LED Reference Designs for the India Market

Multiple Applications for LED Lighting

www.ti.com
Helping You Solve Your Lighting-Design Challenges

This solutions guide 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 The broad product portfolio from Texas Instruments (TI) includes 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 powerline 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 complemented by a comprehensive customer support network, visit: www.ti.com/led

<table>
<thead>
<tr>
<th>AC Powered LED Drivers</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Introduction..................</td>
<td>3</td>
</tr>
<tr>
<td>PMP3599 — LED Light-Bulb-Replacement Driver (TPS92010)</td>
<td>3</td>
</tr>
<tr>
<td>PMP3649 — 5 to 9W Isolated LED Down-Light Driver (TPS92210)</td>
<td>6</td>
</tr>
<tr>
<td>PMP3661 — 12 to 35W Isolated LED Street-Light Driver (TPS92210)</td>
<td>8</td>
</tr>
<tr>
<td>PMP3672 — 18 to 20W LED Tube-Light Driver (TPS92210)</td>
<td>10</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>DC Powered LED Drivers</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Introduction..................</td>
<td>13</td>
</tr>
<tr>
<td>PMP3578 — 1W LED Lantern Driver (TPS54231)</td>
<td>13</td>
</tr>
<tr>
<td>PMP3579 — 3W LED Lantern Driver (TPS61165)</td>
<td>15</td>
</tr>
<tr>
<td>PMP3676 — 3W LED Lantern Driver Using MSP430™ Controller</td>
<td>15</td>
</tr>
<tr>
<td>PMP3543 — 18 to 45W Solar-Street-Light Driver (TPS40211)</td>
<td>17</td>
</tr>
<tr>
<td>PMP3588 — Solar-Powered Down-Lighting Driver (TPS61500)</td>
<td>18</td>
</tr>
<tr>
<td>PMP3598 — Maximum-Power-Point Tracking (MPPT) Solar Charger</td>
<td>19</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>LED Driver Controllers</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>General-Purpose LED-Lighting PWM Controller (TPS92001/2)</td>
<td>20</td>
</tr>
<tr>
<td>8-Pin, High-Efficiency, Offline LED-Lighting Controller (TPS92010)</td>
<td>20</td>
</tr>
<tr>
<td>Resonant-Switching Driver Controller for LED Lighting (TPS92020)</td>
<td>21</td>
</tr>
<tr>
<td>Natural PFC LED Lighting Driver Controller (TPS92210)</td>
<td>21</td>
</tr>
<tr>
<td>LED Lighting Power Controller (UCC28810/1)</td>
<td>22</td>
</tr>
<tr>
<td>Fixed-Frequency Current-Mode Controller for Boost, Flyback and SEPIC (TPS40211)</td>
<td>22</td>
</tr>
<tr>
<td>350mA, 90% Efficient, High-Brightness WLED Driver in 2x2 QFN and SOT-23 (TPS61156)</td>
<td>23</td>
</tr>
<tr>
<td>High-Power White-LED Driver with 3A Switch (TPS61500)</td>
<td>23</td>
</tr>
<tr>
<td>3.5 to 28V Input 2-A DC/DC Converters (TPS54231, TPS54233)</td>
<td>24</td>
</tr>
<tr>
<td>Solar MPPT Charger Supports High Charging Current and Multi-Cell Standalone Applications (bq24650)</td>
<td>24</td>
</tr>
<tr>
<td>Multi-Cell Standalone Charger Supports MPPT Solar Solutions (bq24650)</td>
<td>25</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Evaluation Modules (EVMs)</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>High-Intensity, Light-Output Drivers with PFC + Buck + Multiple LED Strings</td>
<td>26</td>
</tr>
<tr>
<td>110W Multiple-String LED Driver with Universal Line Input and PFC (UCC28810EVM-003 EVM)</td>
<td>26</td>
</tr>
<tr>
<td>230VAC TRIAC-Dimmable Light-Bulb Replacement (TPS92010 EVM)</td>
<td>27</td>
</tr>
<tr>
<td>230VAC TRIAC-Dimmable Light-Bulb Replacement with Natural PFC (TPS92210 EVM)</td>
<td>27</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Resources</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequently Asked Questions</td>
<td>28</td>
</tr>
<tr>
<td>TI Worldwide Technical Support</td>
<td>28</td>
</tr>
</tbody>
</table>
AC Powered LED Solutions

