CCFL to LED Conversion Power Supply

1.0 Design Specifications

<table>
<thead>
<tr>
<th>Inputs</th>
<th>Output #1</th>
</tr>
</thead>
<tbody>
<tr>
<td>VinMin=8V</td>
<td>Vout1=20V</td>
</tr>
<tr>
<td>VinMax=16V</td>
<td>Iout1=0.06A</td>
</tr>
</tbody>
</table>

2.0 Design Description

Better backlight displays for portable devices - Two-Channel 60 mA Backlight LED Driver Design

Backlighting in portable device displays has historically utilized difficult-to-power cold cathode-fluorescent (CCFL) tubes. The tubes run on alternating current (AC) and need a large initial voltage of typically greater than 1 kV in order to fire them. Once they have fired, their operating voltage drops to under a kV. Because a notebook computer, for example, typically operates on low DC voltages (12V, 5V, 3.3V, etc.), a Royer oscillator must be used to transform this low voltage to the high-voltage AC required by the CCFL. The high voltages in the system are a potential safety hazard.

The CCFL to LED conversion power supply reference design replaces the backlight CCFLs with strings of light-emitting diodes (LEDs). LEDs operate at low voltages of 3V TO 4V each and are extremely durable. They produce a brighter light whose spectral content can be more easily custom tailored to the needs of the backlight. Their brightness can be easily controlled to compensate for changes in ambient light. Also in contrast to the glass-tubed CCFLs, the physically small LEDs can be mounted on flexible strips, allowing the display to be more tolerant of and resistant to sudden shocks.

The reference design, with National Semiconductor’s LM3431 three-channel, constant-current LED driver, uses two strings of six series-connected LEDs at a current of 30 mA per string. Each LED has a forward voltage drop of about 3.5V, making the total voltage across each string between 21V and 27V. With a 12V power source, the LM3431 is configured as a boost converter to generate this 21V to 27V output voltage.

The design also includes a circuit utilizing a photodiode to make the brightness of the LEDs proportional to ambient light thus improving the readability of the display under all lighting conditions.

3.0 Features

- 8-16V input voltage range
- Two accurately regulated LED channels at 60mA each and 21-28V
- Expandable to 3 or more LED channels
- 500 kHz switching frequency for small size
- High efficiency (76%)
- LED PWM dimming proportional to ambient light

© 2008 National Semiconductor Corporation www.national.com
FIGURE 1. LED driver schematic
5.0 Bill of Materials

