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**LED Lighting Reference Design Cookbook**

**Helping You Solve Your Lighting Design Challenges**

The LED Lighting Reference Design Cookbook is designed to provide you with a valuable tool to help you solve your lighting design needs. Customers seeking the latest in innovative and affordable LED lighting solutions can benefit from TI's broad product portfolio of AC/DC, DC/DC, LED drivers, power management devices, wireless and wired interface control and embedded processors.

Designers have the option of not only controlling the power stage, but regulating LED currents as well, eliminating the need for multiple components and reducing system cost. Systems can be designed to accurately control voltage and current regulation for precise light intensity and color mixing, temperature monitoring to prevent thermal runaway, intelligent/adaptive dimming, and fault detection (over voltage/current, blown string). Communication with external systems is also possible via power-line communication (PLC), wireless technology or interfaces.

LED lighting designers are challenged with meeting their efficiency and reliability goals faster in advanced lighting designs. TI's lighting portfolio is helping designers achieve their goals at a faster rate.

To see the TI solutions for general lighting, signage, backlighting and automotive, all complimented by a comprehensive customer support network, visit: www.ti.com/led

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**TI has Solutions for Your Lighting Challenges:**

- Precision channel-to-channel and chip-to-chip accuracy to create the best hue and luminance in your RGB message boards and video displays
- Controllers to power and dim high brightness white or RGB LEDs for architectural luminaries and portable lighting
- Powering arrays of HB LEDs off an AC source for use in street lighting and replacing high-intensity discharge (HID) lamps
- Highly integrated ZigBee® transceivers and SoC solutions for wireless lighting control and home automation
LED Lighting Overview

TI is a global market leader that leverages a rich history in Lighting expertise, combines it with analog and embedded processing portfolios, and delivers all of the building blocks for complete system solutions. Choose TI for broadest expertise, breadth of selection, and comprehensive support for efficient, reliable, cost-effective power conversion, communication and smart sensing and control solutions.

www.ti.com/led
**Product Overview**

**AC/DC Analog LED Drivers**

<table>
<thead>
<tr>
<th>Device</th>
<th>Description</th>
<th>Type</th>
<th>Applications</th>
<th>Output Power (W)</th>
<th>PFC</th>
</tr>
</thead>
<tbody>
<tr>
<td>TPS92070</td>
<td>Dimmable AC/DC LED Lighting Driver Controller</td>
<td>AC/DC</td>
<td>Retrofit Bulbs Luminaire</td>
<td>3 to 12</td>
<td>&gt;0.7</td>
</tr>
<tr>
<td>TPS92010</td>
<td>High-Efficiency, Offline LED Lighting Controller</td>
<td>AC/DC</td>
<td>Retrofit Bulbs Luminaire</td>
<td>3 to 12</td>
<td>&gt;0.55</td>
</tr>
<tr>
<td>TPS92001/2</td>
<td>General Purpose LED Lighting PWM Controller</td>
<td>AC/DC</td>
<td>Retrofit Bulbs Luminaire</td>
<td>5 to 20</td>
<td>&gt;0.8</td>
</tr>
<tr>
<td>TPS92210</td>
<td>Natural PFC LED Lighting Driver Controller</td>
<td>AC/DC</td>
<td>Retrofit Bulbs Luminaire</td>
<td>5 to 30</td>
<td>&gt;0.9</td>
</tr>
<tr>
<td>UCC28810/1</td>
<td>LED Lighting Power Controller</td>
<td>AC/DC</td>
<td>Retrofit Bulbs Luminaire</td>
<td>15 to 100</td>
<td>&gt;0.9</td>
</tr>
<tr>
<td>TPS92020</td>
<td>Resonant-Switching Driver Controller for LED Lighting</td>
<td>DC/DC</td>
<td>High-Light Output</td>
<td>80</td>
<td>—</td>
</tr>
</tbody>
</table>

New products are listed in **bold red**. Preview products are listed in **bold blue**.

**Selection Guide**

<table>
<thead>
<tr>
<th>Device</th>
<th>VIN (min) (V)</th>
<th>VIN (max) (V)</th>
<th>LED Voltage (max) (V)</th>
<th>Switching Frequency (kHz)</th>
<th>DC/DC or AC/DC Control</th>
<th>Isolated Applications</th>
<th>Non-Isolated Applications</th>
<th>Topology</th>
<th>LED Configuration</th>
<th>Dimming</th>
<th>PFC</th>
<th>EVM</th>
<th>Package(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>TPS61165</td>
<td>3</td>
<td>18</td>
<td>38</td>
<td>1,200</td>
<td>DC/DC</td>
<td>—</td>
<td>✓</td>
<td>Boost</td>
<td>Series/Parallel</td>
<td>PWM</td>
<td>—</td>
<td>✓</td>
<td>6 SON 6 SOT-23</td>
</tr>
<tr>
<td>TPS61166</td>
<td>2.5</td>
<td>10</td>
<td>17</td>
<td>1,200</td>
<td>DC/DC</td>
<td>—</td>
<td>✓</td>
<td>Boost</td>
<td>Series/Parallel</td>
<td>PWM</td>
<td>—</td>
<td>✓</td>
<td>10 SON</td>
</tr>
<tr>
<td>TPS61195</td>
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<td>21</td>
<td>45</td>
<td>1,000</td>
<td>DC/DC</td>
<td>—</td>
<td>✓</td>
<td>Boost</td>
<td>Series/Parallel</td>
<td>PWM</td>
<td>—</td>
<td>✓</td>
<td>28 WQFN</td>
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<tr>
<td>TPS61500</td>
<td>2.9</td>
<td>18</td>
<td>38</td>
<td>2,200</td>
<td>DC/DC</td>
<td>—</td>
<td>✓</td>
<td>Boost</td>
<td>Series/Parallel</td>
<td>PWM or PWM-to-Analog</td>
<td>—</td>
<td>✓</td>
<td>—</td>
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<tr>
<td>TPS92510</td>
<td>3.5</td>
<td>60</td>
<td>57</td>
<td>2,500</td>
<td>DC/DC</td>
<td>—</td>
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<td>Buck</td>
<td>Series/Parallel</td>
<td>PWM</td>
<td>—</td>
<td>✓</td>
<td>10 MSOP</td>
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<tr>
<td>TPS40211</td>
<td>4.5</td>
<td>52</td>
<td>52</td>
<td>1,000</td>
<td>DC/DC</td>
<td>—</td>
<td>✓</td>
<td>Boost/SEPIC</td>
<td>Series/Parallel</td>
<td>PWM/Analog</td>
<td>—</td>
<td>✓</td>
<td>—</td>
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<tr>
<td>TPS92001</td>
<td>9</td>
<td>19</td>
<td>Configurable</td>
<td>100</td>
<td>AC/DC</td>
<td>✓</td>
<td>✓</td>
<td>Flyback/Buck</td>
<td>Series/Parallel</td>
<td>TRIAC</td>
<td>✓</td>
<td>—</td>
<td>8 MSOP 8 SOIC</td>
</tr>
<tr>
<td>TPS92002</td>
<td>14</td>
<td>19</td>
<td>Configurable</td>
<td>100</td>
<td>AC/DC</td>
<td>✓</td>
<td>✓</td>
<td>Flyback</td>
<td>Series/Parallel</td>
<td>TRIAC</td>
<td>✓</td>
<td>—</td>
<td>8 MSOP 8 SOIC</td>
</tr>
<tr>
<td>TPS92010</td>
<td>6.3</td>
<td>21</td>
<td>Configurable</td>
<td>130</td>
<td>AC/DC</td>
<td>✓</td>
<td>✓</td>
<td>Flyback</td>
<td>Series/Parallel</td>
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<td>—</td>
<td>✓</td>
<td>8 SOIC</td>
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<tr>
<td>TPS92020</td>
<td>11.5</td>
<td>18</td>
<td>Configurable</td>
<td>350</td>
<td>DC/DC</td>
<td>✓</td>
<td>✓</td>
<td>Flyback</td>
<td>Series/Parallel</td>
<td>Multi-String</td>
<td>PWM</td>
<td>—</td>
<td>8 SOIC</td>
</tr>
<tr>
<td>TPS92070</td>
<td>9</td>
<td>21.5</td>
<td>Configurable</td>
<td>146</td>
<td>AC/DC</td>
<td>✓</td>
<td>✓</td>
<td>Flyback</td>
<td>Series/Parallel</td>
<td>TRIAC</td>
<td>✓</td>
<td>✓</td>
<td>16 TSSOP</td>
</tr>
<tr>
<td>TPS92210</td>
<td>9</td>
<td>20</td>
<td>Configurable</td>
<td>140</td>
<td>AC/DC</td>
<td>✓</td>
<td>✓</td>
<td>Flyback</td>
<td>Series/Parallel</td>
<td>TRIAC</td>
<td>✓</td>
<td>✓</td>
<td>8 SOIC</td>
</tr>
<tr>
<td>UCC28810</td>
<td>15.4</td>
<td>18</td>
<td>Configurable</td>
<td>140</td>
<td>AC/DC</td>
<td>✓</td>
<td>✓</td>
<td>Flyback</td>
<td>Series/Parallel</td>
<td>TRIAC</td>
<td>✓</td>
<td>✓</td>
<td>8 SOIC</td>
</tr>
<tr>
<td>UCC28811</td>
<td>12</td>
<td>18</td>
<td>Configurable</td>
<td>140</td>
<td>AC/DC</td>
<td>✓</td>
<td>✓</td>
<td>Flyback</td>
<td>Series/Parallel</td>
<td>PWM/Analog</td>
<td>✓</td>
<td>✓</td>
<td>8 SOIC</td>
</tr>
</tbody>
</table>

New products are listed in **bold red**. Preview products are listed in **bold blue**.

**Wireless Communications**

TI’s new CC2530 is a true system-on-chip solution tailored for IEEE 802.15.4, ZigBee®, ZigBee RF4CE and Smart Energy applications. With its high operating temperature of up to 125° C, the CC2530 is ideal for Lighting applications.

