LP5520,LP5521,LP5522,LP55281

Color-Management LED Drivers Have a Bright Future

Literature Number: SNVA600

POWER designer

Expert tips, tricks, and techniques for powerful designs

No. 119

Feature Article.....1-7

RGB LED Driver Generates "True White" Backlighting 2

LED Driver Offering True Linear Dimming.....4

Fully Integrated Flash LED Driver.....6

Power Design Tools.....8

Color-Management LED Drivers Have a Bright Future

— By Tomi Koskela, Applications Engineer

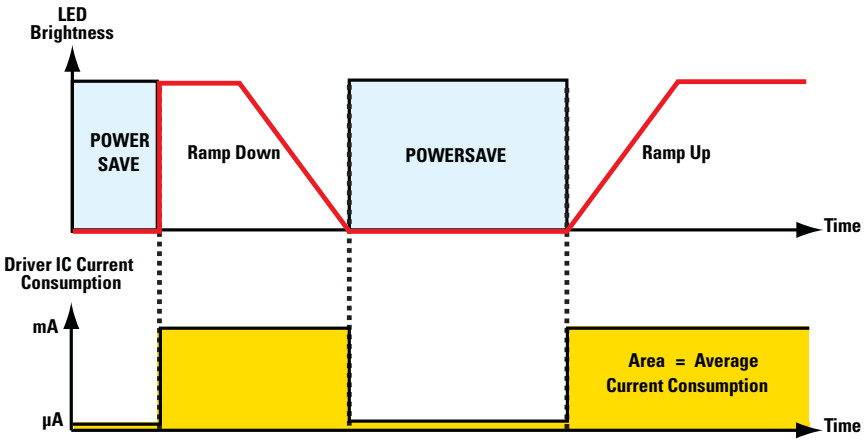


Figure 1. Automatic Power-Save-Mode Operation in the LP5521 LED Driver

Introduction

Color LEDs are becoming more and more popular in portable consumer devices such as mobile phones, portable media players, and gaming and navigation devices. They are commonly used for indication lights, which could be an RGB LED where the color changes according to the event such as Short Message Service (SMS) or incoming calls. These types of LEDs can be driven in various ways such as LED drivers, General Purpose Input/Output (GPIO) pins on the Power Management Unit (PMU), or advanced Lighting Management Unit (LMU).

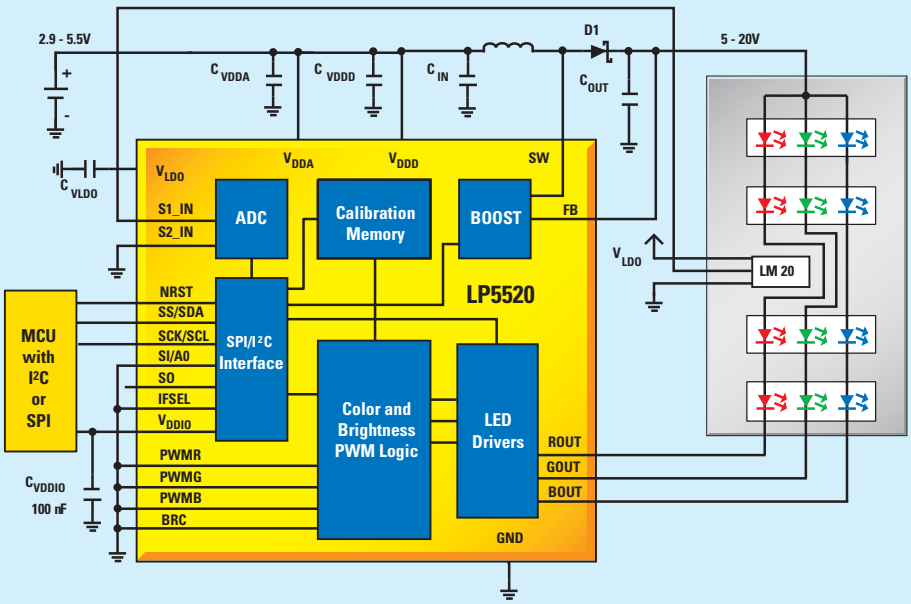
One area that RGB LEDs have been used heavily is for personalizing handsets with keypad lighting, fun lighting, and phone cosmetics. RGB LEDs also can be used for display backlighting. Increases in the RGB-LED count on mobile phones create challenges for the LED drivers as well. The most common challenges in driving color LEDs in portable devices are power consumption, control interface/programmability, EMI, overall solution size, and system cost. Two key areas driving color LEDs in portable devices warrant detailed discussion: indicator and cosmetic lighting, and display backlighting.