<table>
<thead>
<tr>
<th>Product Application</th>
<th>PMP Number</th>
<th>Isolation</th>
<th>Input</th>
<th>LED Configuration</th>
<th>LED Current</th>
<th>Number of LEDs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Light-Bulb Replacement LED Driver</td>
<td>PMP3599</td>
<td>N</td>
<td>80 to 270VAC</td>
<td>Series</td>
<td>350mA</td>
<td>Design supports 3 to 7 LEDs (isolated version is also available)</td>
</tr>
<tr>
<td>LED Down-Light Driver</td>
<td>PMP3649</td>
<td>Y</td>
<td>90 to 270VAC</td>
<td>Series</td>
<td>350mA</td>
<td>Design supports 6 to 12 LEDs</td>
</tr>
<tr>
<td>LED Street-Light Driver</td>
<td>PMP3661</td>
<td>Y</td>
<td>90 to 270VAC</td>
<td>Series</td>
<td>350mA</td>
<td>Design supports 15 to 30 LEDs</td>
</tr>
<tr>
<td>LED Tube-Light Driver</td>
<td>PMP3672</td>
<td>N</td>
<td>120 to 280VAC</td>
<td>Parallel (8S24P)</td>
<td>30mA</td>
<td>Design supports 192 to 224 LEDs</td>
</tr>
</tbody>
</table>

Note: All drivers are of single-stage design and with PF correction (including 3W driver)

Other Information

1. These drivers can be used for different LED configurations by maintaining the total power
2. There are more than 100s of different designs covering various combinations
3. Available high power designs are 100 to 120W (isolated, 1 stage, 4 channel with a PF of 0.97 and efficiency > 86%) and 180W (isolated, 3 stage, 4 channel with a PF of 0.99 and efficiency of >89%)
4. Apart from these designs, additional reference designs and evaluation modules (EVMs) are available at: www.ti.com/led

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.
- Blinking low-power LEDs to act as indicators in an automotive display or in a casino game.
- Controllers to power and dim high-brightness (HB) white or RGB LEDs for architectural luminaries and portable lighting.
- Powering arrays of HB LEDs from 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.

PMP3599 — LED Light-Bulb-Replacement Driver (TPS92010)
AC Powered LED Drivers

PMP3599 — LED Light-Bulb-Replacement Driver (TPS92010)

Performance Data

### LED Current Regulation

<table>
<thead>
<tr>
<th>V\textsubscript{IN} (VAC)</th>
<th>Io (mA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>80</td>
<td>320</td>
</tr>
<tr>
<td>100</td>
<td>325</td>
</tr>
<tr>
<td>120</td>
<td>330</td>
</tr>
<tr>
<td>140</td>
<td>335</td>
</tr>
<tr>
<td>160</td>
<td>340</td>
</tr>
<tr>
<td>180</td>
<td>345</td>
</tr>
<tr>
<td>200</td>
<td>350</td>
</tr>
<tr>
<td>220</td>
<td>355</td>
</tr>
<tr>
<td>240</td>
<td>360</td>
</tr>
</tbody>
</table>

### Efficiency

<table>
<thead>
<tr>
<th>V\textsubscript{IN} (VAC)</th>
<th>Efficiency (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>80</td>
<td>78.0</td>
</tr>
<tr>
<td>100</td>
<td>81.5</td>
</tr>
<tr>
<td>120</td>
<td>82.0</td>
</tr>
<tr>
<td>140</td>
<td>78.5</td>
</tr>
<tr>
<td>160</td>
<td>79.0</td>
</tr>
<tr>
<td>180</td>
<td>79.5</td>
</tr>
<tr>
<td>200</td>
<td>80.0</td>
</tr>
<tr>
<td>220</td>
<td>80.5</td>
</tr>
<tr>
<td>240</td>
<td>81.0</td>
</tr>
<tr>
<td>260</td>
<td>81.5</td>
</tr>
<tr>
<td>280</td>
<td>82.0</td>
</tr>
</tbody>
</table>

### Power Factor

<table>
<thead>
<tr>
<th>V\textsubscript{IN} (VAC)</th>
<th>PF</th>
</tr>
</thead>
<tbody>
<tr>
<td>80</td>
<td>0.950</td>
</tr>
<tr>
<td>100</td>
<td>0.955</td>
</tr>
<tr>
<td>120</td>
<td>0.960</td>
</tr>
<tr>
<td>140</td>
<td>0.965</td>
</tr>
<tr>
<td>160</td>
<td>0.970</td>
</tr>
<tr>
<td>180</td>
<td>0.975</td>
</tr>
<tr>
<td>200</td>
<td>0.980</td>
</tr>
<tr>
<td>220</td>
<td>0.985</td>
</tr>
<tr>
<td>240</td>
<td>0.990</td>
</tr>
<tr>
<td>260</td>
<td>0.995</td>
</tr>
<tr>
<td>280</td>
<td>1.000</td>
</tr>
</tbody>
</table>
AC Powered LED Drivers