<table>
<thead>
<tr>
<th>Designator</th>
<th>Value</th>
<th>Package/Reference</th>
<th>Characteristics</th>
<th>Manufacturer</th>
<th>PartNumber</th>
<th>RoHS</th>
</tr>
</thead>
<tbody>
<tr>
<td>C1</td>
<td>1uF</td>
<td>0805</td>
<td>Ceramic, X7R, 10V, 10%</td>
<td>TDK</td>
<td>C2012X7R1A105K</td>
<td>Y</td>
</tr>
<tr>
<td>C2</td>
<td>10uF</td>
<td>1206</td>
<td>Ceramic, X7R, 10V, 10%</td>
<td>TDK</td>
<td>C3216X7R1A106M</td>
<td>Y</td>
</tr>
<tr>
<td>C3</td>
<td>4.7uF</td>
<td>1206</td>
<td>Ceramic, X5R, 10V, 10%</td>
<td>TDK</td>
<td>C3216XR1A475K</td>
<td>Y</td>
</tr>
<tr>
<td>C4</td>
<td>0.1uF</td>
<td>0805</td>
<td>Ceramic, C0G/NP0, 25V, 5%</td>
<td>TDK</td>
<td>C2012C0G1E103J</td>
<td>Y</td>
</tr>
<tr>
<td>C5, C6</td>
<td>0.047uF</td>
<td>0805</td>
<td>Ceramic, X7R, 100V, 10%</td>
<td>TDK</td>
<td>C2012X7R2A475K</td>
<td>Y</td>
</tr>
<tr>
<td>C7</td>
<td>10uF</td>
<td>1210</td>
<td>Ceramic, X7R, 25V, 20%</td>
<td>TDK</td>
<td>C3225X7R1E106M</td>
<td>Y</td>
</tr>
<tr>
<td>C8</td>
<td>1uF</td>
<td>0805</td>
<td>Ceramic, X7R, 10V, 20%</td>
<td>AVX</td>
<td>0805ZC100MA72A</td>
<td>Y</td>
</tr>
<tr>
<td>C9</td>
<td>4700pF</td>
<td>0805</td>
<td>Ceramic, X7R, 100V, 20%</td>
<td>TDK</td>
<td>C2012X7R2A472M</td>
<td>Y</td>
</tr>
<tr>
<td>C10</td>
<td>100pF</td>
<td>0805</td>
<td>Ceramic, C0G/NP0, 50V, 5%</td>
<td>TDK</td>
<td>C2012C0G1H101J</td>
<td>Y</td>
</tr>
<tr>
<td>C11</td>
<td>0.1uF</td>
<td>0805</td>
<td>Ceramic, X7R, 50V, 10%</td>
<td>TDK</td>
<td>C2012X7R1H104K</td>
<td>Y</td>
</tr>
<tr>
<td>D1</td>
<td>0.5V</td>
<td>SMA</td>
<td>Vr = 40V, Io = 1A, Vf = 0.5V</td>
<td>Diodes Inc.</td>
<td>B140-13-F</td>
<td>Y</td>
</tr>
<tr>
<td>D2, D3, D6, D7</td>
<td>0.24V</td>
<td>SOT-23</td>
<td>Vr = 30V, Io = 0.2A, Vf = 0.24V</td>
<td>Diodes Inc.</td>
<td>BA154-7-F</td>
<td>Y</td>
</tr>
<tr>
<td>D4</td>
<td>0.24V</td>
<td>SOT-323</td>
<td>Vr = 70V, Vf = 0.41V</td>
<td>Central Semiconductor</td>
<td>CMS06263</td>
<td>O</td>
</tr>
<tr>
<td>D5</td>
<td>3.9V</td>
<td>SOT-23</td>
<td>ON</td>
<td>Semiconductor</td>
<td>BZX84C3V9L7G</td>
<td>Y</td>
</tr>
<tr>
<td>D6</td>
<td>5.1V</td>
<td>SOT-23</td>
<td></td>
<td>Diodes, Inc.</td>
<td>BZX84C5V1-7-F</td>
<td>Y</td>
</tr>
<tr>
<td>D10</td>
<td></td>
<td></td>
<td></td>
<td>TDK</td>
<td>BC52015G1</td>
<td>Y</td>
</tr>
<tr>
<td>L1</td>
<td>4.7uH</td>
<td>MSSS131</td>
<td>Shielded Drum Core, 0.38A, 0.32 Ohm</td>
<td>Coilcraft Inc.</td>
<td>MSSS131-473MB</td>
<td>Y</td>
</tr>
<tr>
<td>Q1</td>
<td>60V</td>
<td>TSOP_6</td>
<td>-3.6A, 3.5nC, (DS(on) @ 4.5V) ≤ 10µS</td>
<td>Vishay-Siliconix</td>
<td>SI3456BV</td>
<td>O</td>
</tr>
<tr>
<td>Q2, Q4</td>
<td>0.2V</td>
<td>TO-92</td>
<td>NPN, 0.2A, 40V</td>
<td>Central Semiconductor</td>
<td>2N3904</td>
<td>Y</td>
</tr>
<tr>
<td>R1</td>
<td>105k</td>
<td>0805</td>
<td>1%, 0.125W</td>
<td>Vishay-Date</td>
<td>CRCW0805105kFKEA</td>
<td>Y</td>
</tr>
<tr>
<td>R2, R5</td>
<td>20.0k</td>
<td>0805</td>
<td>1%, 0.125W</td>
<td>Vishay-Date</td>
<td>CRCW080520kFKEA</td>
<td>Y</td>
</tr>
<tr>
<td>R3, R10</td>
<td>1.00</td>
<td>0805</td>
<td>1%, 0.125W</td>
<td>Vishay-Date</td>
<td>CRCW0805R00FKEA</td>
<td>Y</td>
</tr>
<tr>
<td>R4, R9, R15</td>
<td>10.0k</td>
<td>0805</td>
<td>1%, 0.125W</td>
<td>Vishay-Date</td>
<td>CRCW080510kFKEA</td>
<td>Y</td>
</tr>
<tr>
<td>R8</td>
<td>49.9k</td>
<td>0805</td>
<td>1%, 0.125W</td>
<td>Vishay-Date</td>
<td>CRCW080549kFKEA</td>
<td>Y</td>
</tr>
<tr>
<td>R7, R11, R21, R22</td>
<td>100k</td>
<td>0805</td>
<td>1%, 0.125W</td>
<td>Vishay-Date</td>
<td>CRCW0805100kFKEA</td>
<td>Y</td>
</tr>
<tr>
<td>R9, R13</td>
<td>7.50</td>
<td>0805</td>
<td>1%, 0.125W</td>
<td>Vishay-Date</td>
<td>CRCW08057R50FKEA</td>
<td>Y</td>
</tr>
<tr>
<td>R12</td>
<td>1.0</td>
<td>0805</td>
<td>5%, 0.125W</td>
<td>Vishay-Date</td>
<td>CRCW0805R00JNEA</td>
<td>Y</td>
</tr>
<tr>
<td>R14</td>
<td>24.3k</td>
<td>0805</td>
<td>1%, 0.125W</td>
<td>Vishay-Date</td>
<td>CRCW080524kFKEA</td>
<td>Y</td>
</tr>
<tr>
<td>R18</td>
<td>1.0k</td>
<td>0805</td>
<td>1%, 0.125W</td>
<td>Vishay-Date</td>
<td>CRCW0805100FKEA</td>
<td>Y</td>
</tr>
<tr>
<td>R19</td>
<td>7.68k</td>
<td>0805</td>
<td>1%, 0.125W</td>
<td>Vishay-Date</td>
<td>CRCW08057R68FKEA</td>
<td>Y</td>
</tr>
<tr>
<td>R20</td>
<td>100k</td>
<td>0805</td>
<td>5%, 0.125W</td>
<td>Vishay-Date</td>
<td>CRCW0805100JNEA</td>
<td>Y</td>
</tr>
<tr>
<td>R23</td>
<td>1.00Meg</td>
<td>0805</td>
<td>1%, 0.125W</td>
<td>Vishay-Date</td>
<td>CRCW08051M00FKEA</td>
<td>Y</td>
</tr>
<tr>
<td>R24</td>
<td>2.00k</td>
<td>0805</td>
<td>1%, 0.125W</td>
<td>Vishay-Date</td>
<td>CRCW08052k00FKEA</td>
<td>Y</td>
</tr>
<tr>
<td>U1</td>
<td>MXA28A</td>
<td>3-Channel Constant Current LED Driver With Integrated Boost Controller</td>
<td>National Semiconductor</td>
<td>LM3431MH</td>
<td>Y</td>
<td></td>
</tr>
<tr>
<td>U2</td>
<td>M08A</td>
<td>Dual CMOS Low Voltage (2.7V and 3V) R-R Out Op Amp</td>
<td>National Semiconductor</td>
<td>LMC6572AIM</td>
<td>O</td>
<td></td>
</tr>
</tbody>
</table>

