

# LED Reference Designs for the India Market



Multiple Applications for LED Lighting



## → Introduction and Contents

### 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](http://www.ti.com/led)

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## → Introduction

### AC Powered LED Solutions

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

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

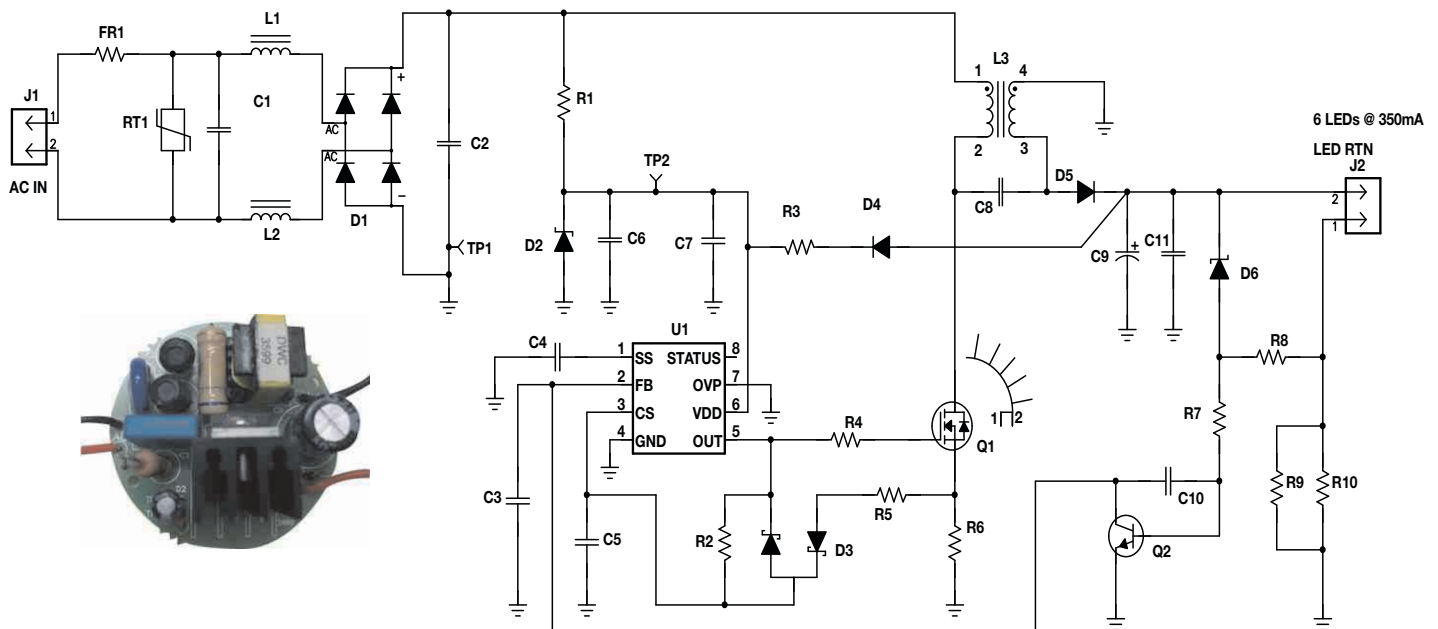
### Other Information

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](http://www.ti.com/led)

### TI has Solutions for Your Lighting Challenges:

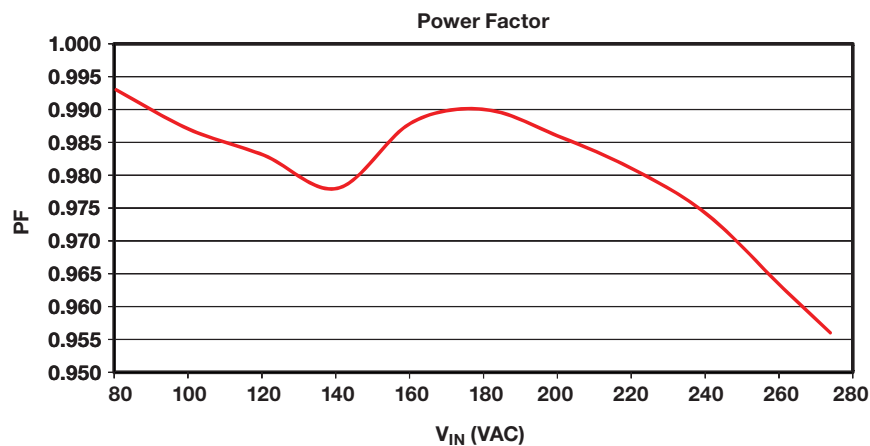
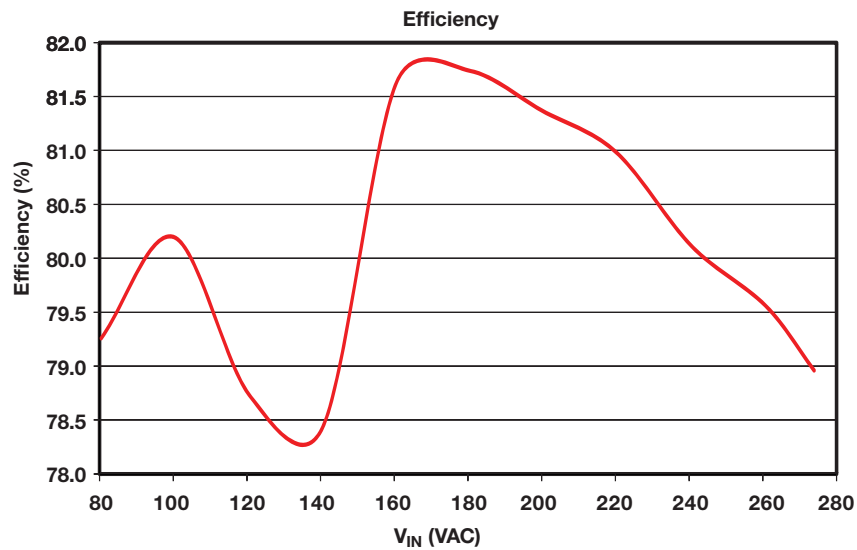
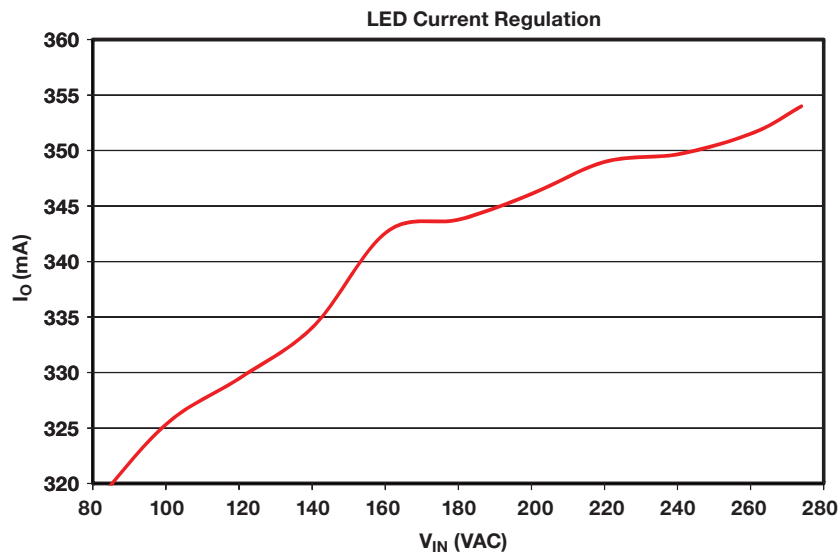
- Precision channel-to-channel and chip-to-chip accuracy to create the best hue and luminance in your RGB message boards and video displays.
- Small-footprint, highest-efficiency programmable LED or OLED backlight controllers.
- Blinking low-power LEDs to act as indicators in an automotive display or 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)



