Figures 4*** and ***5***, based upon a 350 mA to 6A load transient response, equal loop gain bandwidth and phase margin, a 1% device accuracy over a 2% device realizes a 50% reduction in output capacitance. A tighter feedback voltage accuracy specification can translate into lower-value capacitors, saving costs and total solution size.

Tracking and Precision Enable Features

Modern mixed-signal systems require multiple voltage supply rails which power the processor core, I/O, and other analog and digital circuits. Each voltage rail calls for a different voltage and load rating. The startup timing of each voltage rail, in reference to each other, is a critical requirement. Keeping the voltage differential minimized during powerup and/or keeping them sequenced will prevent latch-up, bus contention, and undesirable transistor logic states.

The precision enable feature provides sequential timing necessary for proper startup. A second method of sequencing is the tracking feature; this gives control to the master power supply over the slave's startup rise time. Two common tracking methods are ratio-metric, where the supply voltages reach their regulation point at the same time, and simultaneous startup, where the supply voltages increase with equal slew rates, as shown in ***Figures 6*** and ***7***, respectively. Tracking and precision enable features allow several voltage rails to reach their nominal voltages within a specified target time.

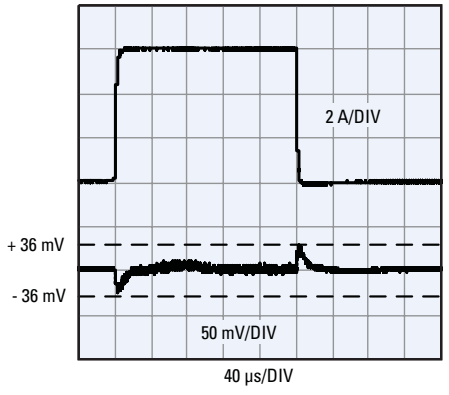


Figure 4. 2% Accurate Device with 940 µF of Output Capacitance

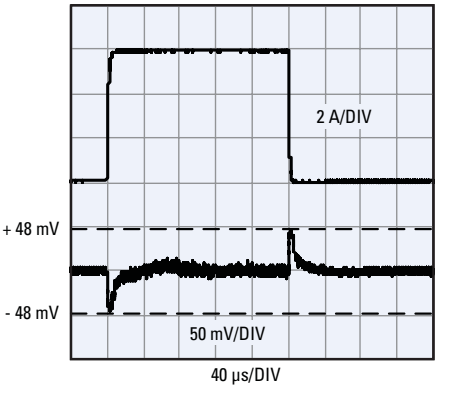


Figure 5. 1% Accurate Device with 470 µF of Output Capacitance

Optimizing Power Controller Designs through Effective Utilization of Performance Features

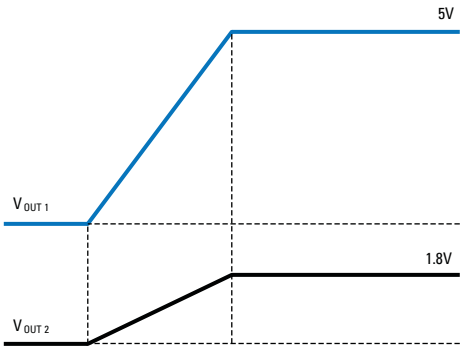


Figure 6. Ratio-Metric Tracking

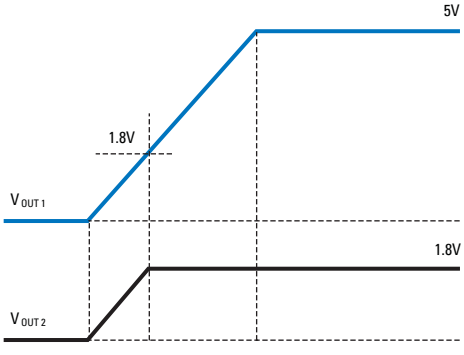


Figure 7. Simultaneous Tracking

Pre-Biased Startup Feature

In reference to the SMPS, pre-biased startup is defined as starting up into a biased output rail. Common output voltage pre-biased situations include redundant power supplies, multiphase voltage regulator modules, or cycling of the SMPS under no load or light load conditions. Discharging the output capacitor may lead to conditions such as the voltage and current of one rail sneaking into the output of another rail through a parasitic p-n junction, which potentially may cause the leakage component to fail. Other loads may trigger the output POWER GOOD flag, output undervoltage protection, and/or the output current protection of the voltage regulator IC.