<table>
<thead>
<tr>
<th>Product</th>
<th>Description</th>
<th>Operating Temperature</th>
<th>Protocol</th>
</tr>
</thead>
<tbody>
<tr>
<td>CC2530</td>
<td>Second Generation System-on-Chip Solution for 2.4 GHz</td>
<td>125° C</td>
<td>IEEE 802.15.4/ZigBee</td>
</tr>
</tbody>
</table>
**Microcontroller (MCU) for Advanced Lighting Solutions**

TI's MCU lighting solutions give designers efficient, flexible and scalable intelligent lighting management and control. TI's portfolio of MCU hardware and software platforms speeds design and development enabling designers to adopt advanced communications and features such as power line communications or 6loWPAN to control lighting designs. In addition, using a digital approach for functionality such as digital power, communications/control, and motion or ambient light sensing can move hardware features into software which increases flexibility.

To get started with TI's broad suite of MCU solutions for your LED and other lighting design and control needs visit below for our demonstration platforms and development kits. Or click the direct links to learn specifically about intelligent lighting and communications control or digitally powered lighting.

<table>
<thead>
<tr>
<th>MCU</th>
<th>Benefits</th>
<th>Applications</th>
</tr>
</thead>
</table>
| MSP430™16-Bit Ultra-Low Power MCUs | • Ultra-low power consumption  
• Integrated intelligent peripherals  
• Ease of use | • Wireless Communications/Control  
(ZigBee, 6loWPAN, 802.15.4, SimpliciTI™, etc.)  
• Wired Communications/Control (DALI, DMX-512, KNX, etc.) |
| C2000™ 32-Bit Real-Time MCUs | • 32-bit performance for real-time control  
• Lower system cost  
• Ease of use  
• Packaging and price for cost sensitive applications | • Digital Power  
• Power line Communications |
| Stellaris® ARM® Cortex™-M3-Based MCUs | • ARM® Cortex™-M3  
• Advanced | • Ethernet Control  
• Wired Communications/Control (DALI, DMX-512, etc.) |

**Digital Power Based on Microcontroller Solutions**

TI provides designers with a portfolio of controllers to solve any lighting digital power system design challenge. Whether designing for isolated or non-isolated solutions from AC/DC to DC/DC, TI’s flexible, customizable and intuitive portfolio enables a variety of solution.

**Intelligent Lighting/Communications and Control**

Intelligent lighting is the ability to reduce the amount of light and/or energy used so that only the right amount of light is delivered exactly when and where it is needed. Digital control of LEDs using MCUs allows developers to take advantage of the unique characteristics of LEDs, such as long life, high dimming ratio, energy efficiency and vibration resistance, and to quickly and easily deliver intelligent lighting solutions. Digital control can be achieved via wired or wireless communications through a number of different communication standards. Texas Instruments offers microcontroller solutions for all your LED lighting design and control needs, including demonstration platforms and development kits.

<table>
<thead>
<tr>
<th>Solutions/Protocol</th>
<th>Product</th>
<th>Tool/Kit/Demo/Platform</th>
<th>For more information:</th>
</tr>
</thead>
<tbody>
<tr>
<td>DALI</td>
<td>MSP430™ MCU</td>
<td>TPS62660 LED-338 EVM</td>
<td>For DALI app note: <a href="http://www.ti.com/dalippnote">www.ti.com/dalippnote</a></td>
</tr>
<tr>
<td>DMX-512</td>
<td>MSP430 MCU / Stellaris®</td>
<td>DMX-512 apps note/Third-party design</td>
<td>MSP430 - Demo code and reference design is available upon request at Technical Support.</td>
</tr>
<tr>
<td>Power Line Communication</td>
<td>C2000™ MCUs</td>
<td>TMDSPLCKIT - V2</td>
<td>Stellaris - Available through third-party Golden IC Technology Co., Ltd. - <a href="mailto:support@golden-ic.com">support@golden-ic.com</a></td>
</tr>
<tr>
<td>ZigBee®/802.15.4</td>
<td>MSP430F54xxA</td>
<td>MSP430F5438 Experimenter's Board</td>
<td><a href="http://www.ti.com/plc">www.ti.com/plc</a></td>
</tr>
</tbody>
</table>
| KNX/KNX-RF         | MSP430 | N/A | www.ti.com/msp430f5438  
Available through 3rd parties; for more information visit:  
TAPKO Technologies GmbH  
Weinzierl Engineering GmbH |
| 6loWPAN            | CC2430(MSP430 MCU + Low-Power RRF) | Third-party design | Available through third-party Sensinode. |
| Ethernet           | Stellaris® | Ethernet development and evaluation kits | www.ti.com/stellariskits |
| General-use MCU(user interface, system supervisor, etc.) | MSP430 MCU | Development and evaluation kits | www.ti.com/msp430 |
Retrofit Lighting - A19/E27

**TPS92001 PMP5163G – Offline, 10-W Dimmable LED Driver**

PMP5163G is a non-isolated, inverted buck LED driver with small form factor suitable for A19/E27 and designs with 9 LEDs at an operating current of 310 mA.

**Design Specifications**

<table>
<thead>
<tr>
<th>Topology (Converter Type)</th>
<th>AC</th>
<th>DC</th>
<th>LED Configuration</th>
<th>Series</th>
<th>Number of LEDs (Typ)</th>
<th>Number of LED Strings (Typ)</th>
<th>Input Voltage Range (Vin) (Typ)</th>
<th>Output Voltage Range (Vout) (Typ)</th>
<th>Typ Power Output (W)</th>
<th>Peak Efficiency (%)</th>
<th>PFC</th>
<th>Isolated/Non-Isolated</th>
<th>Dimmable</th>
<th>Dimming Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inverted Buck</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>90 V to 132 V</td>
<td>29 V to 31 V</td>
<td>94%</td>
<td>0.86</td>
<td>Non-Isolated</td>
<td>Yes</td>
<td>TRIAC</td>
</tr>
</tbody>
</table>

**Efficiency**

![Efficiency Graph]

**Power Factor**

![Power Factor Graph]

**LED Current**

![LED Current Graph]

**PMP5163G Board**

![PMP5163G Board Image]

For more reference designs, see: [www.ti.com/powerreferencedesigns](http://www.ti.com/powerreferencedesigns)

Web Links

Datasheets, user’s guides, samples:

- [www.ti.com/tool/PMP5163](http://www.ti.com/tool/PMP5163)
For more reference designs, see: www.ti.com/powerreferencedesigns
TPS92001 PMP6648C – Offline, Dimmable 10-W LED Driver

PMP6648C a non-isolated, boost LED driver with small form factor suitable for A19/E27 and E26/27 designs with 3 high voltage LEDs at an operating current of 34 mA.

Design Specifications

<table>
<thead>
<tr>
<th>Topology</th>
<th>Converter Type</th>
<th>LED Configuration</th>
<th>Number of LEDs per String (typ)</th>
<th>Number of LED Strings (typ)</th>
<th>Input Voltage Range (min)</th>
<th>Output Voltage Range (typ)</th>
<th>Output Current (typ)</th>
<th>Typ Power Output (W)</th>
<th>Peak Efficiency (%)</th>
<th>PFC</th>
<th>Isolated/Non-Isolated</th>
<th>Dimmable</th>
<th>Dimming Input</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boost AC</td>
<td>AC Series</td>
<td>3</td>
<td>1</td>
<td>108</td>
<td>120</td>
<td>132</td>
<td>300</td>
<td>34 mA</td>
<td>&gt;90</td>
<td>&gt;0.9</td>
<td>Non-Isolated</td>
<td>Yes</td>
<td>TRAC</td>
</tr>
</tbody>
</table>

Web Links
Datasheets, user’s guides, samples:
www.ti.com/tool/PMP6648
www.ti.com/product/TPS92001

For more reference designs, see: www.ti.com/powerreferencedesigns
Output Voltage and Current

For more reference designs, see: www.ti.com/powerreferencedesigns
TPS92210 PMP4304A – Offline, High Power Factor, TRIAC Dimmable 7-W LED Driver

PMP4304A is an isolated primary-side control PFC flyback LED driver with small form factor and low component count for PAR and BR LED lighting applications.

### Design Specifications

<table>
<thead>
<tr>
<th>Topology</th>
<th>Converter Type</th>
<th>LED Configuration</th>
<th>Number of LEDs per String (typ)</th>
<th>Number of LED Strings (typ)</th>
<th>Input Voltage Range (min)</th>
<th>Output Voltage Range (typ)</th>
<th>Output Current (typ)</th>
<th>Typ Power Output (W)</th>
<th>Peak Efficiency (%)</th>
<th>PFC</th>
<th>Isolated/Non-Isolated</th>
<th>Dimmable</th>
<th>Dimming Input</th>
</tr>
</thead>
<tbody>
<tr>
<td>PFC Flyback</td>
<td>AC</td>
<td>Series</td>
<td>6</td>
<td>1</td>
<td>160</td>
<td>220</td>
<td>264</td>
<td>20</td>
<td>300 mA</td>
<td>81</td>
<td>83</td>
<td>&gt;0.9</td>
<td>Isolated</td>
</tr>
</tbody>
</table>

**Power Factor vs. Input Line**
PMP4304 6-LED Driver without Dimmer

**Efficiency vs. Input Line**
PMP4304 6-LED Driver without Dimmer

**Output Current vs. Input Line**
PMP4304 6-LED Driver without Dimmer

**LED Current vs. Dimmer Conduction Angle**
PMP4304 6-LED Driver with Clipsal Dimmer

For more reference designs, see: [www.ti.com/powerreferencedesigns](http://www.ti.com/powerreferencedesigns)

TPS4304A Board
TPS92010 PMP3522
The PMP3522 is a reference design that utilizes the TPS92010 high efficiency LED lighting driver controller.

Residential downlighting has seen a great deal of transition to more efficient sources of light. Compact CFLs have become a mainstay in residential lighting, but as the lifetime cost of LED lamps falls, all the more low-power, small-form-factor designs will be needed. This reference design is an under-10-W, non-isolated SEPIC LED driver specifically laid out for residential downlighting.