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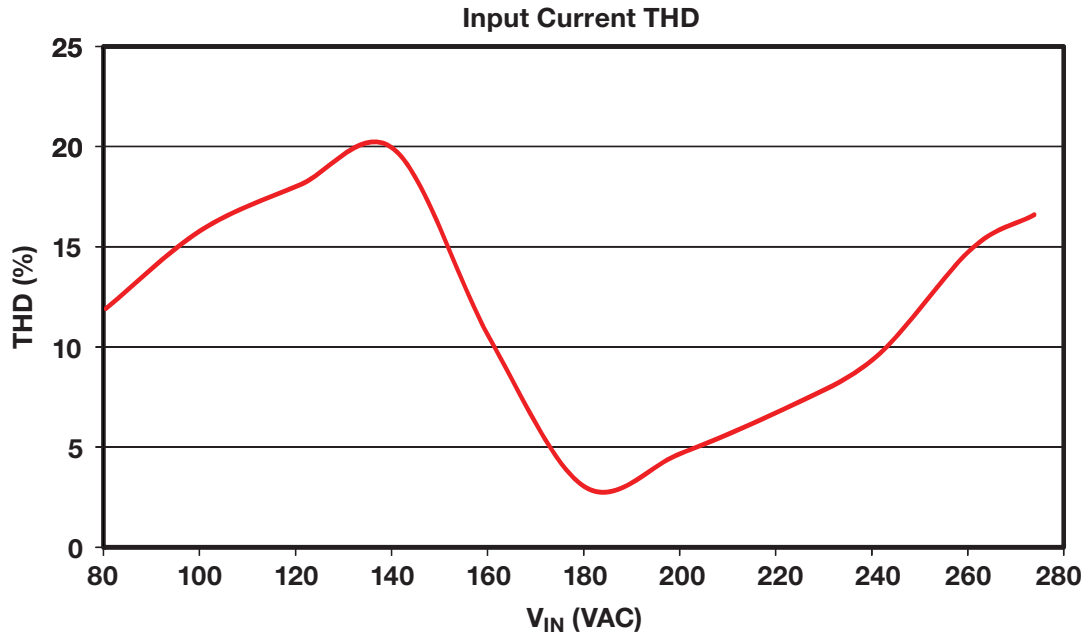
### Performance Data