NEXT ISSUE:
Switching Regulators for Space-Constrained Apps

National Semiconductor
The Sight & Sound of Information

RGB LED Driver Generates Highly Efficient "True White" Backlighting

LP5520 Provides Innovative, Easy-to-Use, Instant Color Gamut Improvement for Small Format Displays



Features

- Temperature compensated LED intensity and color
- Individual calibration coefficients for each color
- Color accuracy ΔX and ΔY ≤ 0.003
- 100% NTSC color gamut, brighter color, better picture quality
- User programmability for effects, aging, dimming
- PWM control inputs for each color

Product	Description	Packaging
NEW LP5520	RGB Backlighting LED driver with integrated white balance compensation	microSMD-25
NEW LP5521	Programmable, low power, 3-channel LED driver	microSMD-20, LLP-24
NEW LP5522	Autonomous single LED controller with one wire interface	microSMD-6
LP5526	Lighting Management Unit with high voltage boost converter with up to 150 mA serial flash LED driver	microSMD-25
LP5527	LED driver for camera flash and 4 LEDs with I²C programmability, LED connectivity, test, and audio synchronization	microSMD-30
NEW LP55281	13 channel LED driver with audio sync, LED connectivity test and independent PWMS/PWMS blinking cycles	microSMD-36

Ideal for navigation systems, mobile phones, medical devices, and other portable devices

For FREE samples, datasheets, and more information on these products, go to:

led.national.com

Color-Management LED Drivers Have a Bright Future

Color Indicator LEDs and Cosmetics Lighting in Portable Devices

New features in mobile phones and most other consumer portable devices are power dependent. Display backlighting and LEDs overall consume considerable power in handheld devices; therefore, power savings with LED driving is critical. Most of today's new LED drivers are focused particularly on improving the overall power efficiency.

The conventional way of driving an indicator LED is with simple current sinks, or with some GPIO pins. These types of LED-driving methods require application-processor control each time the LED is activated. An example application is the indicator LED blinks when an SMS message arrives. When the application processor is required to wake up each time the light effect occurs, the power consumption due to this lighting effect adversely affects battery life.

For a power-conscious, simple indicator-LED driver, it is ideal to program the blinking sequence to the driver and leave the sequence running without application-processor control. This way the processor can be in sleep mode when the device is not in use while the LED driver handles the blinking sequences itself. When a simple on/off control is required with a single, low-forward-voltage color LED, a step-up DC-DC converter is not necessary and the overall power consumption is further reduced. This type of LED driver can be made extremely small and requires a minimal number of external components, or perhaps none at all.

Programmable Lighting Sequences Provide Further Power Savings

The ability to control lighting sequences can improve the power-saving capability on mobile devices. An example of a device with this capability is the LP5522 LED driver from National Semiconductor. Blinking sequences are trained to the LP5522 driver with a single-wire interface. After a training command, the driver can repeat the sequence without external control. The LED current can be adjusted with an external resistor while the default current without the resistor is 5 mA. The size of the LP5522 device is 1.2 mm x 0.8 mm x 0.6 mm and the LED is the only external component, making this small and reduced BOM solution ideal for space-constrained and system-cost-sensitive portable applications.