Key Features
• Single-stage SEPIC, PFC + LED current regulation
• Low-cost, low-component count
• Drives 3 to 6 LEDs at 350 mA

Web Links
Datasets, user’s guides, samples:
www.ti.com/tool/PMP3522
www.ti.com/product/TPS92010

Design Specifications

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Minimum</th>
<th>Typical</th>
<th>Maximum</th>
<th>Unit</th>
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<tbody>
<tr>
<td>Input voltage</td>
<td>120</td>
<td>—</td>
<td>290</td>
<td>V_{AC}</td>
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<tr>
<td>Output voltage</td>
<td>—</td>
<td>—</td>
<td>24</td>
<td>Volts</td>
</tr>
<tr>
<td>Output current</td>
<td>—</td>
<td>0.350</td>
<td>—</td>
<td>Amp</td>
</tr>
</tbody>
</table>

PMP3522 Schematic

For more reference designs, see: www.ti.com/powerreferencedesigns
**Reference Designs**

**Retrofit Lighting - PAR30/38**

### Laid Out for Bulb Replacement

![Diagram showing lay out for bulb replacement](image)

### Control Loop Frequency

![Graph showing control loop frequency](image)

### Regulation

![Graph showing regulation](image)

### Efficiency

![Graph showing efficiency](image)

For more reference designs, see: [www.ti.com/powerreferencedesigns](http://www.ti.com/powerreferencedesigns)
TPS92210 PMP6304 – Offline, High Power Factor, TRIAC Dimmable
10-W LED Driver

PMP6304 is an isolated PFC flyback LED driver with low component count for PAR and BR LED lighting applications.

Web Links
Datasheets, user’s guides, samples:
www.ti.com/tool/PMP6304
www.ti.com/product/TPS92210

Design Specifications

<table>
<thead>
<tr>
<th>Topology</th>
<th>Converter Type</th>
<th>LED Configuration</th>
<th>Number of LEDs per String (typ)</th>
<th>Number of LED Strings (typ)</th>
<th>Input Voltage Range (V)</th>
<th>Output Voltage Range (V)</th>
<th>Output Current (mA)</th>
<th>Typ Power Output (W)</th>
<th>Peak Efficiency (%)</th>
<th>PFC</th>
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<th>Dimming Input</th>
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<tbody>
<tr>
<td>PFC Flyback</td>
<td>AC Series</td>
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<td>176 220 264</td>
<td>30 350 mA</td>
<td>10 82 &gt;-0.9</td>
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<td>Yes</td>
<td>TRIAC</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PFC Flyback</td>
<td>AC Series</td>
<td>9 1</td>
<td>88 110 132</td>
<td>30 350 mA</td>
<td>10 81 &gt;-0.9</td>
<td>Isolated</td>
<td>Yes</td>
<td>TRIAC</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Low Line Output Current

Low Line Power Factor

Low Line Total Harmonic Distortion

Low Line Efficiency

High Line Output Current

High Line Power Factor

High Line Total Harmonic Distortion

High Line Efficiency
TPS92210 PMP6001 – Offline, High Power Factor, Non-Dimmable 13-W LED Driver

PMP6001 is an isolated PFC flyback LED driver with minimal component count for PAR and BR LED lighting applications.

**Design Specifications**

<table>
<thead>
<tr>
<th>Topology</th>
<th>Converter Type</th>
<th>LED Configuration</th>
<th>Number of LEDs per String (typ)</th>
<th>Number of LED Strings (typ)</th>
<th>Input Voltage Range</th>
<th>Output Voltage Range (typ)</th>
<th>Output Current (typ)</th>
<th>Typ Power (W)</th>
<th>Peak Efficiency (%)</th>
<th>PFC</th>
<th>Isolated/Non-Isolated</th>
<th>Dimmable</th>
<th>Dimming Input</th>
</tr>
</thead>
<tbody>
<tr>
<td>PFC Flyback</td>
<td>AC</td>
<td>Series</td>
<td>11</td>
<td>1</td>
<td>90 — —</td>
<td>265</td>
<td>—</td>
<td>38</td>
<td>350 mA</td>
<td></td>
<td>Yes</td>
<td></td>
<td>TRiAC</td>
</tr>
</tbody>
</table>

**Web Links**

Datasheets, user’s guides, samples:
www.ti.com/tool/PMP6001
www.ti.com/product/TPS92210

**Efficiency vs. Input Voltage**

![Efficiency vs. Input Voltage Graph](image)

**Power Factor vs. Input Voltage**

![Power Factor vs. Input Voltage Graph](image)

**Total Harmonic Distortion vs. Input Voltage**

![Total Harmonic Distortion vs. Input Voltage Graph](image)

**Output Current vs. Input Voltage**

![Output Current vs. Input Voltage Graph](image)
For more reference designs, see: www.ti.com/powerreferencedesigns
UCC28810 PMP5682A - Offline, PMW Dimmable High Efficiency, 25-W LED Tube Driver

The PMP5682A has been designed to replace a T8 fluorescent tube. It accepts the high line input (184 V to 265 VAC) and supplies two strings in parallel, 104 LEDs max per string; each string has a nominal current of 40 mA. The first stage performs the PFC function while the second stage delivers a 80 mA constant dimmable current. High efficiency and particular shape of the PCB make this design suitable for the tube replacement.

Design Specifications

<table>
<thead>
<tr>
<th>Topology</th>
<th>Converter Type</th>
<th>LED Configuration</th>
<th>Number of LEDs per String (typ)</th>
<th>Number of LED Strings (typ)</th>
<th>Input Voltage Range</th>
<th>Output Voltage Range (typ)</th>
<th>Output Current (typ)</th>
<th>Typ Power Output (W)</th>
<th>Peak Efficiency (%)</th>
<th>PFC</th>
<th>Isolated/Non-Isolated</th>
<th>Dimmable</th>
<th>Dimming Input</th>
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<tbody>
<tr>
<td>TM Boost +</td>
<td>AC</td>
<td>Series/Parallel</td>
<td>104</td>
<td>2</td>
<td>184 - 265</td>
<td>30 - 350 mA</td>
<td>10</td>
<td>91</td>
<td>&lt;0.9</td>
<td>Non-Isolated</td>
<td>Yes</td>
<td>PWM</td>
<td></td>
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<tr>
<td>TM Buck</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
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</tr>
</tbody>
</table>

**Web Links**

Datasheets, user’s guides, samples:
www.ti.com/tool/PMP5682
www.ti.com/product/UCC28810
Reference Designs

Retrofit Lighting - T8

Efficiency

Power Factor

- Efficiency vs % of Dimming PWM
  - 230Vac
  - 184Vac
  - 265Vac

- Power Factor vs % of Dimming PWM
  - 230Vac
  - 184Vac
  - 265Vac

Warning High Voltage FromBoost

312 V @ 80 mA
2 Strings of 104 LEDs, 2 x 40 mA

UCC28810D
Fsw = 130 KHz

Output: 450 V @ 73 mA

Built Using PMP5623 PWB
Ref. Des. >99 Were Added On the Board

AC Line Connections
Input: 184 to 265 VAC

TP1
TP2
TP3

PWM Dimming

U3
VSENSE VDD
EAOUT GDRV
VINS GND
VSENSE TZE
Fsw = 130 KHz

TP4
TP5
TP6
TP7
TP8

LED+ Out
LED– Out

Texas Instruments  4Q 2011
LED Lighting Reference Design Cookbook
Retrofit Lighting - T8

TPS92210 PMP3672 - Offline, PFC Buck 18-W to 20-W LED Tube Driver

The PMP3672 has been designed to replace a T8 fluorescent tube. It accepts universal line input (90 V to 265 VAC) and supplies 720 mA LED current.

Web Links
Datasheets, user’s guides, samples:
www.ti.com/tool/PMP3672
www.ti.com/product/TPS92210

Design Specifications

<table>
<thead>
<tr>
<th>Topology</th>
<th>Converter Type</th>
<th>AC or DC</th>
<th>LED Configuration</th>
<th>Number of LEDs per String (typ)</th>
<th>Number of LED Strings (typ)</th>
<th>Input Voltage Range (V)</th>
<th>Output Voltage Range (typ)</th>
<th>Output Current (typ)</th>
<th>Typ Power Output (W)</th>
<th>Peak Efficiency (%)</th>
<th>PFC</th>
<th>Isolated/Non-Isolated</th>
<th>Dimmable</th>
<th>Dimming Input</th>
</tr>
</thead>
<tbody>
<tr>
<td>PFC Buck</td>
<td>AC</td>
<td>Series/Parallel</td>
<td>8</td>
<td></td>
<td></td>
<td>90</td>
<td>265</td>
<td>24</td>
<td>720 mA</td>
<td></td>
<td></td>
<td>Non-Isolated</td>
<td>No</td>
<td>—</td>
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</table>
TPS92210 PMP6306 - Offline, High Power Factor, Isolated 18-W Tube LED Driver

PMP6306 is an isolated PFC flyback LED driver for LED tube lighting applications. It accepts universal line inputs and supplies 450 mA at up to 40 V.

Design Specifications

<table>
<thead>
<tr>
<th>Topology</th>
<th>Converter Type</th>
<th>AC or DC</th>
<th>LED Configuration</th>
<th>Number of LEDs per String (typ)</th>
<th>Number of LED Strings (typ)</th>
<th>Input Voltage Range</th>
<th>Output Voltage Range (typ)</th>
<th>Output Current (typ)</th>
<th>Typ Power Output (W)</th>
<th>Peak Efficiency (%)</th>
<th>PFC</th>
<th>Isolated/Non-Isolated</th>
<th>Dimmable</th>
<th>Dimming Input</th>
</tr>
</thead>
<tbody>
<tr>
<td>PFC Flyback</td>
<td>AC</td>
<td>Series</td>
<td>12</td>
<td>1</td>
<td>90 —</td>
<td>265</td>
<td>40</td>
<td>450 mA</td>
<td>18</td>
<td>86 &gt;0.85</td>
<td>Isolated</td>
<td>No</td>
<td>—</td>
<td></td>
</tr>
</tbody>
</table>

Web Links
Datasheets, user's guides, samples:
www.ti.com/tool/PMP6306
www.ti.com/product/TPS92210

For more reference designs, see: www.ti.com/powerreferencedesigns
For more reference designs, see: www.ti.com/powerreferencedesigns
TPS40211 PMP6300 – MR-16 Boost
PMP6300 is a boost based MR-16 solution designed to operate with 1 to 3 LEDs at 700 mA.