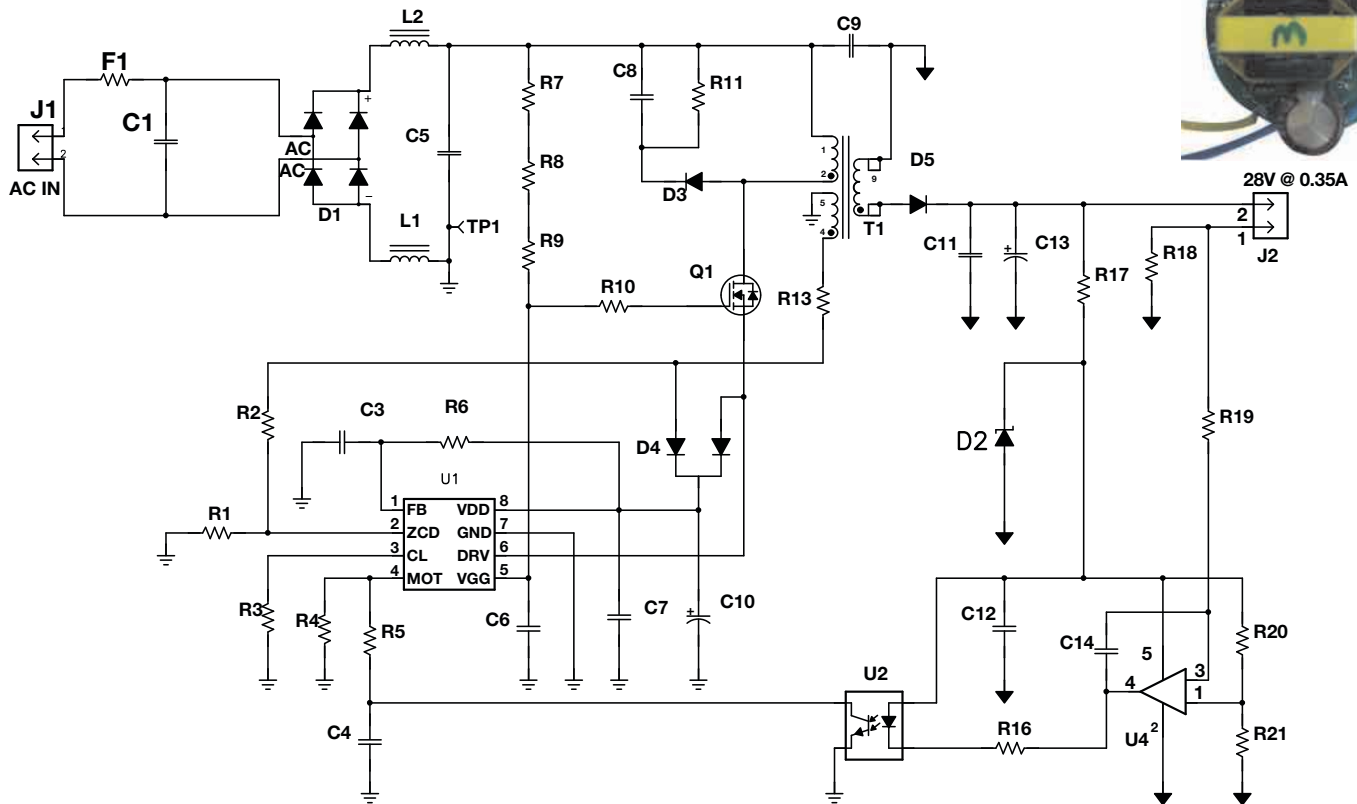
# AC Powered LED Drivers

## → PMP3599 – LED Light-Bulb-Replacement Driver (TPS92010)

### Performance Data (Continued)

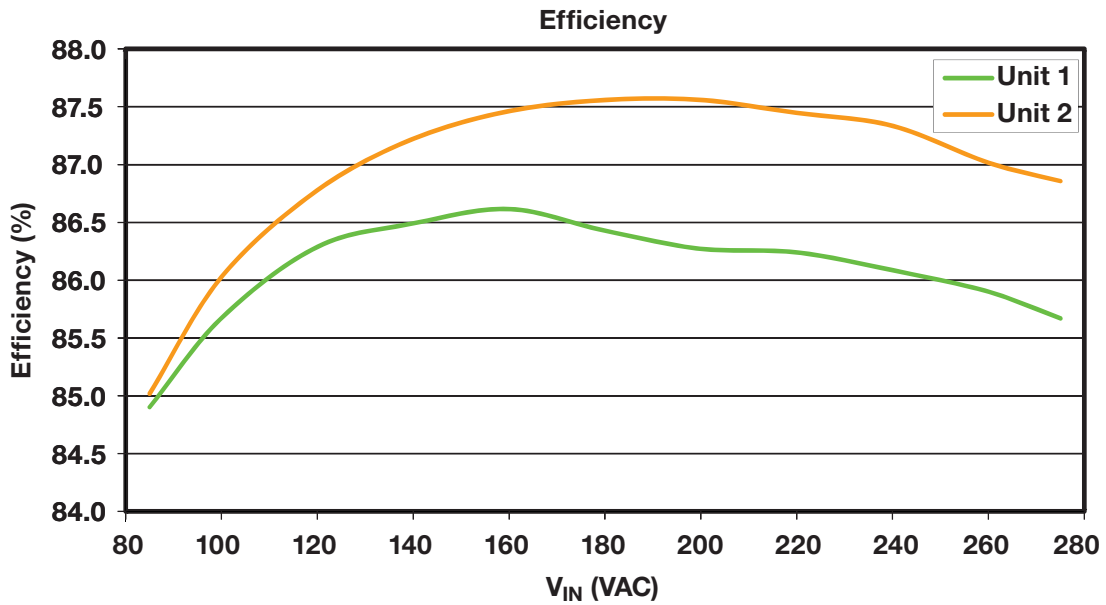
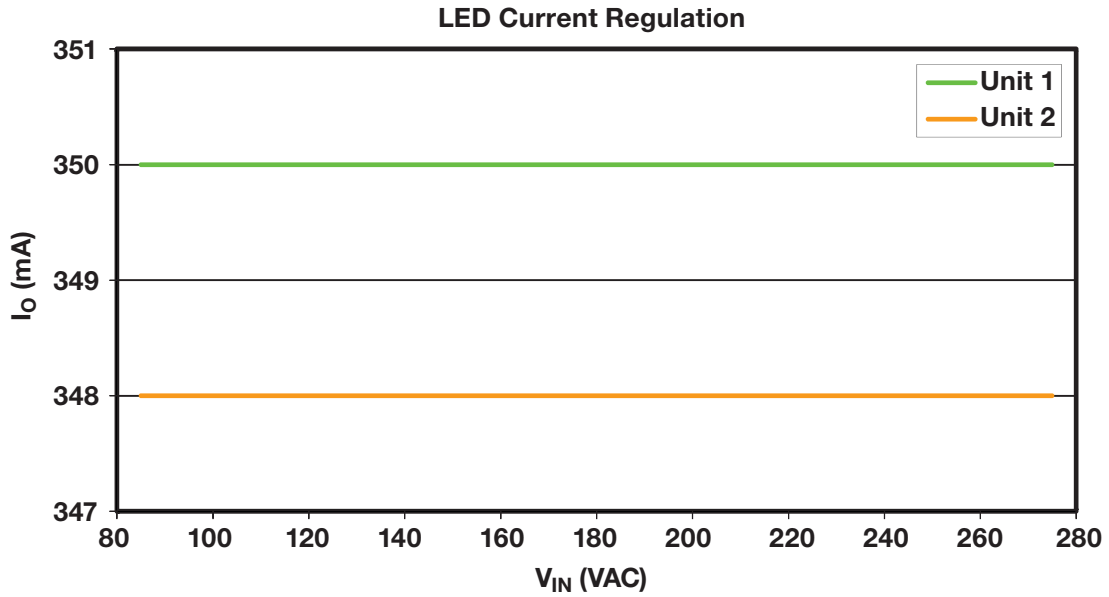