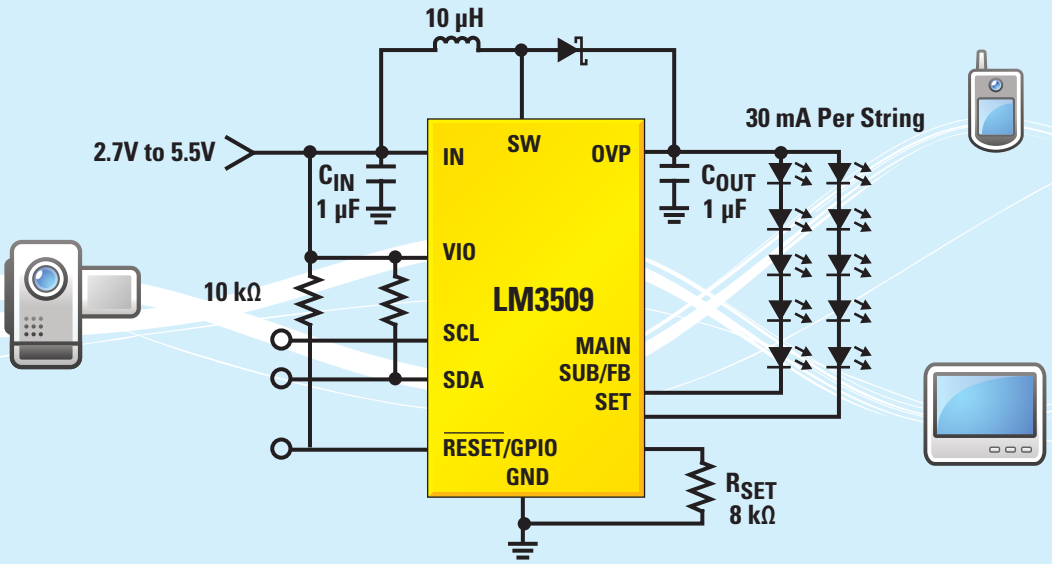
When LEDs with higher forward voltage are used, the single-cell Li-Ion battery voltage is not always sufficient to drive the LEDs. In this case, a step-up DC-DC converter is required. A step-up converter can be either capacitive (charge-pump or switched capacitor) or inductive (magnetic boost). Today, a charge-pump converter is used in driving low-voltage parallel-LED drivers, and a magnetic-boost converter is used in high-voltage serial-LED drivers.

For complex lighting sequences such as smooth transitions between different colors, a sophisticated control method is required besides a simple enable-control pin. An I^2C-control bus is widely used in many portable devices as it provides greater flexibility for controlling an LED driver via only two wires. Usually there are other components, for example a camera module, using the same bus. Therefore, LED driving should not use all of the I^2C bandwidth. Controlling the LED brightness in real time creates considerable I^2C traffic.

A new charge-pump-based color-LED driver, such as National's LP5521 device, allows minimum real-time control by incorporating internal memory for sequencing. Lighting sequences are written to an internal memory after power-up, and an external trigger pin or I^2C write is used to start the sequences. When the sequence is running, processor control is not required. When the phone is in standby mode, the application processor can be in sleep mode while complex lighting sequences can still be achieved. Sequences can include time delays, ramps, blinking, loops, and sending/receiving trigger signals.

Industry's First LED Driver Offering True Linear Dimming for the Human Eye

LM3509 Dual-Output Constant-Current LED Driver Operates at 90% Efficiency

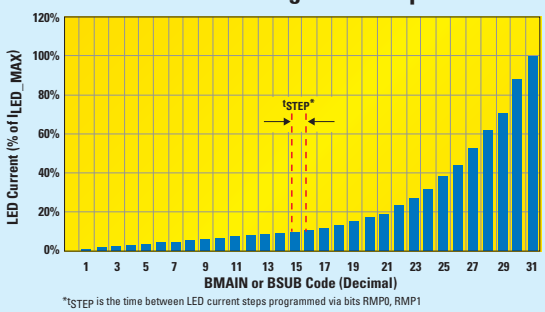


Dual White LED Bias Supply

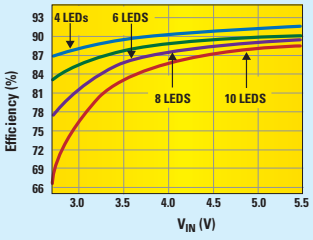
Features

- 32 Exponentially spaced dimming states with 800:1 LED current ratio
- Auto-dimming function enables transition from one dimming state to the other at different speeds
- Integrates OLED power supply
- 2 independently controlled constant current outputs for main and sub displays
- Drives 10 LEDs at 30 mA with 0.15% current matching
- Simultaneously drives 5 LEDs at 20 mA and delivers 21V at 40 mA for OLED power supply
- I²C-compatible programmable brightness control