PMP3599 — LED Light-Bulb-Replacement Driver (TPS92010)

Performance Data (Continued)

![Graph showing THD vs. V_IN (VAC)]

PMP3649 — 5 to 9W Isolated LED Down-Light Driver (TPS92210)

![Diagram of the PMP3649 circuit]
Performance Data

**LED Current Regulation**

- **V IN (VAC)**: 80, 100, 120, 140, 160, 180, 200, 220, 240, 260, 280
- **I O (mA)**: 347, 348, 349, 350, 351

**Efficiency**

- **V IN (VAC)**: 80, 100, 120, 140, 160, 180, 200, 220, 240, 260, 280
- **Efficiency (%)**: 84.0, 84.5, 85.0, 85.5, 86.0, 86.5, 87.0, 87.5, 88.0

---

**PMP3649 — 5 to 9W Isolated LED Down-Light Driver (TPS92210)**

LED Driver Solutions
AC Powered LED Drivers

PMP3649 – 5 to 9W Isolated LED Down-Light Driver (TPS92210)

Performance Data (Continued)

Power Factor

Input Current THD
AC Powered LED Drivers

PMP3661 — 12 to 35W Isolated LED Street-Light Driver (TPS92210)

Performance Data at 28W

LED Current Regulation

<table>
<thead>
<tr>
<th>$I_0$ (mA)</th>
<th>$V_{IN}$ (VAC)</th>
</tr>
</thead>
<tbody>
<tr>
<td>346</td>
<td>80</td>
</tr>
<tr>
<td>348</td>
<td>120</td>
</tr>
<tr>
<td>350</td>
<td>160</td>
</tr>
<tr>
<td>352</td>
<td>200</td>
</tr>
<tr>
<td>354</td>
<td>240</td>
</tr>
<tr>
<td>356</td>
<td>280</td>
</tr>
</tbody>
</table>

- Green: Unit 1
- Orange: Unit 2
AC Powered LED Drivers

PMP3661 — 12 to 35W Isolated LED Street-Light Driver (TPS92210)

Performance Data at 28W (Continued)

![Efficiency Graph]

![Power Factor Graph]
Performance Data at 28W (Continued)

**PMP3661 – 12 to 35W Isolated LED Street-Light Driver (TPS92210)**

![Graph showing Input Current THD vs. VIN (VAC)]

**PMP3672 — 18 to 20W LED Tube-Light Driver (TPS92210)**

![Circuit diagram of PMP3672]
### AC Powered LED Drivers

**PMP3672 — 18 to 20W LED Tube-Light Driver (TPS92210)**

**Performance Data**

#### LED Current Regulation

- **Current (mA)**: 713, 714, 715, 716, 717, 718, 719, 720, 721, 722
- **V IN (VAC)**: 110, 130, 150, 170, 190, 210, 230, 250, 270

#### Power factor

- **PF**: 0.960, 0.965, 0.970, 0.975, 0.980, 0.985, 0.990, 0.995, 1.000
- **V IN (VAC)**: 80, 100, 120, 140, 160, 180, 200, 220, 240, 260, 280
AC Powered LED Drivers

PMP3672 — 18 to 20W LED Tube-Light Driver (TPS92210)

Performance Data (Continued)

Efficiency

<table>
<thead>
<tr>
<th>VIN (VAC)</th>
<th>80</th>
<th>100</th>
<th>120</th>
<th>140</th>
<th>160</th>
<th>180</th>
<th>200</th>
<th>220</th>
<th>240</th>
<th>260</th>
<th>280</th>
</tr>
</thead>
<tbody>
<tr>
<td>Efficiency (%)</td>
<td>80.0</td>
<td>80.5</td>
<td>81.0</td>
<td>81.5</td>
<td>82.0</td>
<td>82.5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Input Current THD

<table>
<thead>
<tr>
<th>VIN (V, AC)</th>
<th>80</th>
<th>100</th>
<th>120</th>
<th>140</th>
<th>160</th>
<th>180</th>
<th>200</th>
<th>220</th>
<th>240</th>
<th>260</th>
<th>280</th>
</tr>
</thead>
<tbody>
<tr>
<td>THD (%)</td>
<td>12</td>
<td>11</td>
<td>10</td>
<td>9</td>
<td>8</td>
<td>7</td>
<td>6</td>
<td>5</td>
<td>4</td>
<td>4</td>
<td>4</td>
</tr>
</tbody>
</table>
DC Powered LED Solutions