Design Specifications

<table>
<thead>
<tr>
<th>Topology</th>
<th>Converter Type</th>
<th>LED Configuration</th>
<th>Number of LEDs per String (typ)</th>
<th>Number of LED Strings (typ)</th>
<th>Input Voltage Range</th>
<th>Output Voltage Range (typ)</th>
<th>Output Current (typ)</th>
<th>Typ Power Output (W)</th>
<th>Peak Efficiency (%)</th>
<th>PFC</th>
<th>Isolated/Non-Isolated</th>
<th>Dimmable</th>
<th>Dimming Input</th>
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<tbody>
<tr>
<td>Boost</td>
<td>AC or DC</td>
<td>Series</td>
<td>3</td>
<td>1</td>
<td>8 – 15</td>
<td>10 mV</td>
<td>700 mA</td>
<td>7</td>
<td>71</td>
<td></td>
<td>Non-Isolated</td>
<td>Yes</td>
<td>TRiAC</td>
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</tbody>
</table>

Web Links
Datasheets, user's guides, samples:
www.ti.com/tool/PMP6300
www.ti.com/product/TPS40211

12 V<sub>DC</sub> Efficiency

12 V<sub>AC</sub> Efficiency

12 V<sub>DC</sub> Output Current Accuracy

12 V<sub>AC</sub> Output Current Accuracy

12 V<sub>AC</sub> Power Factor

PMP6300 Board
Reference Designs

Retrofit Lighting - MR-16

For more reference designs, see: www.ti.com/powerreferencedesigns
Retrofit Lighting - MR-16

TPS54260 PMP6004 – MR-16 Buck Reference Design

PMP6004 is a buck based MR-16 solution designed to operate with 1 to 2 LEDs at 1000 mA.

### Design Specifications

<table>
<thead>
<tr>
<th>Topology</th>
<th>Converter Type</th>
<th>LED Configuration</th>
<th>Number of LEDs per String (typ)</th>
<th>Number of LED Strings (typ)</th>
<th>Input Voltage Range</th>
<th>Output Voltage Range (typ)</th>
<th>Output Current (typ)</th>
<th>Typ Power Output (W)</th>
<th>Peak Efficiency (%)</th>
<th>PFC</th>
<th>Isolated/Non-Isolated</th>
<th>Dimmable</th>
<th>Dimming Input</th>
</tr>
</thead>
<tbody>
<tr>
<td>Buck</td>
<td>AC or DC</td>
<td>Series</td>
<td>1</td>
<td>1</td>
<td>8</td>
<td>5.7</td>
<td>1,000 mA</td>
<td>6</td>
<td>80</td>
<td>&gt;0.95</td>
<td>Non-Isolated</td>
<td>Yes</td>
<td>TRAC</td>
</tr>
</tbody>
</table>

**Web Links**

Datasheets, user's guides, samples:
- [www.ti.com/tool/PMP6004](http://www.ti.com/tool/PMP6004)

**For more reference designs, see:** [www.ti.com/powerreferencedesigns](http://www.ti.com/powerreferencedesigns)
PowerLab™ Power Reference Design Library

- The industry’s most extensive collection of tested power management reference designs.

- Hundreds of power management designs for a wide range of applications and power conversion topologies.

- Reference designs include both isolated and non-isolated designs for lighting, telecommunication, computing, consumer electronics and more.

www.ti.com/powerlab

The PowerLab™ library includes an interactive and powerful search engine for design engineers looking for a proven and tested solution to their power supply requirements. This interactive search tool allows engineers to find designs by application, topology, input type, input voltage or output voltage.

www.ti.com/powerlab
## LED Driver/Ballast

### TPS92210 PMP6305 – Offline, High Power Factor, Isolated 25-W LED Driver

PMP6305 is an isolated PFC flyback LED driver for LED tube lighting applications. It accepts universal line inputs and supplies 450 mA at up to 40 V.

#### Design Specifications

<table>
<thead>
<tr>
<th>Topology</th>
<th>Converter Type</th>
<th>LED Configuration</th>
<th>Number of LEDs per String (typ)</th>
<th>Number of LED Strings (typ)</th>
<th>Input Voltage Range (min)</th>
<th>Output Voltage Range (typ)</th>
<th>Output Current (typ)</th>
<th>Typ Power Output (W)</th>
<th>Peak Efficiency (%)</th>
<th>PFC</th>
<th>Isolated/Non-Isolated</th>
<th>Dimmable</th>
<th>Dimming Input</th>
</tr>
</thead>
<tbody>
<tr>
<td>PFC Flyback</td>
<td>AC Series</td>
<td>10</td>
<td>1</td>
<td>176</td>
<td>220</td>
<td>284</td>
<td>35</td>
<td>700 mA</td>
<td>25</td>
<td>83</td>
<td>&gt;0.9</td>
<td>Yes</td>
<td>TRIAC</td>
</tr>
<tr>
<td>PFC Flyback</td>
<td>AC Series</td>
<td>10</td>
<td>1</td>
<td>88</td>
<td>110</td>
<td>132</td>
<td>35</td>
<td>700 mA</td>
<td>25</td>
<td>84</td>
<td>&gt;0.9</td>
<td>Yes</td>
<td>TRIAC</td>
</tr>
</tbody>
</table>

#### Web Links

Datasheets, user’s guides, samples:
- www.ti.com/tool/PMP6305
- www.ti.com/product/TPS92210

#### Graphs

- Low Line Output Current
- Low Line Power Factor
- Low Line Total Harmonic Distortion
- Low Line Efficiency
- High Line Output Current
- High Line Power Factor
- High Line Total Harmonic Distortion
- High Line Efficiency
UCC28810 PMP5732B – Offline, High Power Factor, Isolated 50-W LED Driver

PMP5732B is an isolated PFC flyback LED driver for LED ballast/power supply applications. It accepts universal line inputs (85 to 305 V) and supplies 1.5 A at up to 40 V.

Design Specifications

<table>
<thead>
<tr>
<th>Topology</th>
<th>Converter Type</th>
<th>LED Configuration</th>
<th>Number of LEDs per String (%)</th>
<th>Number of LED Strings (%)</th>
<th>Input Voltage Range</th>
<th>Output Voltage Range (V)</th>
<th>Output Current (mA)</th>
<th>Typ Power Output (W)</th>
<th>Peak Efficiency (%)</th>
<th>Power Factor</th>
<th>Isolated/Non-Isolated</th>
<th>Dimmable</th>
<th>Dimming Input</th>
</tr>
</thead>
<tbody>
<tr>
<td>PFC Flyback</td>
<td>AC Series</td>
<td>10</td>
<td>1</td>
<td>85</td>
<td>—</td>
<td>36</td>
<td>1,500 mA</td>
<td>50</td>
<td>83</td>
<td>&gt;0.9</td>
<td>Yes</td>
<td>Yes</td>
<td>Analog</td>
</tr>
</tbody>
</table>

Efficiency

The efficiency is shown in the graph below. For simplicity and accuracy of measurements, the data was measured using a DC input with a resistive load.

Output Current Regulation

Power Factor

Load = LEDs (V_{OUT} = 33 V, I_{OUT} = 1.5 A)

For more reference designs, see: www.ti.com/powerreferencedesigns
For more reference designs, see: www.ti.com/powerreferencedesigns
UCC28810 PMP4501 - Offline, 34-W LED Driver with PFC
The PMP4501 is an isolated, off-line, AC-to-DC LED-current driver with PFC for applications such as commercial fixture lighting and general isolated LED drivers. The PMP4501 is a single-stage flyback PFC converter that delivers up to 34 W with a 180- to 265-VAC input voltage while providing a 10- to 48-V output voltage at a constant output current of 700 mA ±2%.

The PMP4501 implements secondary-side current control for the LED string. Overvoltage protection prevents dangerous output voltages from occurring during open-string conditions. A current-sense amplifier reduces the sensing resistor’s power dissipation, thus increasing overall efficiency. The internal reference voltage of the operational amplifier achieves excellent LED-current regulation versus output power and input voltage. The PMP4501 achieves high efficiency (90% peak), high power density and a high power factor. The reference design protects against scenarios with open and short LED strings, and the control stage is a simple and robust design.

**Key Features**
- Isolated single stage LED driver
- Naturally high PFC
- 90% efficient
- Universal input voltage range
- 700-mA output current
- Low LED ripple current

**Web Links**
Datasheets, user’s guides, samples:  
www.ti.com/tool/PMP4501  
www.ti.com/product/UCC28810

---

**Design Specifications**

<table>
<thead>
<tr>
<th>Description</th>
<th>Parts</th>
<th>VIN (AC) Range</th>
<th>VOUT (DC) Range</th>
<th>Number of LEDs</th>
<th>IOUT (max)</th>
<th>POUT (max)</th>
<th>Eff.</th>
<th>PFC</th>
<th>ISO</th>
<th>Dimming In</th>
<th>Dimming Out</th>
<th>EVM</th>
</tr>
</thead>
<tbody>
<tr>
<td>UCC28810 34-W PMP4501 Secondary side current loop</td>
<td>UCC28810</td>
<td>180</td>
<td>10 V</td>
<td>3-13</td>
<td>700 mA</td>
<td>34 W</td>
<td>90%</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>UCC28810 34-W PMP4501 Secondary side current loop</td>
<td>TL103W</td>
<td>265</td>
<td>48.5 V</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

---

**PMP4501 Reference Design Schematic**
PMP4501 Board

Efficiency vs. Rectified-Equivalent Line Voltage and Output Power

Output Current Ripple. Input Voltage = 230 VAC, Output Voltage = 48 V @ 700 mA

Power Factor vs. Line Voltage and Output Power

AC Input Current and Voltage at Full Load and Nominal Input Voltage
Reference Designs

LED Streetlight

UCC28810 PMP3976 - 100-W, Offline PFC SEPIC LED Driver

The PMP3976 circuit shown below was designed for a commercial LED lighting fixture. The SEPIC topology has the advantage over a flyback converter in that it clamps the switching waveforms on the power semiconductor, allowing the use of lower voltage and hence more efficient parts. This provides an estimated 2% improvement in efficiency in this application. Additionally, there is less ringing in the SEPIC, making EMI filtering easier.