In many situations, accidentally discharging a pre-biased load on the output rail of a SMPS is not acceptable. Only regulators with synchronous rectification have the ability to discharge the output capacitor in a pre-biased condition through the low-side MOSFET. Synchronous SMPSs equipped with soft-start pre-biased circuitry are able to sustain a charged output capacitor during the powerup period. This feature prevents the inadvertent discharge of the output rail during a pre-bias startup.

External Reference Feature

Regulators with an external reference feature can be advantageous in specific applications. One example of where the external reference feature proves beneficial is meeting double data rate (DDR) and DDR2 SDRAM termination specifications. DDR and DDR2 memory require a single power source for primary supply voltages (VDD) to ensure that all voltage levels track each other, especially critical during powerup. At initial powerup, all supply power should be stable and meet specification timing. The external reference voltage is expected to equal 1/2 VDD and must track variations in the DC voltage level. ***Figure 8*** shows a typical application circuit for a DDR2 solution.

Optimizing Power Controller Designs through Effective Utilization of Performance Features

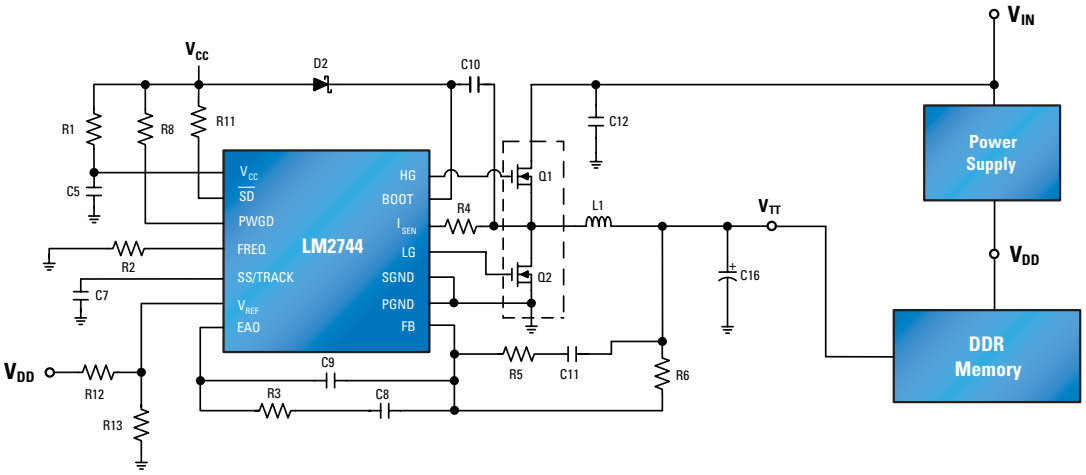


Figure 8. Typical DDR2 Application Circuit

Frequency Synchronization

Data communication and high-quality audio and video electronics require low noise to maintain uncompromised signal integrity. Typically, a single rail bus supplies power to multiple SMPSs which subsequently provide voltage rails to a number of electronic components in a system. Beat noise occurs when two or more SMPSs are connected to the same input supply or when the input of one SMPS connects to the output of another SMPS. The sum and difference between switching frequencies of non-synchronized SMPSs will develop beat frequencies. The power supplies will reflect beat noise to the input bus and conduct into any electrical circuit connected to it, such as other SMPSs.

Techniques used to attenuate the beat noise include:

1. Additional filtering at the front end of each switching regulator
2. Increasing the loop gain sufficiently at the beat frequency in order to reject the input-to-output noise transfer
3. Setting the switching frequency of one of the SMPSs to switch at two times greater than the second SMPS

These techniques increase the solution size and/or increase design time. A better alternative involves synchronizing the SMPS oscillators. Synchronizing two or more internal oscillators will eliminate beat noise and relieve conducted noise interaction with other loads. Synchronizing also keeps the generated EMI to a predictable set of frequencies, as seen in ***Figures 9*** and ***10***.