Introduction

DC Powered LED Solutions

<table>
<thead>
<tr>
<th>Product</th>
<th>PMP Number</th>
<th>Input</th>
<th>LED Configuration</th>
<th>LED Current</th>
<th>Number of LEDs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solar Lantern</td>
<td>PMP3578/79</td>
<td>5 to 7VDC</td>
<td>Series</td>
<td>300 to 450mA</td>
<td>1W and 3W options Also can be used for up to 10 LED lanterns with 3W maximum power</td>
</tr>
<tr>
<td></td>
<td>PMP3676</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Solar Street Light</td>
<td>PMP3543</td>
<td>10 to 28VDC</td>
<td>Series-Parallel 9S(22S/2P)</td>
<td>700mA</td>
<td>Can support up to 45W and from 9 to 22 LEDs</td>
</tr>
<tr>
<td>Solar Down Lighter</td>
<td>PMP3588</td>
<td>9 to 16VDC</td>
<td>Series</td>
<td>450mA</td>
<td>Can drive 15W power with 12V battery or 28W with 24V battery (with number of LEDs in string limited to 10 LEDs)</td>
</tr>
</tbody>
</table>

PMP3578 — 1W LED Lantern Driver (TPS54231)

![PMP3578 Circuit Diagram](image-url)
Performance Data

**LED Current Regulation**

- **LED Current (I<sub>o</sub>)** (mA)
  - 300.0
  - 300.5
  - 301.0
  - 301.5
  - 302.0
  - 302.5
  - 303.0
  - 303.5
  - 304.0
  - 304.5

- **Input Voltage (V<sub>IN</sub>)** (VDC)
  - 5.4
  - 5.6
  - 5.8
  - 6.0
  - 6.2
  - 6.4
  - 6.6
  - 6.8
  - 7.0

**Efficiency**

- **Efficiency (%)**
  - 87.00
  - 87.25
  - 87.50
  - 87.75
  - 88.00
  - 88.25
  - 88.50
  - 88.75
  - 89.00

- **Input Voltage (V<sub>IN</sub>)** (VDC)
  - 5.4
  - 5.6
  - 5.8
  - 6.0
  - 6.2
  - 6.4
  - 6.6
  - 6.8
  - 7.0
**Performance Data**

### LED Current Regulation

<table>
<thead>
<tr>
<th>$V_{IN}$ (V DC)</th>
<th>$I_o$ (mA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.4</td>
<td>360</td>
</tr>
<tr>
<td>5.6</td>
<td>358</td>
</tr>
<tr>
<td>5.8</td>
<td>356</td>
</tr>
<tr>
<td>6.0</td>
<td>354</td>
</tr>
<tr>
<td>6.2</td>
<td>352</td>
</tr>
<tr>
<td>6.4</td>
<td>350</td>
</tr>
<tr>
<td>6.6</td>
<td>348</td>
</tr>
<tr>
<td>6.8</td>
<td>352</td>
</tr>
<tr>
<td>7.0</td>
<td>358</td>
</tr>
</tbody>
</table>

### Efficiency (%)

<table>
<thead>
<tr>
<th>$V_{IN}$ (VDC)</th>
<th>Efficiency (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.4</td>
<td>88.5</td>
</tr>
<tr>
<td>5.6</td>
<td>88.0</td>
</tr>
<tr>
<td>5.8</td>
<td>87.5</td>
</tr>
<tr>
<td>6.0</td>
<td>87.0</td>
</tr>
<tr>
<td>6.2</td>
<td>86.5</td>
</tr>
<tr>
<td>6.4</td>
<td>86.0</td>
</tr>
<tr>
<td>6.6</td>
<td>85.5</td>
</tr>
<tr>
<td>6.8</td>
<td>85.0</td>
</tr>
<tr>
<td>7.0</td>
<td>84.5</td>
</tr>
</tbody>
</table>

**DC Powered LED Drivers**

**PMP3676 — 3W LED Lantern Driver Using MSP430™ Controller**
DC Powered LED Drivers

**PMP3543 — 18 to 45W Solar-Street-Light Driver (TPS40211)**

Performance Data

### Efficiency Vs Output Voltage

- **10V**
- **14V**
- **20V**
- **28V**

![Efficiency Vs Output Voltage Graph](image-url)
DC Powered LED Drivers

PMP3543 — 18 to 45W Solar-Street-Light Driver (TPS40211)