### FIGURE 2. LED driver bill of materials

6.0 Other Operating Values

<table>
<thead>
<tr>
<th>Description</th>
<th>Parameter</th>
<th>Value</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulation Frequency</td>
<td>Frequency</td>
<td>500</td>
<td>KHz</td>
</tr>
<tr>
<td>Total output power</td>
<td>Pout</td>
<td>1.5</td>
<td>W</td>
</tr>
<tr>
<td>Steady State Efficiency</td>
<td>Efficiency</td>
<td>75</td>
<td>%</td>
</tr>
<tr>
<td>Peak-to-peak ripple voltage</td>
<td>Vout p-p</td>
<td>n/a</td>
<td>mV</td>
</tr>
<tr>
<td>Static load regulation</td>
<td>Static load</td>
<td>n/a</td>
<td>mV</td>
</tr>
<tr>
<td>Dynamic load regulation</td>
<td>Dynamic load</td>
<td>n/a</td>
<td>mV</td>
</tr>
</tbody>
</table>
7.0 Board Photos

8.0 Quick Start
A photograph of the reference design is shown in Figure 3. To operate the board follow the steps outlined below.

1. Connect an LED string with an operating current of 30 mA and a rated voltage in the range 12-28V between the posts P4 (VA) and P3 (VC1). The anode side of the LED string should go to P4, and the cathode side to P3.
2. Connect a second LED string between posts P4 and P5 (VC2), again with polarity of anode to P4 and cathode to P5.
3. Apply an input voltage of 12V to the posts P1 (VIN) and P2 (SGND). The positive input voltage terminal should go to P1, and the negative terminal to P2.
4. The two LED strings should now be lighted.
5. To investigate the dimming function, shine a light more or less directly at the photodiode D10 on the board and notice how the LED strings brightens or dims according to whether there is more or less light falling on D10.
6. The equations 5, 6 and 7 given above can be used to fine tune the dimming function to conform to the characteristics of the display being used.