Optimizing Power Controller Designs through Effective Utilization of Performance Features

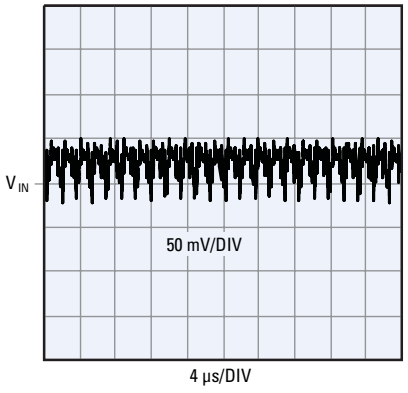


Figure 9. Two Independent Internal Oscillators, Synchronized

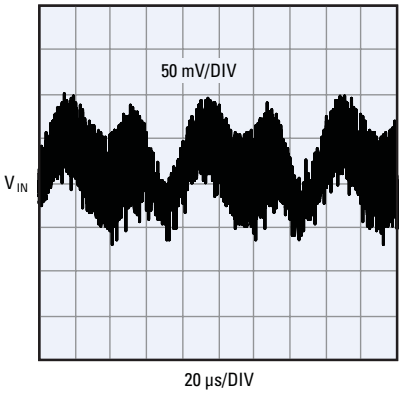


Figure 10. Two Independent Internal Oscillators, Not Synchronized

Conclusion

The selection of appropriate devices with proper features can help satisfy system specifications and enhance the performance of the power supply and the load. Key features presented in this article: adjustable switching frequency, feedback voltage accuracy, startup tracking, power sequencing, pre-biased startup, utilizing an external reference, and synchronizing to an external clock, are incorporated in National Semiconductor's family of LM2742 through LM2748 high-performance controllers.

The LM274x is a forced pulse-width modulation (PWM) voltage-mode controller family of products that has an idyllic load-specific feature set optimized for powering existing and future generations of complex digital and analog loads.

For additional information on the high-performance LM274x family and on National's power management solutions, visit national.com/power and refer to application note AN-1603.

References

1. *LM2747 Product Folder:*
www.national.com/pf/LM/LM2747.html

2. *Application Notes:*
AN-1603: LM274x Reference Designs:
www.national.com/an/AN/AN-1603.pdf

AN-1641: LM2747-19A Demo Board:
www.national.com/an/AN/AN-1641.pdf

AN-1573: LM2745-19A Demo Board:
www.national.com/an/AN/AN-1573.pdf

AN-1640: LM2743-19A Demo Board:
www.national.com/an/AN/AN-1640.pdf

3. *Power Products Selection Guide:*
www.national.com/appinfo/power/files/PowerSelGuide.pdf

Power Design Tools

Tools for Energy-Efficient Designs

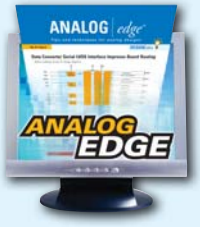
Access white papers, reference designs, and application notes on PowerWise® products and systems.

www.national.com/powerwise

Analog Edge℠ App Notes

National's monthly analog design technical journal.

www.national.com/analogedge



Online Seminars

Free online seminars by industry experts. Log onto National's analog online seminars today.

www.national.com/onlineseminars

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

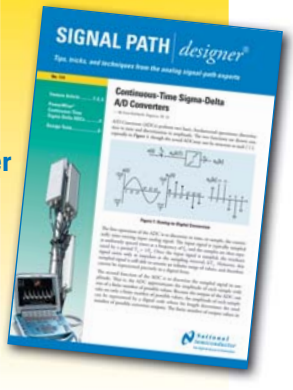
Don't miss a single issue!

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

www.national.com/powerdesigner

Read our Signal Path Designer® online today at:

www.national.com/spdesigner



National Semiconductor
The Sight & Sound of Information

©2008, National Semiconductor Corporation. National Semiconductor, N, PowerWise, and Signal Path Designer are registered trademarks and Analog Edge is a service mark of National Semiconductor. All other brand or product names are trademarks or registered trademarks of their respective holders. All rights reserved.

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		**Applications**	
Audio	www.ti.com/audio	Communications and Telecom	www.ti.com/communications
Amplifiers	amplifier.ti.com	Computers and Peripherals	www.ti.com/computers
Data Converters	dataconverter.ti.com	Consumer Electronics	www.ti.com/consumer-apps
DLP® Products	www.dlp.com	Energy and Lighting	www.ti.com/energy
DSP	dsp.ti.com	Industrial	www.ti.com/industrial
Clocks and Timers	www.ti.com/clocks	Medical	www.ti.com/medical
Interface	interface.ti.com	Security	www.ti.com/security
Logic	logic.ti.com	Space, Avionics and Defense	www.ti.com/space-avionics-defense
Power Mgmt	power.ti.com	Transportation and Automotive	www.ti.com/automotive
Microcontrollers	microcontroller.ti.com	Video and Imaging	www.ti.com/video
RFID	www.ti-rfid.com		
OMAP Mobile Processors	www.ti.com/omap		
Wireless Connectivity	www.ti.com/wirelessconnectivity		
	TI E2E Community Home Page		e2e.ti.com

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