Performance Data

**LED Current Regulation**

<table>
<thead>
<tr>
<th>Output Voltage (V)</th>
<th>Current (A)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10V</td>
<td>0.686</td>
</tr>
<tr>
<td>14V</td>
<td>0.687</td>
</tr>
<tr>
<td>20V</td>
<td>0.689</td>
</tr>
<tr>
<td>28V</td>
<td>0.690</td>
</tr>
</tbody>
</table>

PMP3588 — Solar-Powered Down-Lighting Driver (TPS61500)

8 LEDs @ 450mA LED RTN
DC Powered LED Drivers

PMP3588 — Solar-Powered Down-Lighting Driver (TPS61500)

Performance Data

![LED Current Regulation Graph]

![Efficiency Graph]

PMP3598 — Maximum-Power-Point Tracking (MPPT) Solar Charger

Key Features

- Max. Input – 40V
- Charger Rating – 120W
- Auto select between 12V and 24V batteries
- Charge Current – 10A for 12V and 5A for 24V batteries
- Battery under voltage protection
  – auto set at 1.7V/2V cell
- Load disconnect beyond 10A
- Load disconnect during battery low conditions
General-Purpose LED-Lighting PWM Controller

**Key Features**
- Ideal for single stage LED driver designs
- Isolated and non-isolated topologies
- TRIAC-dimmable application circuit
- 30% fewer external components
- Convenient 5V reference output
- Undervoltage lockout for safe operation
- 0.4A source/0.8A sink FET driver

**Benefits**
- Adds LED load flexibility
- Above 0.7 power factor
- Low-cost, deep-dimmable solution
- High density, small form factor

**Applications**
- Retrofit LED bulbs – A19, PAR30/38, GU10
- Residential LED lighting drivers
- Drivers for wall sconces, pathway and overhead lighting

---

8-Pin, High-Efficiency, Offline LED-Lighting Controller

**Key Features**
- High efficiency LED lighting current
- Quasi resonant and low power modes
- High performance TRIAC dimming with application circuit
- Programmable overvoltage protection
- Internal over-temperature protection
- Current-limit protection
- Cycle-by-cycle power limit
- Primary side overcurrent hiccup
- Restart mode
- TrueDrive™ gate drive 1A sink, 0.75A source

**Benefits**
- 87% achievable efficiency – higher than standard flyback topologies
- Less than 400mW standby current allows efficient deep dimming
- 20% more efficient dimming compared with other methods

**Applications**
- Residential LED lighting drivers
- Drivers for wall sconces, pathway and overhead lighting
- Drivers for wall washing, architectural and display lighting
Resonant-Switching Driver Controller for LED Lighting

TPS92020

Key Features
- LLC resonant switching controller
- Half-bridge topology
- Fixed or variable switching frequency control
- Upper and lower frequency bounded
- Programmable soft-start
- Internal over-temperature protection
- Current limit protection
- Integrated gate drive 0.8A sink, 0.4A source

Benefits
- Zero voltage switching for 90%+ efficiency
- 15% smaller solution size compared to flyback
- Tune to resonant frequency for higher efficiency
- 20% savings in system cost; reduces overdesign
- Provides flexible dimming option
- Safely shuts down driver from over temperature
- Protects driver from load short circuit
- Can drive pulse transformer directly

Applications
- Commercial/industrial LED lighting drivers
- High bay
- Street lighting and area lighting
- Wall washing and architectural fixtures

Natural PFC LED Lighting Driver Controller

TPS92210

Key Features
- Flexible operation modes: peak primary current, constant ON-time or both
- Cascoded MOSFET configuration
- Works with TRIAC dimmers
- DCM or transition-mode operation
- Advanced overcurrent protection

Benefits
- Constant On-time implements single stage PFC
- Lower switch losses, line surge rugged better than internal HV FET
- Continuous linear dimming
- High efficiency, low EMI
- No reverse recovery loss in output rectifier
- Smaller size and lower system cost

Applications
- Residential LED lighting drivers A19 (E27/26, E14), PAR30/38, GU10
- Drivers for wall sconces, pathway and overhead lighting
- Drivers for wall washing, architectural and display lighting
- Commercial troffers and down lights
LED Lighting Power Controller

**UCC28810/1**

**Key Features**
- Transformer zero-energy detection (transition-mode control)
- Implements single-stage power-factor correction and LED current regulation
- Application circuit implements industry standard TRIAC phase-angle dimming
- Improved transient response
- UVLO, OVP and open feedback
- Low startup current and accurate internal VREF
- 750mA gate-drive current

**Benefits**
- Low cost, high efficiency and low EMI
- Achieves lighting standards requirements, reduces cost and size
- Uniform dimming of LED fixture achieved without changing wall dimmer
- Cost effectively improves performance of LED in secondary side LED control schemes
- Improves reliability and life time of lighting fixture
- Low power consumption, better efficiency and provides consistent performance in high-volume lighting production
- Eliminates the need for an external driver