9.0 Hardware Description
The reference design schematic is shown in Figure 1. The boost converter consists of part of the LM3431, as well as C1, C2, C7, L1, Q1, R3 and D1 and produces an output voltage given by Eq. 1.

Equation 1 is derived as follows. One switching period consists of a time interval DT during which Q1 is on, and a complementary interval (1-D)T during which D1 is on. During Q1’s on time the voltage across the inductor L1 is the input voltage, causing the inductor current to increase. When Q1 goes off the diode D1 turns on and the inductor current commutes into it to the output capacitor C7 and the LED strings. Under steady state conditions the output voltage, which appears across C7, is greater than the input voltage, so that during the (1-D)T interval the voltage across the inductor is equal to the difference between the output and input voltages. The net volt-seconds across the inductor are zero over one switching period, as given by Eq. 2

Rearranging Eq. 2 gives Eq. 1.

The currents flowing through the LED strings are set by the voltages at the SNS1, NDRV1, SNS2 and NDRV2 pins through the transistors Q2 and Q4. The voltages across the two diode strings are monitored at the SC and CFB pins of the LM3431 via diodes D2, D3, D6 and D7. The larger of the LED string voltages, i.e., the more negative one of the collector voltages of either Q2 or Q4, is used by the LM3431 to...
adjust the output voltage of the boost converter to a value that is just high enough for both LED strings to pass the right current, but no higher, in order to minimize the power dissipated in the transistors.

Each transistor Q2 or Q4 is configured as a linear voltage regulator with a fixed emitter voltage. The current through the diodes string connected to Q2 is given by Eq. 3.

The current through the LED string connected to Q4 follows the same equation, but with R13 replaced by R8. With only very minor modifications to the components this board is capable of driving LED strings at significantly higher currents.

If there is a fault and the LED strings open, the resistors R19 and R20 limit the output voltage to a safe value that is set to be slightly greater than the highest normal operating voltage.

The LM3431’s datasheet gives a complete description of all of the IC’s functions.

The LM3431 supports either digital or analog dimming of the LEDs via the DIM pin. The present design uses analog dimming which is selected by connecting the mode pin to ground through a capacitor C5. An analog signal is applied to the DIM pin to cause the current through the LEDs to be PWM controlled at a frequency that is low relative to the switching frequency. The dimming PWM frequency, can be set to be as high as 25kHz, and is set by C5 according to Eq. 4.

It is recommended to use a dimming frequency in the 100-200Hz range. The duty ratio of the dimming signal increases proportionally from 0 to 100% as the analog voltage increases from 0.4V to 2.5V.

It is desirable for the brightness of the LEDs to be proportional to ambient light conditions so that the display is not too bright in dark conditions and is easy to view under bright light. A photodiode circuit comprising D10, op-amp U2 and associated components is used to implement this. If diode D4 is used the output voltage of this circuit appearing at pin 1 of U2 is exponentially proportional to the light intensity sensed by D10. If D4 is omitted and some of the resistors are re-sized, then U2A becomes a voltage follower and the output voltage of the circuit is simply directly proportional to the light intensity. A circuit comprising D5, R9, R11 and R14 applies an offset voltage to the dimming pin so that even if there is no ambient light the display retains a minimum brightness level.

The following equations can be used to calculate component values in the dimming circuit.

The output voltage of the photodiode amplifier appearing at pin 7 of U2 is given by Eq. 5.

For the linear version of the dimming circuit (with D4 omitted) the output voltage at pin 1 is also equal to that at pin 7.

For the exponential version the voltage at pin 1 is given by Eq. 6. The exponential term in the expression for the diode current in Eq. 6 is typically much greater than unity, so that the equation reduces to Eq. 7. This equation is nearly exponential if R24 is made large so that the voltage across it is much greater than that across D4. The fraction of the voltage at pin 1 of voltage that appears at the DIM pin of the LM3431 is given by Eq. 8.

The offset voltage that ensures that some light is produced by the LED even when no light impinges on the photodiode is related to the breakdown voltage of zener diode D5 by Eq. 9.

The total voltage at the DIM pin of U1 is the sum of the voltages in equations 8 and 9 and is given by Eq. 10. The quantities in Eq. 10 can be adjusted to give the desired dimming behavior.

### 10.0 Test Results

— Figure 4 shows the currents in the two LED strings at maximum brightness. The currents are continuous at 30 mA. The trace is the drain-source voltage of Q1, and the bottom two traces are the currents in the two LED strings.