Key Features
- Non-isolated single LED string driver
- 92% efficient solution
- SEPIC control boosts for high voltage
- Natural single stage with >0.9 PFC
- Low-cost solution with few external parts
- Meets European harmonic requirements

Web Links
Datasets, user’s guides, samples: www.ti.com/tool/PMP3976
www.ti.com/product/UCC28810

Reference designs: www.ti.com/powerreferencedesigns

For more reference designs, see: www.ti.com/powerreferencedesigns

PMP3976 Schematic

150VAC to 240VAC Input

Design Specifications

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Minimum</th>
<th>Typical</th>
<th>Maximum</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Input voltage</td>
<td>150</td>
<td>—</td>
<td>264</td>
<td>VAC</td>
</tr>
<tr>
<td>Output voltage</td>
<td>—</td>
<td>—</td>
<td>300</td>
<td>Volts</td>
</tr>
<tr>
<td>Output current</td>
<td>—</td>
<td>0.350</td>
<td>—</td>
<td>Amp</td>
</tr>
</tbody>
</table>

For more reference designs, see: www.ti.com/powerreferencedesigns
The circuit is built on a PMP3976 Rev A PWB.
Reference Designs

LED Streetlight

The image above shows a thermal image of the board. The ambient temperature was 26ºC with no forced air flow. The input was 230 VAC.

Efficiency and Power Factor

<table>
<thead>
<tr>
<th>IOUT</th>
<th>VOUT</th>
<th>VIN</th>
<th>L_IN</th>
<th>PF</th>
<th>POUT</th>
<th>Losses</th>
<th>Efficiency %</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.349</td>
<td>245.5</td>
<td>150.4</td>
<td>0.646</td>
<td>0.983</td>
<td>85.65</td>
<td>9.827</td>
<td>89.7</td>
</tr>
<tr>
<td>0.349</td>
<td>245.4</td>
<td>176.4</td>
<td>0.544</td>
<td>0.980</td>
<td>85.64</td>
<td>8.398</td>
<td>91.1</td>
</tr>
<tr>
<td>0.349</td>
<td>245.3</td>
<td>202.6</td>
<td>0.473</td>
<td>0.979</td>
<td>85.61</td>
<td>8.208</td>
<td>91.3</td>
</tr>
<tr>
<td>0.350</td>
<td>245.3</td>
<td>226.3</td>
<td>0.430</td>
<td>0.975</td>
<td>85.86</td>
<td>9.201</td>
<td>90.5</td>
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<tr>
<td>0.350</td>
<td>245.3</td>
<td>248.4</td>
<td>0.399</td>
<td>0.969</td>
<td>85.86</td>
<td>10.184</td>
<td>89.4</td>
</tr>
</tbody>
</table>

Harmonic Content

The harmonic content and the EN61000-3-2 Class C (lighting equipments) Limits are shown above; input voltage was set to 230 VAC.

<table>
<thead>
<tr>
<th>IOUT</th>
<th>VOUT</th>
<th>VIN</th>
<th>L_IN</th>
<th>PF</th>
<th>POUT</th>
<th>Losses</th>
<th>Efficiency %</th>
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</thead>
<tbody>
<tr>
<td>0.348</td>
<td>303.9</td>
<td>149.9</td>
<td>0.803</td>
<td>0.988</td>
<td>105.75</td>
<td>13.168</td>
<td>88.9</td>
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<tr>
<td>0.349</td>
<td>303.3</td>
<td>175.2</td>
<td>0.677</td>
<td>0.983</td>
<td>105.85</td>
<td>10.742</td>
<td>90.8</td>
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<tr>
<td>0.349</td>
<td>303.8</td>
<td>199.9</td>
<td>0.588</td>
<td>0.984</td>
<td>106.03</td>
<td>9.634</td>
<td>91.7</td>
</tr>
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<td>0.349</td>
<td>303.3</td>
<td>224.8</td>
<td>0.527</td>
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<td>105.85</td>
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<td>90.9</td>
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<td>303.2</td>
<td>249.8</td>
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<td>0.978</td>
<td>105.82</td>
<td>11.338</td>
<td>89.9</td>
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<td>0.349</td>
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<td>264.2</td>
<td>0.461</td>
<td>0.975</td>
<td>105.75</td>
<td>13.004</td>
<td>89.0</td>
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</tbody>
</table>
The frequency response of the feedback loop is shown in the plot above. The input was set to 220 V_{AC}. The lower gain plot was taken with a 300 V output. The upper gain plot was taken with a 250 V output.

The image above shows the drain-to-source voltage on Q3. The input was set to 250.

The image above shows the input voltage and current. The input voltage was 230 V_{AC}.

The image above shows the voltage on the anode of D1. The input was set to 250 V_{DC}.

The two images above show the currents in the individual windings of the inductor.
DC LED Lighting

TPS40211 PMP4026
The circuit shown below was designed with an automotive input-voltage range. The driver was built to operate under low-power to nominal battery conditions and to survive load-dump incidents. The application, powered directly from $V_{BAT}$, can have a string of up to ten 700-mA LEDs in series or two parallel strings with up to ten 350-mA LEDs in each string.

An additional reference design is available. This design is a 700-mA, nonsynchronous boost current regulator for an LED driver. It has an 8- to 18-V input and a 20- to 35-V output.

Key Features
- Wide 4.5- to 52-V input range
- Low-cost non-synchronous boost
- High efficiency from low 260-mV $V_{REF}$
- Simple loop compensation
- Supports versatile SEPIC topology

Web Links
Datasheets, user’s guides, samples:
www.ti.com/tool/PMP4026
www.ti.com/product/TPS40211

It can be found along with a demonstration board at:
http://focus.ti.com/docs/toolsw/folders/print/tps40211evm-352.html

Design Specifications

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Minimum</th>
<th>Typical</th>
<th>Maximum</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Input voltage</td>
<td>9</td>
<td>—</td>
<td>16</td>
<td>V$_{DC}$</td>
</tr>
<tr>
<td>Output voltage</td>
<td>—</td>
<td>—</td>
<td>40</td>
<td>Volts</td>
</tr>
<tr>
<td>Output current</td>
<td>—</td>
<td>0.700</td>
<td>—</td>
<td>Amp</td>
</tr>
<tr>
<td>Switching frequency</td>
<td>—</td>
<td>150</td>
<td>—</td>
<td>kHz</td>
</tr>
</tbody>
</table>

PMP4026 Schematic

For more reference designs, see: www.ti.com/powerreferencedesigns
The input voltage was set at 12 V, with 0.15 (LED) + 1 (resistor) A load on the outputs.

Total output current was 1.15 A, output voltage was 20 volts.

Output response to driving TP%. The input voltage was set to 12 V.
**TPS40211 PMP3943 - Wide-Input DC Voltage SEPIC Driver**

The TPS40211 is a wide-input-voltage (4.5- to 52-V) nonsynchronous boost controller. It is suitable for topologies that require a grounded source n-channel FET such as boost, flyback, SEPIC and various LED-driver applications. The TPS40211 features a programmable soft start; overcurrent protection with automatic retry; and a programmable oscillator frequency. Current-mode control provides improved transient response and simplified loop compensation. The feedback pin has a reference voltage of 260 mV to help reduce the power usage and cost of the sense resistor.

The PMP3943 circuit shown below was designed with an automotive input-voltage range. The driver was built to operate under low-power battery conditions and to survive load-dump incidents. The TPS40211 was chosen for this application due to its low feedback voltage and wide input-voltage range.

An additional reference design is available. This design is a 700-mA, nonsynchronous boost current regulator for an LED driver. It has an 8-to 18-V input and a 20- to 35-V output.

### Key Features
- Wide 4.5- to 52-V input range
- Low-cost non-synchronous boost
- High efficiency from low 260-mV $V_{REF}$
- Simple loop compensation
- Supports versatile SEPIC topology

### Web Links
Datasets, user’s guides, samples:
- [www.ti.com/tool/PMP3943](http://www.ti.com/tool/PMP3943)

It can be found along with a demonstration board at:

### Design Specifications

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Minimum</th>
<th>Typical</th>
<th>Maximum</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Input voltage</td>
<td>8</td>
<td>—</td>
<td>40</td>
<td>Volts</td>
</tr>
<tr>
<td>Output voltage</td>
<td>—</td>
<td>13</td>
<td>—</td>
<td>Volts</td>
</tr>
<tr>
<td>Output current</td>
<td>—</td>
<td>0.350</td>
<td>—</td>
<td>Amp</td>
</tr>
<tr>
<td>Switching frequency</td>
<td>—</td>
<td>300</td>
<td>—</td>
<td>kHz</td>
</tr>
</tbody>
</table>

### PMP3943 Schematic

For more reference designs, see: [www.ti.com/powerreferencedesigns](http://www.ti.com/powerreferencedesigns)
Current Loop Frequency Response

3 Green and 1 Red OSRAM LEDs Used as Load for Vf About 12 V

<table>
<thead>
<tr>
<th>V_IN Volts</th>
<th>I_IN mA</th>
<th>V_OUT1 Volts</th>
<th>I_OUT1 mA</th>
<th>Efficiency %</th>
</tr>
</thead>
<tbody>
<tr>
<td>40.22</td>
<td>123.6</td>
<td>12.27</td>
<td>341.8</td>
<td>84.4</td>
</tr>
<tr>
<td>20.11</td>
<td>238.5</td>
<td>12.27</td>
<td>341.3</td>
<td>87.3</td>
</tr>
<tr>
<td>7.93</td>
<td>619.4</td>
<td>12.27</td>
<td>341.3</td>
<td>85.3</td>
</tr>
</tbody>
</table>

Regulation and efficiency: 25 degrees Celsius ambient. Target I_OUT1 was 350 mA, hence actual current is 2.5% low.