**Applications**
- AC Input general LED lighting applications
- Industrial, commercial and residential lighting fixtures
- LED lighting ballasts
- Outdoor lighting: street, roadway, and parking-lot lighting,
- Interior and exterior ornamental LED lighting
- Light bulb replacements

---

Fixed-Frequency Current-Mode Controller for Boost, Flyback and SEPIC

**TPS40211**

**Key Features**
- Wide input operating voltage: 4.5V to 52V
- Programmable switching frequency from 35kHz to 1MHz
- Frequency synchronization (requires external components)
- Closed-loop soft start
- 260mV voltage reference
- Internal undervoltage lockout with 300mV hysteresis
- Integrated low-side driver
- Programmable overcurrent protection

**Benefits**
- Number of LEDs in series is limited by external MOSFET and boost ratio
- Enables use of small ISENSE resistors with lower power dissipation

**Applications**
- High-current LED drivers
- LED lighting solutions
- LED backlighting
**LED Driver Controllers**

**350mA, 90% Efficient, High-Brightness WLED Driver in 2x2 QFN and SOT-23**

**TPS61165**

**Key Features**
- 3 to 18 V input voltage range
- Multi-function digital pin (CTRL)
- 2x2 mm QFN or SOT-23 package

**Benefits**
- Wide input voltage range supports industrial power rails: 12V/16V
- Provides PWM signal or one wire dimming methods without audible noise
- Small solution size

**Applications**
- High brightness LED lighting
- White LED backlighting up to 7” displays
- Matrix setup with up to 60 LEDs (6x10 example)

---

**High-Power White-LED Driver with 3A Switch**

**TPS61500**

**Key Features**
- 2.9V to 18V input voltage range
- 3.0A current switch (integrated FET)
- Four 3W LEDs from 5VIN
- Eight 3W LEDs from 12VIN
- 200kHz to 2.2MHz switching frequency
- Analog and PWM brightness dimming
- User defined softstart
- Up to 93% efficiency
- 14-pin HTSSOP package

**Benefits**
- Wide input supply range for 12V or 15V industrial power rails
- Up to 1A output current
- HTSSOP package for best thermal behavior

**Applications**
- High-brightness LED lighting
- High-power LED supply
**Key Features**
- Pulse-skipping Eco-mode™ with 110µA operating and 1µA shutdown current
- Integrated 80m high-side MOSFET
- 570kHz (TPS54231) or 285kHz (TPS54233) fixed switching frequency
- Output voltage adjustable down to 0.8V
- Adjustable slow start time
- External compensation with current mode control

**Benefits**
- High efficiency under light loads saves energy and extends battery life
- Greater than 85% efficiency at 2A full load

**Applications**
- Set-top boxes, CPE equipment, LCD displays, peripherals, and battery chargers
- Industrial and car audio power supplies
- 5V, 12V and 24V distributed power systems

---

**Solar MPPT Charger Supports High Charging Current and Multi-Cell Standalone Applications**

**Key Features**
- Maximum power point tracking (MPPT) capability with programmable input voltage regulation
- 600kHz NMOS-NMOS controller supports up to 10A programmable charging current
- Charge up to 26V for lead acid, 7 LiFePO4 cells or 6 Li-Ion/polymer cells
- ±0.5% charge voltage regulation accuracy over 0 to 85°C

**Benefits**
- Simple resistor programmable MPPT vs. software/MCU-based solution – “Set it and forget it”
- 5X the charging current vs. competing solution for the max battery capacity
- Supports 2 additional cells in series vs. competing solar charging solution
- Maximize capacity after 100’s of charge cycles with 10+% more capacity than competing solution
- LiFePO4 applications
- Portable handheld instruments
- 12V to 24V automotive systems
- Current limited power source

**Applications**
- Solar powered applications
- Remote monitoring stations
Multi-Cell Standalone Charger Supports MPPT Solar Solutions

bq24650

Key Features

- Maximum power point (MPP) of solar-panel output occurs at a specific load current and output voltage level (VMPP)
- If load is less than optimal, not all power is utilized
- If load is more than optimal, output voltage collapses and full power cannot be delivered
- Maximum power point tracking (MPPT) – Charger output current is adjusted to optimize the solar-panel output power with all levels of illumination
Evaluation Modules (EVMs)

High-Intensity, Light-Output Drivers with PFC + Buck + Multiple LED Strings

Key Features
- PFC Stage: Required in any implementation
- Low-Side Buck: Provides constant LED current and main control
- Series Transformers: Provides constant current to each LED string