## → PMP3649 – 5 to 9W Isolated LED Down-Light Driver (TPS92210)



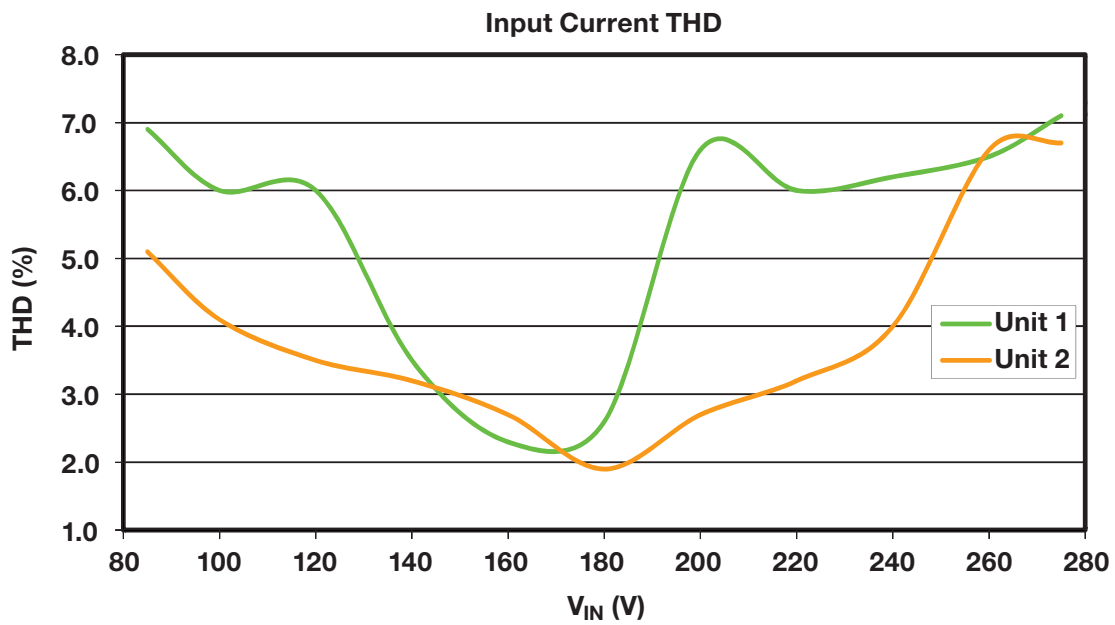
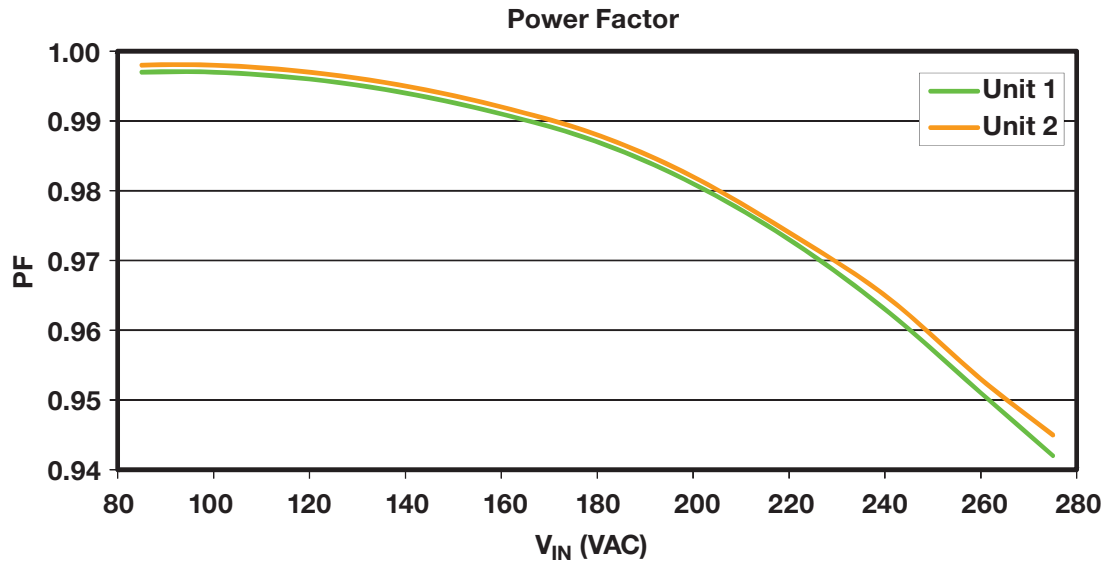
## → PMP3649 – 5 to 9W Isolated LED Down-Light Driver (TPS92210)

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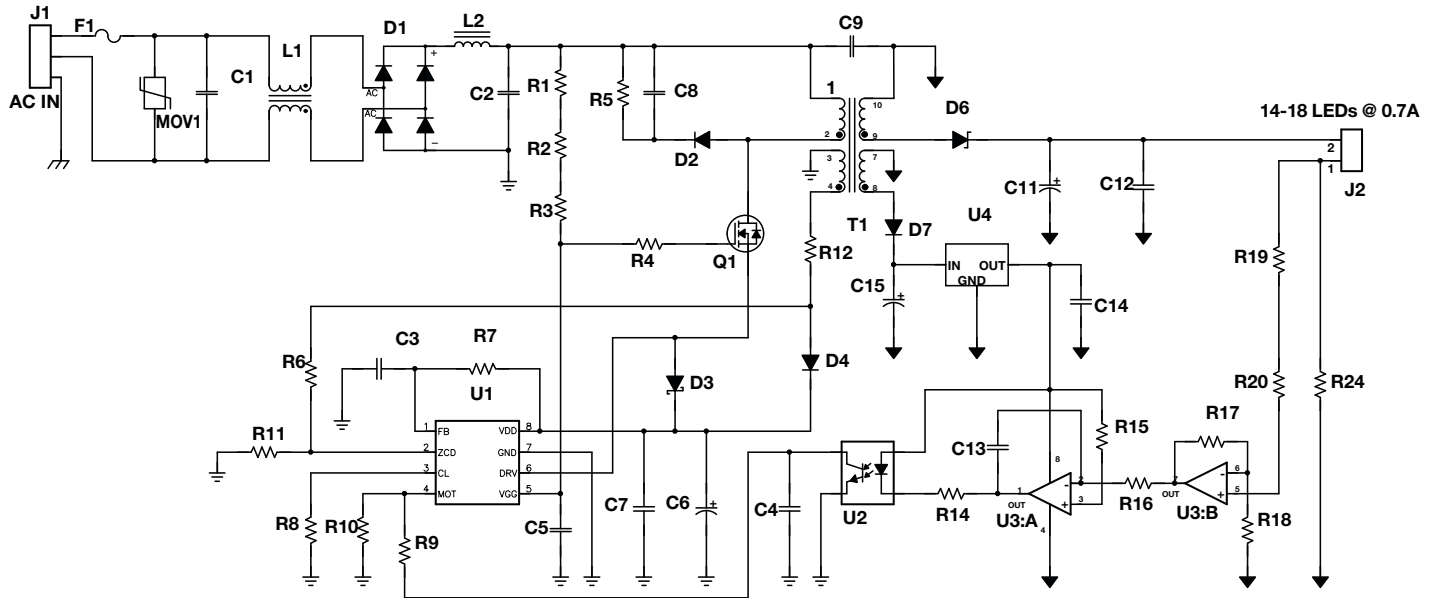
## → PMP3649 – 5 to 9W Isolated LED Down-Light Driver (TPS92210)