When Diode Load is Opened, V_OUT Goes to About 18 V

<table>
<thead>
<tr>
<th>V_IN Volts</th>
<th>I_IN mA</th>
<th>V_OUT1 Volts</th>
<th>I_OUT1 mA</th>
</tr>
</thead>
<tbody>
<tr>
<td>40.42</td>
<td>8.79</td>
<td>18.44</td>
<td>0</td>
</tr>
<tr>
<td>20.08</td>
<td>10.75</td>
<td>18.41</td>
<td>0</td>
</tr>
<tr>
<td>8.00</td>
<td>19.12</td>
<td>18.40</td>
<td>0</td>
</tr>
</tbody>
</table>

Short Circuit: Output Current Holds Steady

<table>
<thead>
<tr>
<th>V_IN Volts</th>
<th>I_IN mA</th>
<th>V_OUT1 Volts</th>
<th>I_OUT1 mA</th>
</tr>
</thead>
<tbody>
<tr>
<td>40.14</td>
<td>21.24</td>
<td>0.694</td>
<td>341.6</td>
</tr>
<tr>
<td>20.06</td>
<td>34.20</td>
<td>0.694</td>
<td>341.5</td>
</tr>
<tr>
<td>8.00</td>
<td>77.70</td>
<td>0.694</td>
<td>341.4</td>
</tr>
</tbody>
</table>

For more reference designs, see: www.ti.com/powerreferencedesigns
Reference Designs

Low Voltage Buck Boost for LED Torch

TPS63000 PMP3038
The TPS63000 provides a power-supply solution for products that use a two- or three-cell alkaline, NiCd or NiMH battery, or a one-cell Li-Ion or Li-Polymer battery. The buck-boost converter is based on a fixed-frequency PWM controller that uses synchronous rectification to obtain maximum efficiency. The maximum average current in the switches is limited to a typical value of 1800 mA, and the converter can be disabled to minimize battery drain. During shutdown, the load is disconnected from the battery. The device is packaged in a 10-pin QFN PowerPAD™ (DRC) package measuring 3 x 3-mm.

The PMP3038 circuit was designed for a torch or rugged flashlight. Most torch applications still use alkaline batteries with a common configuration of two or three cells in series that have a maximum voltage of 5 V. During operation, the $V_{BAT}$ drops below the $V_f$ of the LED, and the TPS63000 automatically switches from buck mode to boost mode to create the constant current needed for the LED. The TPS63000 can boost from voltages as low as 1.2 V. A switch that brings R4 into or out of the feedback loop provides a dimming mechanism for the flashlight to toggle between 300 and 600 mA.

Key Features
- Buck-boost converter topology
- Ideal for battery applications
- 1.8-A output capability
- Auto buck-boost mode switching
- Dual LED brightness levels
- Operates down to 1.2 V

Web Links
Datasheets, user’s guides, samples:
www.ti.com/tool/PMP3038
www.ti.com/product/TPS63000

Design Specifications

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Minimum</th>
<th>Maximum</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Input voltage</td>
<td>1.2</td>
<td>5</td>
<td>VDC</td>
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<tr>
<td>Output voltage</td>
<td>—</td>
<td>5</td>
<td>Volts</td>
</tr>
<tr>
<td>Output current</td>
<td>300</td>
<td>600</td>
<td>mAmp</td>
</tr>
<tr>
<td>Switch frequency</td>
<td>—</td>
<td>1.5</td>
<td>MHz</td>
</tr>
</tbody>
</table>

PMP3038 Schematic

For more reference designs, see: www.ti.com/powerreferencedesigns
Output Current Graphs with DC Coupling

Output current with $V_N = 3\, V$.

Output current with $V_N = 4\, V$.

Efficiency Curve for $I_O = 0.32\, A$ and $I_O = 0.62\, A$

![Efficiency curve graph](image)

Control Loop Response Graphs

Control loop response with 0.63 A.

Control loop response with 0.32 A.

Turn On with 0.63 A

Efficiency.
TPS61500
The TPS61500 is a monolithic switching regulator with an integrated 3-A, 40-V power switch. It is an ideal driver for high-brightness 1- or 3-W LEDs. The device has a wide input-voltage range to support applications with input voltage from multiscell batteries or regulated 5-V to 12-V power rails.

The LED current is set with an external sense resistor, R3, and with feedback voltage that is regulated to 200 mV by a current-mode PWM control loop, as shown in the schematic below. The device supports analog and pure PWM dimming methods for LED brightness control. Connecting a capacitor to the DIMC pin configures the device to be used for analog dimming, and the LED current varies in proportion to the duty cycle of an external PWM signal. Floating the DIMC pin configures the IC for pure PWM dimming, with the average LED current being the PWM signal's duty cycle times a set LED current.

The device features a programmable soft-start function to limit inrush current during start-up and has other protection features built in, such as pulse-by-pulse overcurrent limiting, overvoltage protection and thermal shutdown. The TPS61500 is available in a 14-pin HTSSOP package with PowerPAD™.

Key Features
- Supports boost topology
- Integrated 3-A 40-V power switch
- Supports PWM or AM dimming
- Protection features:
  - Pulse by pulse
  - Thermal shutdown

Web Links
Datasets, user's guides, samples:
www.ti.com/tool/TPS61500evm-369
www.ti.com/product/TPS61500

LED Current vs. Input Supply and LED Number

<table>
<thead>
<tr>
<th>Input Supply</th>
<th>5 V</th>
<th>12 V</th>
</tr>
</thead>
<tbody>
<tr>
<td>LED number 4</td>
<td>1000 mA</td>
<td>2000 mA</td>
</tr>
<tr>
<td>LED number 6</td>
<td>600 mA</td>
<td>1200 mA</td>
</tr>
<tr>
<td>LED number 8</td>
<td>450 mA</td>
<td>1000 mA</td>
</tr>
</tbody>
</table>

Note: Assumption that LED forward voltage is 3.5V, and TPS61500's conversion efficiency is 85%.

Typical Application Schematic

For more reference designs, see: www.ti.com/powerreferencedesigns
Efficiency vs. Output Current

PWM Dimming Application Circuit: Circuit for the TPS61500 to Perform Analog Dimming Using an Injected Analog Signal

Analog Dimming by External DAC: Pure PWM Dimming Method
TRIAC Dimmable LED Lighting

TPS92010EVM
This design uses the TPS92010 8-pin, high-efficiency off-line LED lighting controller. This controller incorporates many features, such as frequency fold-back and a low-power mode, to implement a low-cost, high-efficiency flyback converter.

An application of this converter is retrofitting light bulbs with LEDs. The converter can drive 3 to 5 high-brightness LEDs in series with a constant current of 0.35 A.

The flyback topology is chosen because it allows a lower component count and lower cost than other topologies. LED current is sensed directly to ensure its tight regulation. A special circuit for compatibility with TRIAC dimmers adjusts the output current linearly, avoiding any stroboscopic effects or audible noise that might otherwise occur. The TPS92011 is designed for low-power lighting applications that do not require power-factor correction.

Key Features
- AC/DC TRIAC dimmable LED reference design
- Ideal for residential lighting
- 3- to 12-W applications

Output Current Regulation

Adjusting the Output Current

<table>
<thead>
<tr>
<th>Output Current (A)</th>
<th>R15 (Ω)</th>
<th>R17 (Ω)</th>
<th>R1 (Ω)</th>
<th>R42 (Ω)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.20</td>
<td>1,000</td>
<td>150</td>
<td>330</td>
<td>1,000</td>
</tr>
<tr>
<td>0.225</td>
<td>1,200</td>
<td>86</td>
<td>390</td>
<td>1,000</td>
</tr>
<tr>
<td>0.25</td>
<td>1,200</td>
<td>220</td>
<td>470</td>
<td>1,000</td>
</tr>
<tr>
<td>0.275</td>
<td>1,000</td>
<td>560</td>
<td>680</td>
<td>680</td>
</tr>
<tr>
<td>0.30</td>
<td>1,500</td>
<td>220</td>
<td>680</td>
<td>680</td>
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<tr>
<td>0.325</td>
<td>1,500</td>
<td>330</td>
<td>470</td>
<td>1,500</td>
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<td>0.35</td>
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<td>0.40</td>
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<td>0.45</td>
<td>2,200</td>
<td>390</td>
<td>1,500</td>
<td>1,000</td>
</tr>
<tr>
<td>0.50</td>
<td>2,700</td>
<td>220</td>
<td>1,500</td>
<td>1,000</td>
</tr>
<tr>
<td>0.60</td>
<td>3,300</td>
<td>150</td>
<td>1,500</td>
<td>1,500</td>
</tr>
<tr>
<td>0.70</td>
<td>3,900</td>
<td>270</td>
<td>2,200</td>
<td>1,500</td>
</tr>
</tbody>
</table>

Efficiency without Dimmer

Efficiency with Dimmer

Dimming Performance

Web Links
Datasets, user’s guides, samples:
www.ti.com/tool/TPS92010evm-592
www.ti.com/tool/TPS92010evm-631
www.ti.com/product/TPS92010
**TPS92210EVM**

The TPS92210EVM is a natural power-factor-correction (PFC) LED lighting driver controller with advanced energy features to provide high-efficiency control for LED lighting applications. The TPS92210EVM is capable of providing a high power factor, TRIAC dimming, load protection and extended life in a small space at low cost.

The TPS92210EVM employs quasi constant “on” time that enables single-stage PFC in an isolated flyback configuration. Intended for low-power lighting applications, it can be packaged in a variety of ways, including individual lamp designs and generic PCB form factors for many types of lighting. The driver preserves dimmer holding current and features dual-slope output control to improve dimming linearity when used with common TRIAC-based phase-control dimmers. The TPS92210 controller is programmed to operate at a fixed frequency with a constant “on” time for the internal switch that drives the primary power FET.