— Figure 5 shows the LED strings’ currents when dimmed at a frequency of 200Hz to a duty ratio of about 20%. This condition corresponds to the minimum duty ratio for the LEDs when the photodiode is in the dark.

— Figure 6 shows the LED strings’ currents at a duty ratio of 50%.
11.0 Waveforms

FIGURE 4. LED currents with no dimming and maximum ambient light
FIGURE 5. Fully dimmed LED currents with no ambient light
FIGURE 6. Half dimmed LED currents

12.0 Appendix
Equations

\[ V_{OUT} = \frac{V_{IN}}{1-D} \]  
Eq. 1

\[ D \] is the duty ratio of Q1.

\[ V_{IN}DT = (V_{OUT} - V_{IN})(1-D)T \]  
Eq. 2

\[ I_{LED} = \frac{V_{REF}}{R_{3}} = \frac{V_{REF}R_{5}}{(R_{2} + R_{3})R_{3}} \]  
Eq. 3

\[ V_{REF} = 2.5V \] and \[ V_{REF} \] are respectively the voltages at the REF and REFIN pins of the LM3431.

\[ f_{DMW} = \frac{40\mu}{4.26}\]  
Eq. 4

\[ V_p = I_pR_{23} \]  
Eq. 5

where \[ I_p \] is the photodiode current.

\[ V'_4 = V_{D4} + i_{D4}R_{44} = V_{D4} + R_{34}I_{D4} \approx V_{D4} + R_{34}I_{D4} \left( \frac{V_{D4}}{e^{\frac{V_{D4}}{kT}} - 1} \right) \]  
Eq. 6

where \[ V_{D4} \] and \[ I_{D4} = I_{D4} \left( \frac{V_{D4}}{e^{\frac{V_{D4}}{kT}} - 1} \right) \] are respectively the voltage across and the current in D4, and \[ I_{D4} \] is the diode’s saturation current.

\[ V'_4 = V_{D4} + R_{34}I_{D4} \left( \frac{V_{D4}}{e^{\frac{V_{D4}}{kT}} - 1} \right) \]  
Eq. 7.

\[ V_{DUMP} = \frac{V_{R_{23}}}{R_{11} + R_{24}} \]  
Eq. 8

\[ V_{out} = \frac{V_{out} + R_{14}}{R_{11} + R_{24}} \]  
Eq. 9

FIGURE 7. Equations
National Semiconductor’s design tools attempt to recreate the performance of a substantially equivalent physical implementation of the design. Reference designs are created using National’s published specifications as well as the published specifications of other device manufacturers. While National does update this information periodically, this information may not be current at the time the reference design is built. National and/or its licensors do not warrant the accuracy or completeness of the specifications or any information contained therein. National and/or its licensors do not warrant that any designs or recommended parts will meet the specifications you entered, will be suitable for your application or fit for any particular purpose, or will operate as shown in the simulation in a physical implementation. National and/or its licensors do not warrant that the designs are production worthy. You should completely validate and test your design implementation to confirm the system functionality for your application.

National does not assume any responsibility for use of any circuitry described, no circuit patent licenses are implied and National reserves the right at any time without notice to change said circuitry and specifications.

For the most current product information visit us at www.national.com.

LIFE SUPPORT POLICY
NATIONAL’S PRODUCTS ARE NOT AUTHORIZED FOR USE AS CRITICAL COMPONENTS IN LIFE SUPPORT DEVICES OR SYSTEMS WITHOUT THE EXPRESS WRITTEN APPROVAL OF THE PRESIDENT AND GENERAL COUNSEL OF NATIONAL SEMICONDUCTOR CORPORATION. As used herein:

1. Life support devices or systems are devices or systems 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.

2. A critical component is any component of 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.

BANNED SUBSTANCE COMPLIANCE
National Semiconductor certifies that the products and packing materials meet the provisions of the Customer Products Stewardship Specification (CSP-9-111C2) and the Banned Substances and Materials of Interest Specification (CSP-9-111S2) and contain no “Banned Substances” as defined in CSP-9-111S2.

Leadfree products are RoHS compliant.
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 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 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 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 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 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 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.

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

**Products**  |  **Applications**
--- | ---
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

**Automotive and Transportation** | www.ti.com/automotive
**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
**Video and Imaging** | www.ti.com/video

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265
Copyright © 2012, Texas Instruments Incorporated