### Performance Data (Continued)

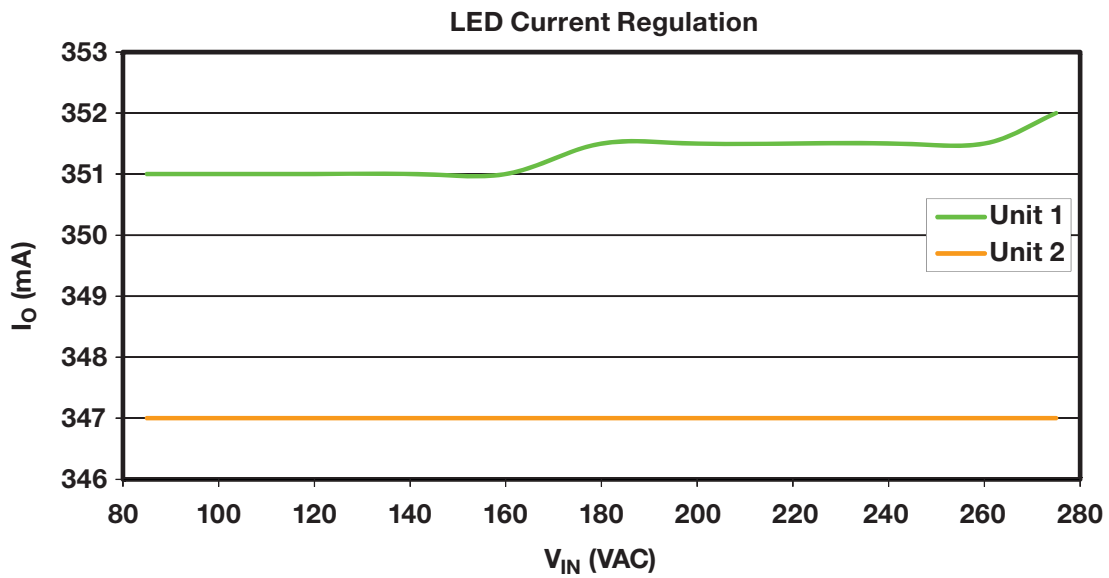


# AC Powered LED Drivers

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



### Performance Data at 28W

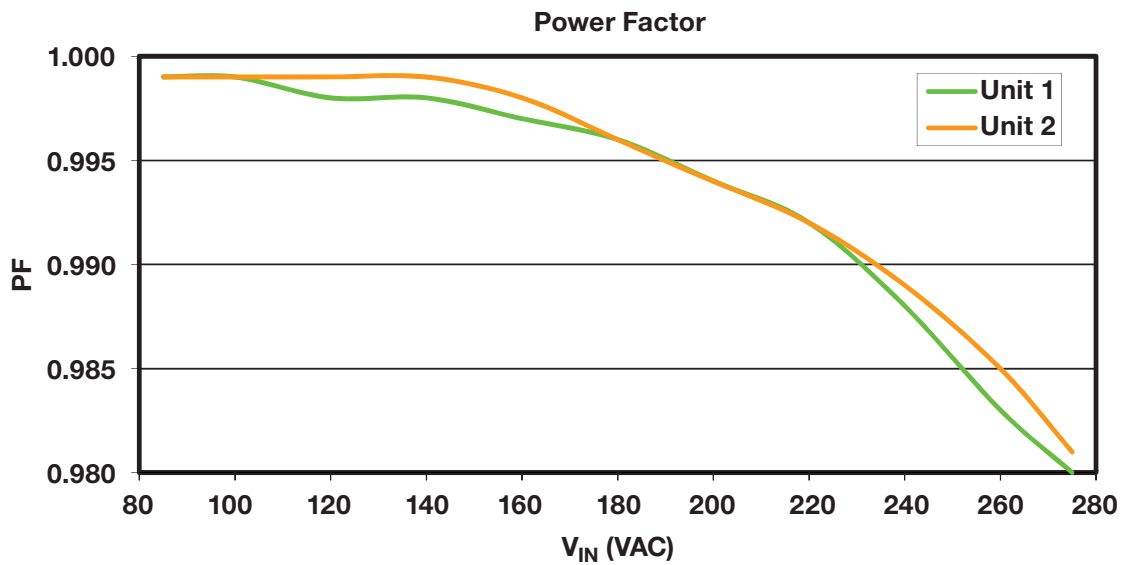
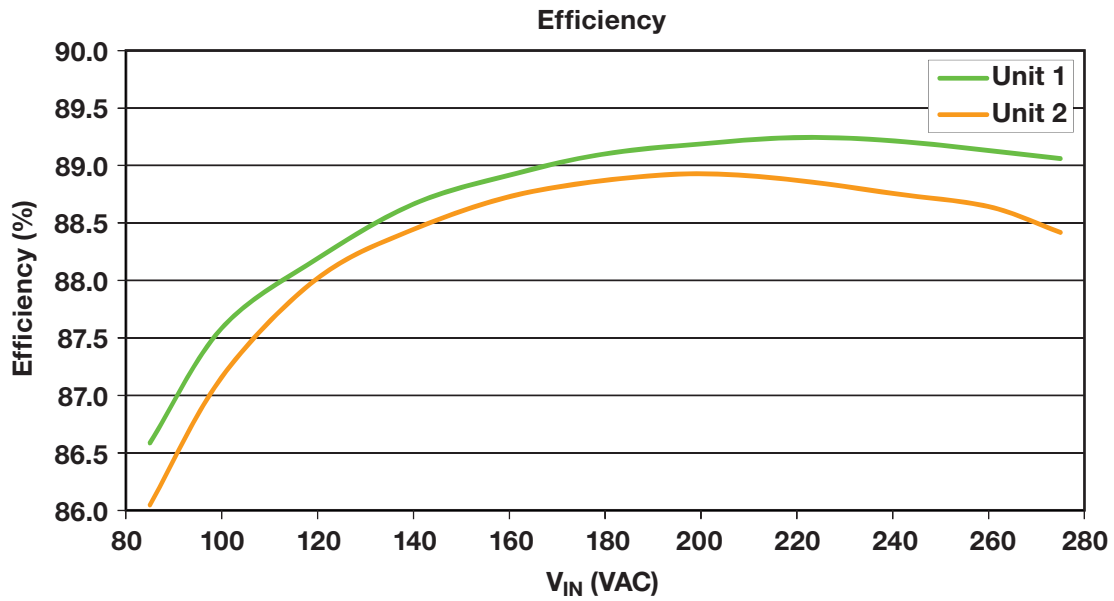