**Key Features**
- AC/DC TRIAC dimmable LED driver with PFC
- Ideal for residential lighting
- Single stage (PFC and LED current regulation)
- 12- to 25-W applications
- Deep TRIAC dimming capability

**Web Links**
- [www.ti.com/tool/TPS92210evm-613](http://www.ti.com/tool/TPS92210evm-613)

---

**TPS92210EVM Block Diagram**

**Table: Description of TPS92210EVM Models**

<table>
<thead>
<tr>
<th>Description</th>
<th>Parts</th>
<th>$V_{in}$ Range</th>
<th>$V_{out}$ (DC) Range</th>
<th>Number of LEDs</th>
<th>$I_{out}$ (max)</th>
<th>$P_{out}$ (max)</th>
<th>Eff.</th>
<th>PFC</th>
<th>ISO</th>
<th>Dimming In</th>
<th>Dimming Out</th>
</tr>
</thead>
<tbody>
<tr>
<td>TPS92210EVM-613</td>
<td>TPS92210</td>
<td>184</td>
<td>265</td>
<td>30 to 36</td>
<td>9 to 10</td>
<td>350 mA</td>
<td>12</td>
<td>87</td>
<td>Yes</td>
<td>Yes</td>
<td>TRIAC</td>
</tr>
<tr>
<td>TPS92210EVM-647</td>
<td>TPS92210</td>
<td>85</td>
<td>144</td>
<td>19 to 32</td>
<td>6 to 10</td>
<td>350 mA</td>
<td>12</td>
<td>85</td>
<td>Yes</td>
<td>Yes</td>
<td>TRIAC</td>
</tr>
</tbody>
</table>

For more reference designs, see: [www.ti.com/powerreferencedesigns](http://www.ti.com/powerreferencedesigns)
Efficiency

![Efficiency Graph]

Load Regulation

![Load Regulation Graph]

Line Regulation

![Line Regulation Graph]

Bode Plot

![Bode Plot Graph]

Power Factor

![Power Factor Graph]

TRIAC Dimmer Performance

![TRIAC Dimmer Performance Graph]
100-Watt, Constant-Current, Non-Isolated Driver with PFC

UCC28810/UCC28810-EVM-002

The UCC28810EVM-002 evaluation module (EVM) is a constant-current non-isolated power supply for LED lighting applications that require high brightness, such as street, parking or area lighting. The reference design converts the universal mains (90 to 265 V<sub>RMS</sub>) to a 0.9-A constant-current source to drive a 100-W LED load.

The UCC28810EVM-002 is a two-stage design. The first stage, a transition-mode circuit with PFC, ensures that the design meets various standards such as the EN61000-3-2. The PFC circuit converts the AC input to a regulated DC voltage, which can be configured as a boost-follower PFC or a fixed output voltage. The boost-follower PFC tracks the AC input’s peak voltage for increased efficiency at low-line operation. The PFC’s DC output voltage is then regulated to a fixed value in the region of 396 V<sub>DC</sub>. The second stage of the design also uses transition mode but is configured as a buck converter. It converts the PFC output voltage to a fixed 0.9-A current to drive an LED load. The second stage accepts PWM dimming inputs (either externally or from an onboard circuit) and appropriately toggles itself on or off.

Key Features
- High-power AC/DC LED driver with PFC
- Ideal for street, parking or area lighting
- Universal-input, non-isolated design
- Tightly regulated LED current
- PWM dimming, 200 Hz to 1 kHz
- High efficiency through dimming
- Active power-factor correction

Web Links
Datasets, user’s guides, samples:
www.ti.com/tool/UCC28810evm-002
www.ti.com/product/UCC28810

Design Specifications

<table>
<thead>
<tr>
<th>Description</th>
<th>Parts</th>
<th>V&lt;sub&gt;IN&lt;/sub&gt;(AC) Range</th>
<th>V&lt;sub&gt;OUT&lt;/sub&gt;(DC) Range</th>
<th>Number of LEDs</th>
<th>I&lt;sub&gt;OUT&lt;/sub&gt;(max)</th>
<th>P&lt;sub&gt;OUT&lt;/sub&gt;(max)</th>
<th>Eff.</th>
<th>PFC</th>
<th>ISO</th>
<th>Dimming In</th>
<th>Dimming Out</th>
<th>EVM</th>
</tr>
</thead>
<tbody>
<tr>
<td>UCC28810 EVM002 100-W</td>
<td>UCC28810</td>
<td>90</td>
<td>55</td>
<td>15 to 30</td>
<td>900 mA</td>
<td>100 W</td>
<td>93%</td>
<td>Yes</td>
<td>No</td>
<td>PWM</td>
<td>PWM</td>
<td>Yes</td>
</tr>
<tr>
<td>LED lighting driver</td>
<td>UCC28811</td>
<td>265</td>
<td>100</td>
<td>15 to 30</td>
<td>900 mA</td>
<td>100 W</td>
<td>93%</td>
<td>Yes</td>
<td>No</td>
<td>PWM</td>
<td>PWM</td>
<td>Yes</td>
</tr>
</tbody>
</table>

UCC28810EVM-002 Block Diagram

For more reference designs, see: www.ti.com/powerreferencedesigns
Efficiency and Power Factor vs. Line Voltage

UCC28810EVM-002 efficiency and power factor vs. line voltage 30 Cree XRE LED's at 900 mA.

PWM Dimming Waveforms

UCC28810EVM-002 transition mode buck PWM response, Ch1: Buck VIN, Ch2: Buck VDS, Ch3: LED current (0.5 A/Div), Ch4: LED voltage. Ch1 and Ch4 share GND reference.

THD Factor vs. Line Voltage

UCC28810EVM-002 THD vs. line voltage 30 Cree XRE LED's at 900 mA.

PWM Dimming Response

UCC28810EVM-002 transition mode buck PWM response (expanded). Ch1: LED VDS, Ch2 PWM, Ch3 buck inductor current 500 mA/Div, Ch4 VDS Ch1 and Ch4 Share GND reference.

Line Regulation 30 LEDs at 900 mA, (98 W)

LED current regulation as a function of line voltage.
110-Watt, Constant-Current, Isolated Driver with PFC

UCC28810/UCC28810EVM-003
The UCC28810EVM-003 evaluation module (EVM) is an off-line AC-to-DC LED current driver with PFC for applications such as street, high-bay, and medium- or large-infrastructure lighting. The UCC28810EVM-003 is a three-stage converter design that delivers up to 110 W. The first stage is a universal input boost-PFC circuit providing a 305- to 400-VDC output. The second stage is a low-side buck circuit providing the controlled current source, and the third stage is a series of two half-bridge DC/DC transformers that provides isolation of multiple LED strings.

This patent-pending solution provides an easily scalable and cost-effective method of driving multiple LED strings. The UCC28810EVM-003 implements single-reference current control and universal dimming (via AM or PWM) for all LEDs. The reference design effectively drives a large number of LEDs connected in series, but the voltage on the LED strings is safe (low) and isolated from the AC line. The multistring architecture is more cost-effective than an architecture with a constant voltage plus a buck stage for each LED string. The LED-driver architecture is readily scalable to very high power levels. Excellent LED current matching between strings is achieved with this architecture. The UCC28810EVM-003 achieves high efficiency (91%), high power density and a high power factor. The control stage is a simple and robust design, and the EVM protects against scenarios with open and short LED strings.

Key Features
- SimpLEDrive™ high-power dimmable AC/DC LED driver with PFC
- Ideal for street, high-bay or infrastructure lighting
- Isolated from the AC line
- Readily scalable to higher power levels
- LED current matching between strings
- High efficiency and power density
- Active power-factor correction

Web Links
Datasets, user’s guides, samples:
www.ti.com/tool/UCC28810evm-003
www.ti.com/product/UCC28810

Design Specifications

<table>
<thead>
<tr>
<th>Description</th>
<th>Parts</th>
<th>$V_{IN}$ (AC) Range</th>
<th>$V_{OUT}$ (DC) Range</th>
<th>Number of LEDs</th>
<th>$I_{OUT}$ (max)</th>
<th>$P_{OUT}$ (max)</th>
<th>Eff.</th>
<th>PFC</th>
<th>ISO</th>
<th>Dimming In</th>
<th>Dimming Out</th>
<th>EVM</th>
</tr>
</thead>
<tbody>
<tr>
<td>UCC28810EVM003 100-W isolated multi-string LED lighting driver w/multiple transformers</td>
<td>UCC28810</td>
<td>100, 265</td>
<td>22 V, 60 V</td>
<td>4X (7 to 15)</td>
<td>500 mA</td>
<td>110 W</td>
<td>91%</td>
<td>Yes</td>
<td>Yes</td>
<td>PWM</td>
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<td>Jul-09</td>
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<td>TPS92020</td>
<td>UCC28811</td>
<td>90, 265</td>
<td>22 V, 60 V</td>
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UCC28810EVM-003 Block Diagram
Evaluation Modules/Kits

110-Watt, Constant-Current, Isolated Driver with PFC

Efficiency vs. Line Voltage

UCC28810EVM-003 efficiency vs. line voltage and load 4 x 15 Cree XRE LED’s at 500 mA.

IoUT Matching vs. Line Voltage

UCC28810EVM-003 IoUT matching vs. line voltage 4 x 15 Cree XRE LED’s at 500 mA.

Power Factor vs. Line Voltage

UCC28810EVM-003 power factor vs. line voltage 4 x 15 Cree XRE LED’s at 500 mA.

UCC28810EVM-003 AC Input Current During PWM Dimming

Ch1: V_BUCK+, Ch2: V_BUCK, Ch3: AC line current 1 A/Div, Ch4: V_BUCK - Ch1 and Ch 4 share GND reference.

Texas Instruments  4Q 2011  LED Lighting Reference Design Cookbook
Description
The TPS92070EVM-648 is designed to demonstrate the TPS92070 Dimmable Quasi-Resonant LED Lighting Controller in a typical LED driver application. The TPS92070EVM-648 uses 180 VAC to 240 VAC input to drive five high brightness LEDs with a drive current of 370 mA.