Benefits
- One control section for all string currents
- Lower part count, higher reliability and lower cost

Drawback
- If dimming is required, all strings will be dimmed simultaneously

110W Multiple-String LED Driver with Universal Line Input and PFC

UCC28810EVM-003 Evaluation Module
230VAC TRIAC-Dimmable Light-Bulb Replacement

**TPS92010 Evaluation Module**

**Key Features**
- TRIAC compatible dimming
- Low-cost line-powered LED driver solution
- Includes five HB-LED’s as a sample load
- Allows easy use of users own LED load
- Test points for LED voltage and current
- Accurate current sensing to maintain constant current to LED’s
- Modifiable output current from 0.2 A to 0.7 A, 0.325 A is default

**Applications**
- Household light bulb replacement

**Performance Data**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Minimum</th>
<th>Typical</th>
<th>Maximum</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Input Voltage Range</td>
<td>185</td>
<td>–</td>
<td>265</td>
<td>V&lt;sub&gt;rms&lt;/sub&gt;</td>
</tr>
<tr>
<td>Maximum Input Current</td>
<td>–</td>
<td>0.52</td>
<td>–</td>
<td>A&lt;sub&gt;rms&lt;/sub&gt;</td>
</tr>
<tr>
<td>Output Voltage, V&lt;sub&gt;OUT&lt;/sub&gt;</td>
<td>14</td>
<td>–</td>
<td>17</td>
<td>VDC</td>
</tr>
<tr>
<td>Output Load Current, I&lt;sub&gt;OUT&lt;/sub&gt;</td>
<td>0.31</td>
<td>0.325</td>
<td>0.34</td>
<td>ADC</td>
</tr>
<tr>
<td>System Efficiency</td>
<td>–</td>
<td>85%</td>
<td>–</td>
<td>–</td>
</tr>
</tbody>
</table>

230VAC TRIAC-Dimmable Light-Bulb Replacement with Natural PFC

**TPS92210 Evaluation Module**

**Key Features**
- Single-stage power-factor correction achieves PF greater than 0.95
- TRIAC dimming to zero LED current
- Test points for output voltage/current
- Cascoded configuration for fully integrated current control with no external sense resistor

**Applications**
- Commercial/household LED lighting

**Performance Data**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Minimum</th>
<th>Typical</th>
<th>Maximum</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Input Voltage Range</td>
<td>185</td>
<td>–</td>
<td>265</td>
<td>V&lt;sub&gt;rms&lt;/sub&gt;</td>
</tr>
<tr>
<td>Maximum Input Current</td>
<td>–</td>
<td>0.52</td>
<td>–</td>
<td>A&lt;sub&gt;rms&lt;/sub&gt;</td>
</tr>
<tr>
<td>Output Voltage, V&lt;sub&gt;OUT&lt;/sub&gt;</td>
<td>14</td>
<td>–</td>
<td>17</td>
<td>VDC</td>
</tr>
<tr>
<td>Output Load Current, I&lt;sub&gt;OUT&lt;/sub&gt;</td>
<td>0.31</td>
<td>0.325</td>
<td>0.34</td>
<td>ADC</td>
</tr>
<tr>
<td>Output Current Ripple at V&lt;sub&gt;N&lt;/sub&gt; = 230 VAC</td>
<td>–</td>
<td>36</td>
<td>–</td>
<td>mA&lt;sub&gt;pp&lt;/sub&gt;</td>
</tr>
<tr>
<td>Switching Frequency</td>
<td>–</td>
<td>115</td>
<td>–</td>
<td>kHz</td>
</tr>
<tr>
<td>Peak Efficiency</td>
<td>–</td>
<td>87.3%</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Full-Load Efficiency</td>
<td>–</td>
<td>87%</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Power Factor at V&lt;sub&gt;N&lt;/sub&gt; = 230 VAC</td>
<td>–</td>
<td>&gt;0.95</td>
<td>–</td>
<td>–</td>
</tr>
</tbody>
</table>
How can I get updates from TI?

The monthly Analog Connection e-newsletter keeps you up to date on new analog products from TI. You can register for the e-newsletter and read previous issues at: www.ti.com/analogconnection.

Additionally, register for a my.TI™ account to receive updates on new products and training opportunities that are relevant to your product and application areas. http://my.ti.com

See the Product Information Center contact information on the back cover.

How can I order free samples?

Samples are available via the product folders on www.ti.com by just clicking on the “order free samples” link and follow the instructions.

Where can I find a current listing of TI literature?