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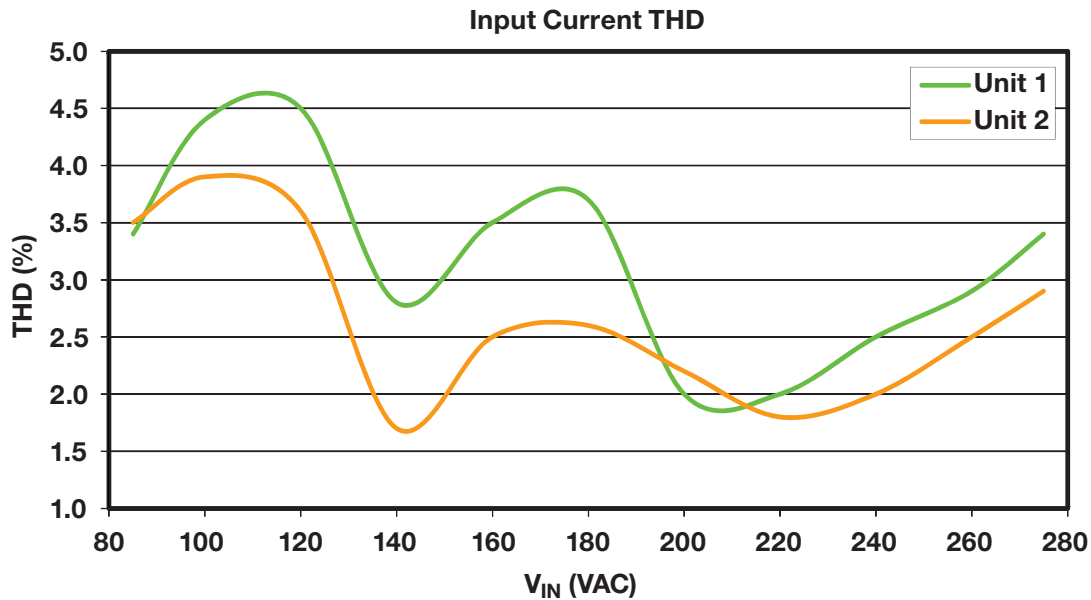
### Performance Data at 28W (Continued)