Non-Linear Brightness Steps



*tSTEP is the time between LED current steps programmed via bits RMP0, RMP1



Ideal for driving LEDs in mobile phones, digital cameras, and navigation system displays

For FREE samples, datasheets, and more information on the LM3509, go to:

led.national.com

Color-Management LED Drivers Have a Bright Future

Reducing Power Consumption in LED Drivers

To further decrease power consumption, the LP5521 driver has an automatic power-save-mode operation. The DC-DC converter in the LP5521 device starts up only when the Li-Ion battery voltage is not sufficient enough to supply the LEDs. The LP5521 driver also shuts down other unused blocks when the LEDs are not active and while the sequence is running internally. This significantly decreases the average power consumption. Automatic power-save-mode operation implemented in the LP5521 LED driver can be seen in ***Figure 1.***

A charge-pump-based RGB-LED driver such as the LP5521 device requires only four small capacitors. With a small footprint and minimum external components, the total solution size can be as small as 7 mm^2. The small solution height makes it suitable for slim design applications. Also with such a small solution size, it is possible to create a localized rather than centralized solution, meaning that the LED driver is located near the LEDs. This way the PCB routing is much easier, and the EMI is reduced. The LP5521 LED driver has external control pins which are used for synchronizing several drivers, making it possible to achieve very interesting lighting effects.

RGB LEDs as Small-Panel Display Backlighting in Portable Devices

Typically, small-panel LCD-display backlighting can be achieved with a couple of white LEDs. The problem with white LEDs is that their spectrum is not ideal for photographic reproduction. This is caused by the fact that white LEDs are basically blue LEDs with yellow phosphor on top. The spectrum has two peaks: one at blue, and a second at yellow. A typical white-LED versus RGB-LED spectrum can be seen in ***Figure 2***.

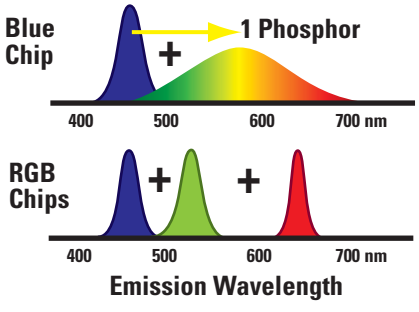


Figure 2. Typical White-LED vs. RGB-LED Spectrum

To filter the right color to each color cell (red, green, blue), color filters are used. Color filters waste some of the power and even after color filtering, the color spectrum passing through the LCD is not ideal. With white-LED backlighting, it is possible to get up to 75% of the National Television Standards Committee (NTSC) colors on an LCD display (the red end of the conventional LCD display is especially limited). When RGB LEDs are used for LCD-display backlighting, the color reproduction can be adjusted to cover over 100% of the NTSC color gamut which results in brighter color and better picture quality. With optimized color filters, less power is wasted than in white-LED backlighting. The structure of an LCD display can be seen in ***Figure 3.***