A complete listing of TI product selection guides, end-equipment solution guides and other literature is available at: www.ti.com/analogliterature.

What are some of the design tools available to help me with my design?

TI has a variety of selection, design and simulation software, along with applications notes, reference designs and other tools to help ease your design process and speed your time to market. Just visit our Analog eLab™ Design Center at: www.ti.com/analogelab.
IMPORTANT NOTICE

Texas Instruments Incorporated and its subsidiaries (TI) reserve the right to make corrections, modifications, enhancements, improvements, and other changes to its products and services at any time and to discontinue any product or service without notice. Customers should obtain the latest relevant information before placing orders and should verify that such information is current and complete. All products are sold subject to TI’s terms and conditions of sale supplied at the time of order acknowledgment.

TI warrants performance of its hardware products to the specifications applicable at the time of sale in accordance with TI’s standard warranty. Testing and other quality control techniques are used to the extent TI deems necessary to support this warranty. Except where mandated by government requirements, testing of all parameters of each product is not necessarily performed.

TI assumes no liability for applications assistance or customer product design. Customers are responsible for their products and applications using TI components. To minimize the risks associated with customer products and applications, customers should provide adequate design and operating safeguards.

TI does not warrant or represent that any license, either express or implied, is granted under any TI patent right, copyright, mask work right, or other TI intellectual property right relating to any combination, machine, or process in which TI products or services are used. Information published by TI regarding third-party products or services does not constitute a license from TI to use such products or services or a warranty or endorsement thereof. Use of such information may require a license from a third party under the patents or other intellectual property of the third party, or a license from TI under the patents or other intellectual property of TI.

Reproduction of TI information in TI data books or data sheets is permissible only if reproduction is without alteration and is accompanied by all associated warranties, conditions, limitations, and notices. Reproduction of this information with alteration is an unfair and deceptive business practice. TI is not responsible or liable for such altered documentation. Information of third parties may be subject to additional restrictions.

Resale of TI products or services with statements different from or beyond the parameters stated by TI for that product or service voids all express and implied warranties for the associated TI product or service and is an unfair and deceptive business practice. TI is not responsible or liable for any such statements.

TI products are not authorized for use in safety-critical applications (such as life support) where a failure of the TI product would reasonably be expected to cause severe personal injury or death, unless officers of the parties have executed an agreement specifically governing such use. Buyers represent that they have all necessary expertise in the safety and regulatory ramifications of their applications, and acknowledge and agree that they are solely responsible for all legal and regulatory requirements concerning their products and any use of TI products in such safety-critical applications, notwithstanding any applications-related information or support that may be provided by TI. Further, Buyers must fully indemnify TI and its representatives against any damages arising out of the use of TI products in such safety-critical applications.

TI products are neither designed nor intended for use in military/aerospace applications or environments unless the TI products are specifically designated by TI as military-grade or “enhanced plastic.” Only products designated by TI as military-grade meet military specifications. Buyers acknowledge and agree that any such use of TI products which TI has not designated as military-grade is solely at the Buyer’s risk, and that they are solely responsible for compliance with all legal and regulatory requirements in connection with such use.

TI products are neither designated nor intended for use in automotive applications or environments unless the specific TI products are designated by TI as compliant with ISO/TS 16949 requirements. Buyers acknowledge and agree that, if they use any non-designated products in automotive applications, TI will not be responsible for any failure to meet such requirements.

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

<table>
<thead>
<tr>
<th>Products</th>
<th>Applications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Audio</td>
<td>Communications and Telecom</td>
</tr>
<tr>
<td>Amplifiers</td>
<td>Computers and Peripherals</td>
</tr>
<tr>
<td>Data Converters</td>
<td>Consumer Electronics</td>
</tr>
<tr>
<td>DLP® Products</td>
<td>Energy and Lighting</td>
</tr>
<tr>
<td>DSP</td>
<td>Industrial</td>
</tr>
<tr>
<td>Clocks and Timers</td>
<td>Medical</td>
</tr>
<tr>
<td>Interface</td>
<td>Security</td>
</tr>
<tr>
<td>Logic</td>
<td>Space, Avionics and Defense</td>
</tr>
<tr>
<td>Power Mgmt</td>
<td>Transportation and Automotive</td>
</tr>
<tr>
<td>Microcontrollers</td>
<td>Video and Imaging</td>
</tr>
<tr>
<td>RFID</td>
<td>Wireless</td>
</tr>
<tr>
<td>RF/IF and ZigBee® Solutions</td>
<td><strong>TI E2E Community Home Page</strong></td>
</tr>
</tbody>
</table>

**e2e.ti.com**