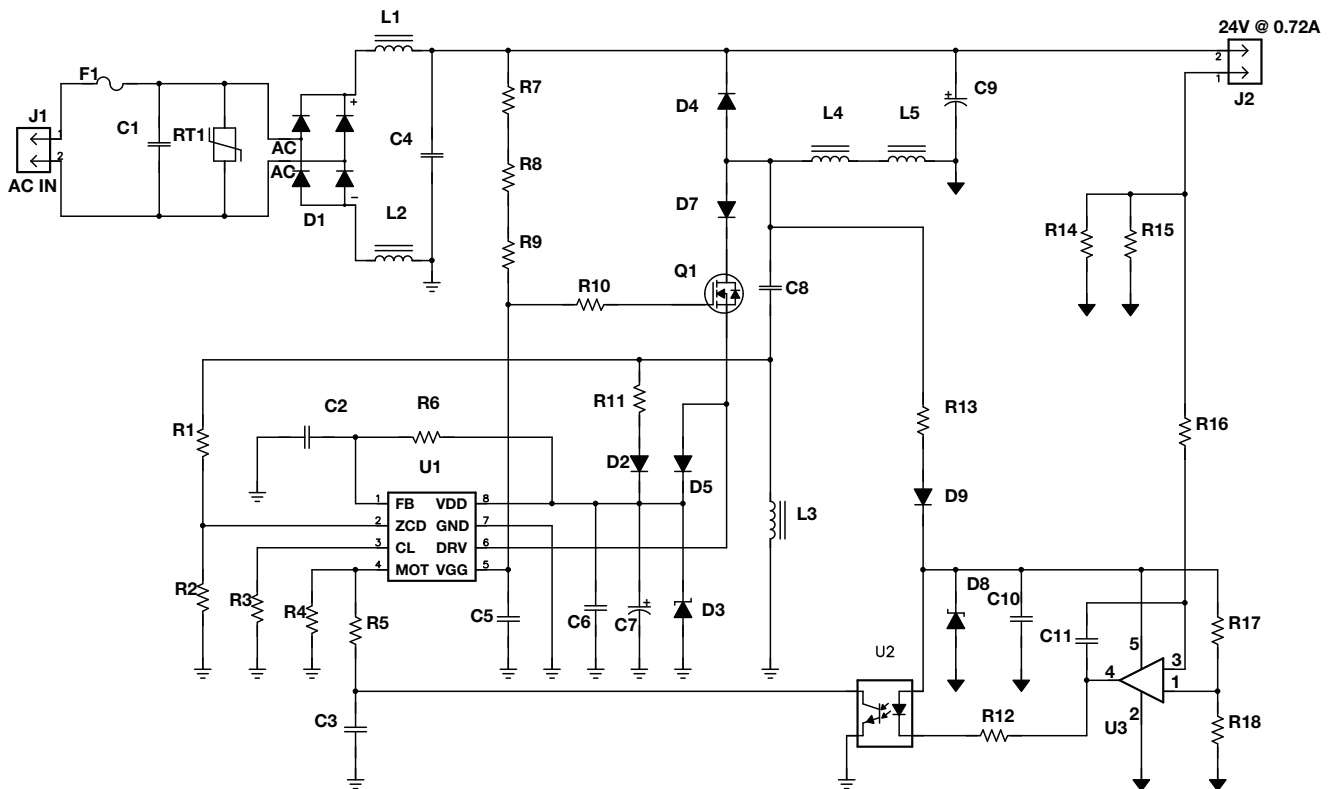
# AC Powered LED Drivers

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

### Performance Data at 28W (Continued)

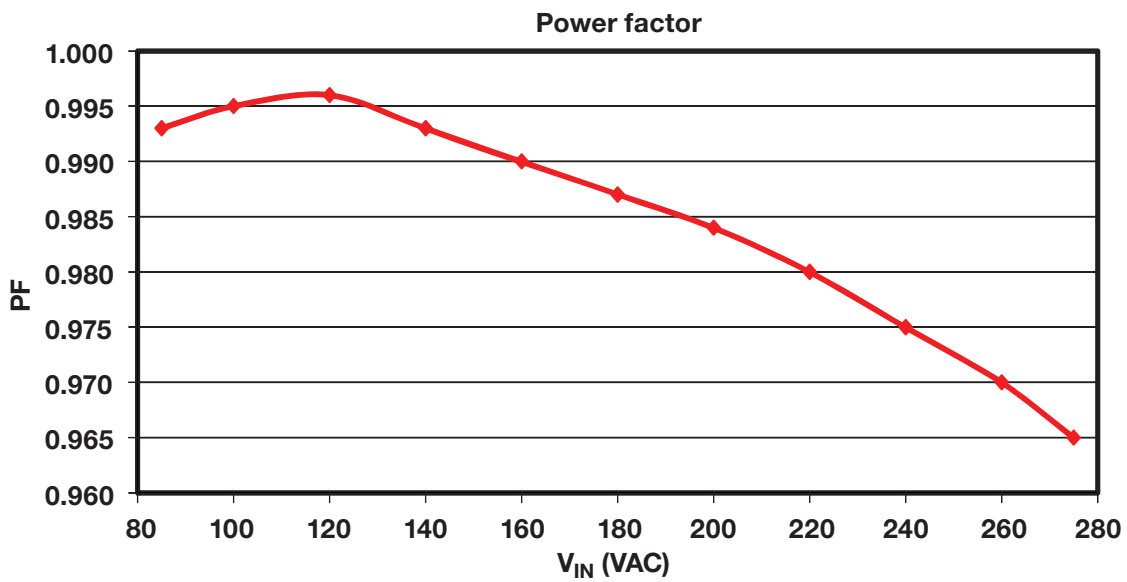
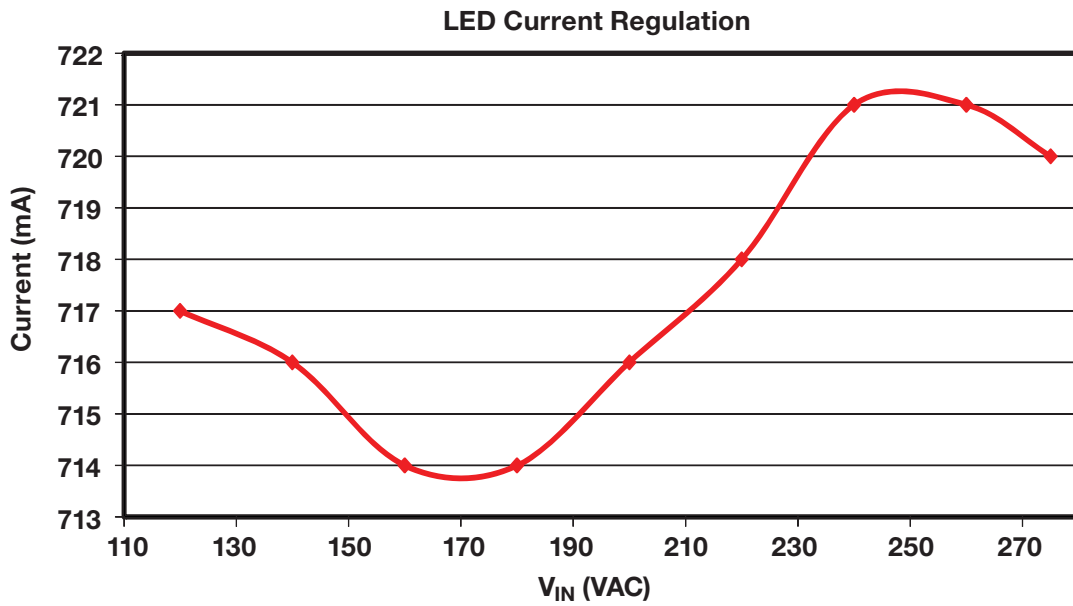


## ➔ PMP3672 – 18 to 20W LED Tube-Light Driver (TPS92210)



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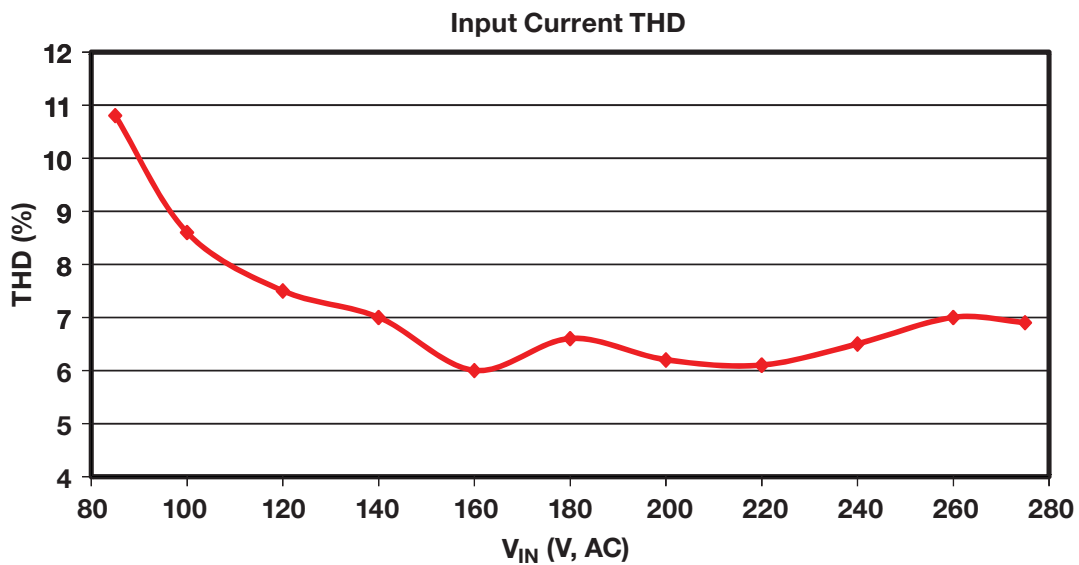
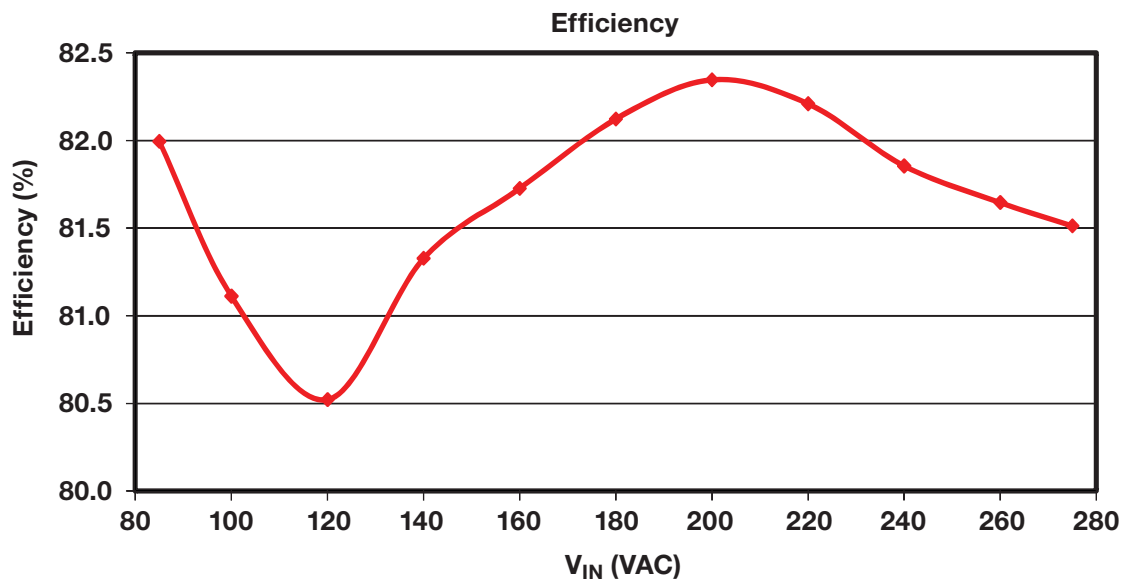
### Performance Data