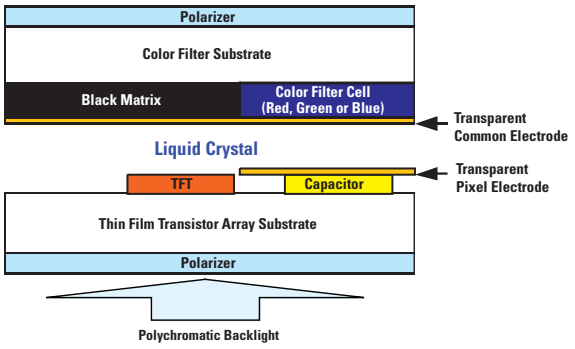


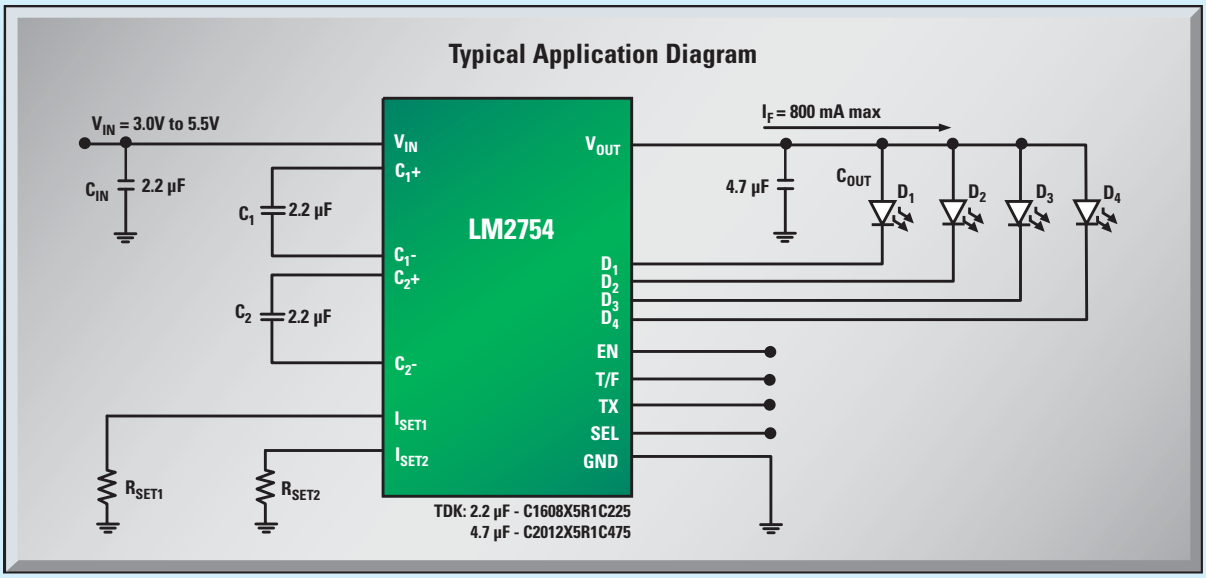
Figure 3. Structure of an LCD Display

Generating "True White" Backlighting Through Open-Loop Compensation

With RGB backlighting, the LED driver must correct the brightness balance between the primary colors (red, green, and blue) when the LED temperature changes. The LED driver keeps the white point of the RGB backlight adjusted correctly at any operating temperature. Compensation can be either closed loop or open loop. With closed-loop compensation, an optical sensor is used for measuring the

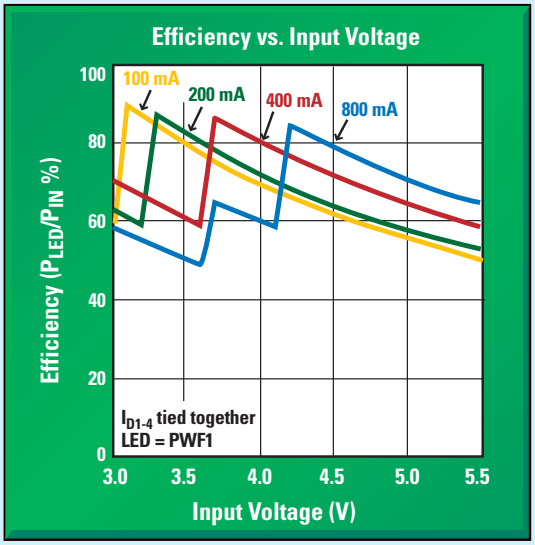
Industry's Smallest, Fully Integrated Flash LED Driver

High-Power LED Driver Optimized for Driving Single- and Multiple-Die Flash LED Technologies in Handheld Applications



LM2754 Features

- Total solution size without LED < 28 mm^2
- Time-out circuit limit flash duration to 1s, protects LED from over-heating
- No inductor required
- True shutdown output disconnect
- <1 µA shutdown current
- TX input ensures synchronization with RF power amplifier pulse
- Ability to disable one current sink via the SEL pin to accommodate 3-LED flash modules
- Internal soft-start limits inrush current
- Available in LLP-24 (4 mm x 4 mm x 0.8 mm) packaging



Ideal for camera flashes for mobile phones and flashes for digital still cameras

For FREE samples, datasheets and more information on the LM2754, go to:

led.national.com

Color-Management LED Drivers Have a Bright Future

white point. With open-loop compensation, the temperature is measured and predefined compensation curves are used to adjust the white point.