Web Links
www.ti.com/tool/TPS92070evm-648
www.ti.com/tool/TPS92070evm-682
www.ti.com/product/TPS92070

<table>
<thead>
<tr>
<th>Description</th>
<th>Parts</th>
<th>Vin Range</th>
<th>Vout (DC) Range</th>
<th>Number of LEDs</th>
<th>Iout (max)</th>
<th>Pout (max)</th>
<th>Eff.</th>
<th>PFC</th>
<th>ISO</th>
<th>Dimming In</th>
<th>Dimming Out</th>
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<tbody>
<tr>
<td>TPS92070EVM-648</td>
<td>TPS92070</td>
<td>180 to 265</td>
<td>15 to 17</td>
<td>5</td>
<td>370 mA</td>
<td>6</td>
<td>83%</td>
<td>Yes</td>
<td>Yes</td>
<td>TRIAC</td>
<td>Exponential</td>
</tr>
<tr>
<td>TPS92070EVM-682</td>
<td>TPS92070</td>
<td>85 to 144</td>
<td>Preview</td>
<td>5</td>
<td>370 mA</td>
<td>6</td>
<td>83%</td>
<td>Yes</td>
<td>Yes</td>
<td>TRIAC</td>
<td>Exponential</td>
</tr>
</tbody>
</table>
Description
The TPS40211EVM-352 evaluation module (EVM) is a fixed frequency, (300 kHz), non-synchronous boost converter providing fixed 700-mA output at 20 V to 35 V from a 8-V to 18-V input source. The EVM is designed to start up from a single supply, so no additional bias voltage is required for start-up. The module uses the TPS40211 Non-Synchronous Current Mode Control Boost Controller with integral N-channel FET driver.
TPS40211EVM-352 is designed to use a loosely regulated 12-V (8 V to 18 V) source to produce a regulated current driver at 700 mV for constant current loads such as high-brightness LEDs. TPS40211EVM-352 is designed to demonstrate the TPS40211 in a typical LED Driver for 6 to 10 LEDs while providing a number of test points to evaluate the performance of the TPS40211 in a given application. The EVM can be modified to other input voltages or output currents by changing some of the components.
Evaluation Modules/Kits

TMS320C2000™ PLC Modem Evaluation Kit

**TMDSPLCKIT-V1**

Power-line communication (PLC) is an inexpensive way to add lighting control to existing or new buildings and infrastructures without laying down new control cabling. The TMDSPLCKIT-V1 is a PLC evaluation kit based on the C2000™ series of real-time microcontrollers. It operates in both OFDM and S-FSK modulation schemes and has data rates of up to 76.8 kbps.

The kit comes with an easy-to-use GUI that makes testing the communications link intuitive and simple.

**Specifications**
- OFDM and S-FSK modulation schemes
- Data rates of up to 76.8 kbps for one phase (phase selection is provided)
- PLC system on module (SoM) with interface to host controller (I²C, SPI, SCI)
- Compatible with CENELEC EN50065 and IEC 61000-3 standards
- Operating frequency range: 24 to 94.5 kHz CENELEC A band, B band to release in 1Q10.
- Universal AC-voltage input (85 to 270 VAC)

**Web Links**
- www.ti.com/plcevm

**Datasheets, user’s guides, samples:**

---

**TMDSPLCKIT-V1 Block Diagram**

For more reference designs, see: www.ti.com/powerreferencedesigns
TMS320C2000™ PLC Modem Evaluation Kit

PLC Data Signal

50- or 60-Hz Power Line

For more reference designs, see: www.ti.com/powerreferencedesigns
Digital Addressable Lighting Interface (DALI)

DALI Implementation with the MSP430™ MCU
Intelligent lighting control can provide large efficiency gains and energy savings. The digital addressable lighting interface (DALI) standard is becoming increasingly popular for this application.

The DALI evaluation kit enables the designer to run DALI on the popular MSP430 series of microcontrollers. Software libraries and hardware reference files are provided to allow quick evaluation and development with the DALI standard.

Specifications
- Full hardware reference files, including schematics, Gerber files and BOM
- Full software libraries
- Support for the entire DALI command set, including bidirectional commands

Web Links
Application Note: www.ti.com/lit/SLAA422

MSP430-Based DALI Reference Design

For more reference designs, see: www.ti.com/powerreferencedesigns
TPS62260LED
Residential and commercial lighting can take advantage of the additive color mixing of red, green and blue LEDs. This reference design demonstrates how to remotely manage the color output of an LED lamp with a low-power wireless controller. The color is generated by three LEDs (red, green and blue). An MSP430™ ultra-low-power microcontroller controls the brightness of each LED with constant current generated by three TPS62260 buck converters, one for each LED.

The color look-up table takes the form of an array stored in the MSP430. Whenever the rotary encoder is turned, new red, green and blue values are read from the array and used to generate the three PWM output signals. Currently 252 values are stored, which can be changed if desired. A decimal value of 100 switches the LED off, and a value of 65535 produces a mark-space ratio of 100%. When the 5-V supply is applied, the design goes into a demonstration mode where the values stored in the array are read and output in sequence in an infinite loop. As soon as the rotary encoder is turned, the sequence stops and a particular fixed color value can be selected.

There is a pin header that can be used to plug in the RF board from the MSP430 Wireless Development Tool (the eZ430-RF2500), which is separately available. With this additional module, the lamp's colors can be controlled remotely via the wireless RF interface.

If a designer prefers to reprogram the MSP430, a separate MSP430 flash emulation tool can be ordered, such as the MSP-FET430UIF. More information on the eZ430-RF2500 and MSP-FET430UIF tools can be found respectively at:
http://focus.ti.com/docs/toolsw/folders/print/ez430-rf2500.html
and
http://focus.ti.com/docs/toolsw/folders/print/msp-fet430uiif.html

Key Features
• Wireless RGB color mixing
• Ultra-low-power MSP430 controller
• Wireless development tool available

Web Links
Datasets, user's guides, samples:
www.ti.com/product/TPS62260

EVM:
www.ti.com/tps62260led-338

Design Specifications

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Minimum</th>
<th>Typical</th>
<th>Maximum</th>
<th>Unit</th>
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<tbody>
<tr>
<td>Input voltage</td>
<td>4.5</td>
<td>5</td>
<td>5.5</td>
<td>VDC</td>
</tr>
<tr>
<td>Output current</td>
<td>—</td>
<td>0.300</td>
<td>—</td>
<td>Amp</td>
</tr>
</tbody>
</table>

For more reference designs, see: www.ti.com/powerreferencedesigns

TPS62260LED-338 Schematic
Wireless-Controlled Triple LED Driver

For more reference designs, see: www.ti.com/powerreferencedesigns
The Multi-DC/DC Color LED Kit includes all of the hardware and software to start experimenting and developing a digitally controlled multi-DC/DC LED lighting system. This kit is based on the Piccolo microcontroller and the controlCARD development platform. One Piccolo MCU is able to directly control eight separate DC/DC power stages as well as up to eight LED strings of various LED types and string lengths. The development board takes 12 to 24 VDC input and employs six Boost and two SEPIC DC/DC power stage topologies to drive LED strings. The six separate Boost stages drive two RGB LED strings, controlling the red, green, and blue color components of each RGB LED string. The two SEPIC stages drive two white LED strings. Alternatively, up to eight separate white LED strings could be driven via the eight separate power stages. An included graphical user interface allows users to quickly begin the evaluation process by providing simplified control to adjust power stage current levels for experimentation with brightness and color mixing. Furthermore, through controlSUITE™, the kit includes closed loop, open source software examples for the control of the DC/DC power stages and LED lighting stages. The kit hardware is also completely open source, with the gerbers, schematics, and BOMs all available for free. For more information, please see the quick start guide for the kit.

**Key Features**
- Input voltage: 12 to 24 V
- Output voltage: 24 to 50 V
- Output current: 400 mA, ±0.5% (higher currents available by changing external MOSFET)
- Digital power with Piccolo™ real-time MCU

**Web Links**
www.ti.com/tool/TMDSRGBLEDKIT
The AC input multi-string lighting kit accepts universal AC input and can control up to six LED strings. The AC input is converted to DC and then an onboard MCU converts this DC voltage to the string voltage through an isolated LLC DC/DC. The string voltage is adjustable to make it easy to use one design to cover many different requirements for string lengths, types of LEDs and number of strings. LEDs can be dimmed either through PWM to keep constant color or through the adjusting string voltage. In addition, it is a communications/control platform and has power line communications, DALI, DMX-512 and low power RF lighting control.

Key Features
- Input voltage: 85 to 277 V
- Output: 200 W, six independently dimmable strings, 28 to 36 V, 1.25 A per string
- Communications supported: Power line communications, DALI, DMX-512, low power RF
- Digital power with Piccolo real-time MCU

For more reference designs, see: www.ti.com/powerreference designs
TI's system block diagrams provide comprehensive technical resources for the development of LED Lighting application and end equipment solutions. Find block diagrams, application notes, tools and software and other related information.

Additional LED Lighting System Block Diagrams
Architectural Lighting www.ti.com/led_arch
Bulb Replacement www.ti.com/led_bulb
Down Light/Low Bay www.ti.com/led_downlight
General www.ti.com/led_gen
Multi String LED Driver www.ti.com/led_multistring
TI Worldwide Technical Support

Internet
TI Semiconductor Product Information Center
Home Page
support.ti.com

TI E2E™ Community Home Page
e2e.ti.com

Product Information Centers

**Americas**
- **Phone**: +1(972) 644-5580
- **Brazil**: Phone 0800-891-2616
- **Mexico**: Phone 0800-670-7544
  - **Fax**: +1(972) 927-6377
  - **Internet/Email**: support.ti.com/sc/pic/americas.htm

**Europe, Middle East, and Africa**
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  - **International**: +49 (0) 8161 80 2121
  - **Russian Support**: +7 (4) 95 98 10 701
  - **Fax**: +49 (0) 8161 80 2045
  - **Internet**
  - **Support**: support.ti.com/sc/pic/euro.htm
  - **Direct Email**: asktexas@ti.com

**Asia**
- **Phone**
  - **International**: +91-80-41381665
  - **Domestic**
    - **Toll-Free Number**: 0800-820-8682
    - **Fax**: +8621-23073686
    - **Email**: tiasia@ti.com or ti-china@ti.com
  - **Internet**
    - **Support**: support.ti.com/sc/pic/asia.htm

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