For RGB backlighting, National offers the LP5520 RGB-LED driver, which is an open-loop-compensated LED driver. The principle of the open-loop color compensation can be seen in *Figure 4*. With open-loop compensation, an accurate white point is maintained through the operation temperature range. The temperature compensation curves are measured for the actual RGB-LED type used in the application, and these curves are programmed to the chip's internal EEPROM memory. The chip is integrated into the LCD display module, and the module manufacturer programs compensation curves in production. An RGB-LED backlight-optimized color filter is used as well.

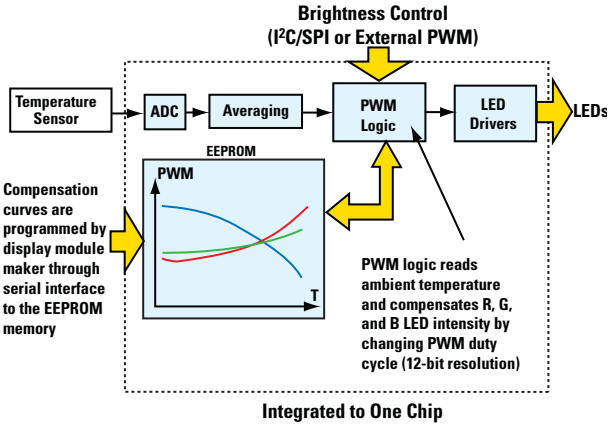


Figure 4. Principle of Open-Loop Color Compensation in the LP5520 LED Driver

Controlling display brightness with the LP5520 device is similar to that of white-LED backlighting. The brightness level is controlled through a SPI or I²C bus, and the LP5520 device calculates the actual Pulse Width Modulation (PWM) values according to the compensation curves to maintain the white point. Automatic fade in and out can be used to get a smooth transition. The brightness can be controlled alternatively with an external PWM, and the LP5520 device also has an interface for an ambient-light sensor. Therefore, this color compensation is invisible to the manufacturers, and no special software is needed for controlling the RGB backlight. Fast implementation of an RGB-backlit display to end devices is possible because display vendors have ready-made solutions available.

Additional LED Driver Features

Because the number of LEDs in handsets and other portable consumer devices is continually increasing, a fast and reliable way to test the connection to each LED is needed. Testing LED connectivity in end-device production usually requires test points on the PCB for each LED, or optical testing must be used. Incorporating test points to the application PCB is not an easy task considering how tightly packed PCBs in portable devices are today. Furthermore, optical-testing methods are difficult and expensive to implement.

With built-in LED-connectivity tests in LED drivers, it is possible to test the connection to each LED through an I²C or SPI bus and get accurate results in milliseconds. This makes the production testing very easy to implement and it is also fast and effective. For example, the LED-connectivity test has been integrated into the LP55281, a quad RGB-LED driver. The LED-connectivity test is just one example of a built-in feature which provides extra value to designers.

Conclusion

RGB LEDs create interesting possibilities to personalize handsets and other portable consumer devices. However, increasing and more versatile use of RGB LEDs in handsets create challenges for the LED drivers. The most significant challenge is how to drive all of these LEDs efficiently in a cost-effective manner and in the smallest solution size. National's new family of lighting-management products provides solutions that meet the challenges of these new lighting trends. For more information, please refer to lighting.national.com. ■

Power Design Tools

Lighting Solutions Guide

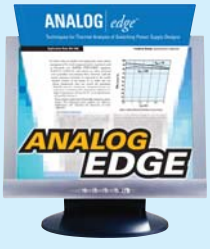
For information on National's LED lighting solutions and to download the guide, visit:

led.national.com

Analog Edge℠ App Note

National's monthly app note highlight

edge.national.com



Reference Designs

National's power reference design library provides a comprehensive library of practical reference designs to speed system design and time-to-market.

www.national.com/refdesigns

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

National Semiconductor
The Sight & Sound of Information

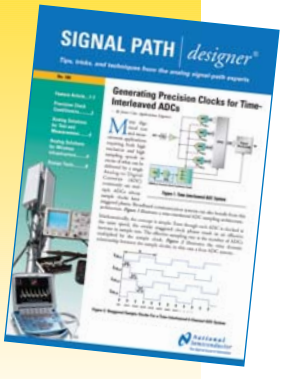
Don't miss a single issue!

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



©2007, National Semiconductor Corporation. National Semiconductor, , 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.

550263-019

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