# AC Powered LED Drivers

## → PMP3672 – 18 to 20W LED Tube-Light Driver (TPS92210)

### Performance Data (Continued)

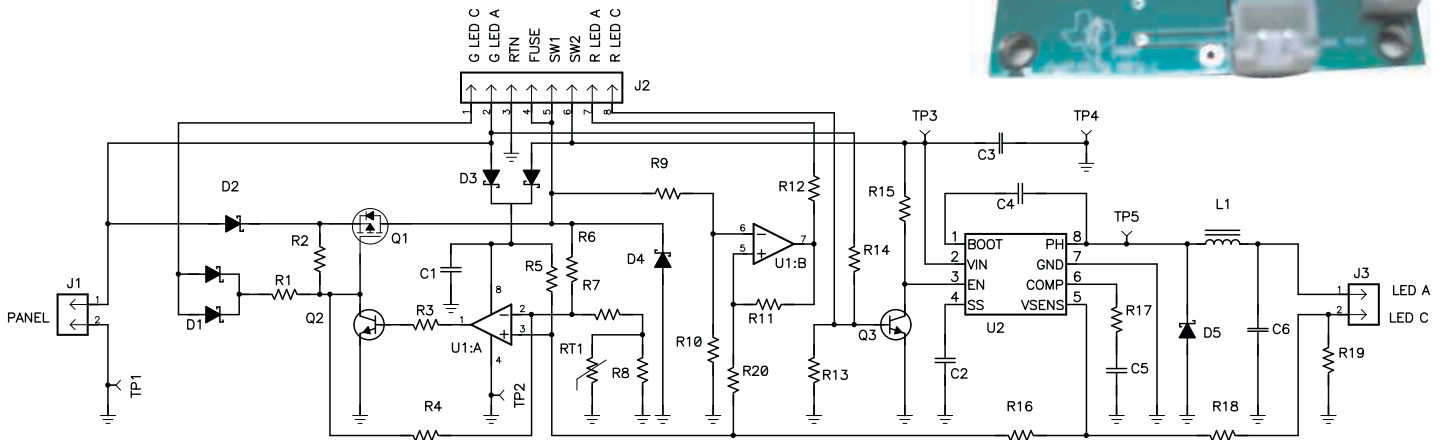


## → Introduction

### DC Powered LED Solutions

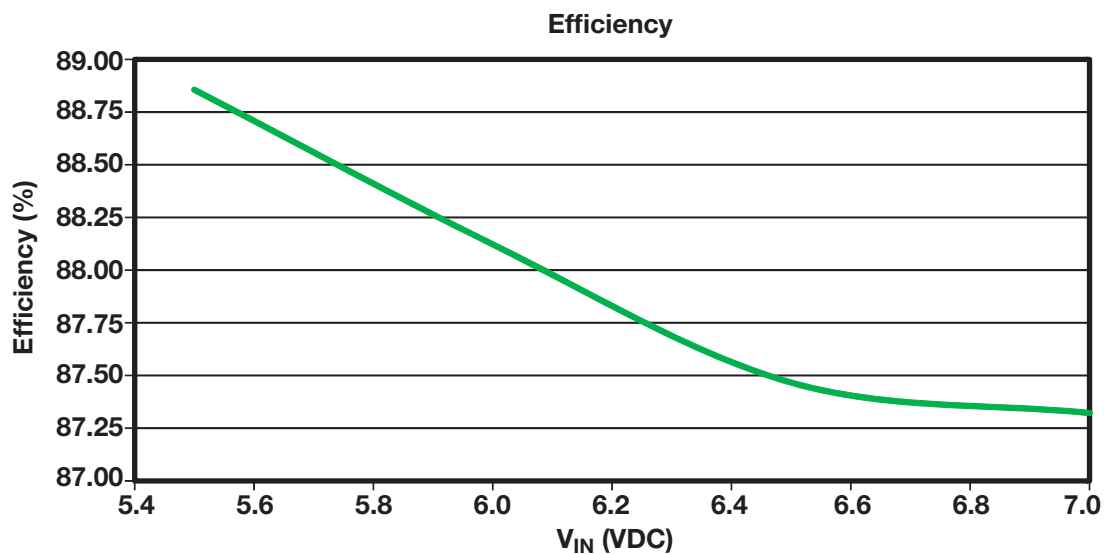
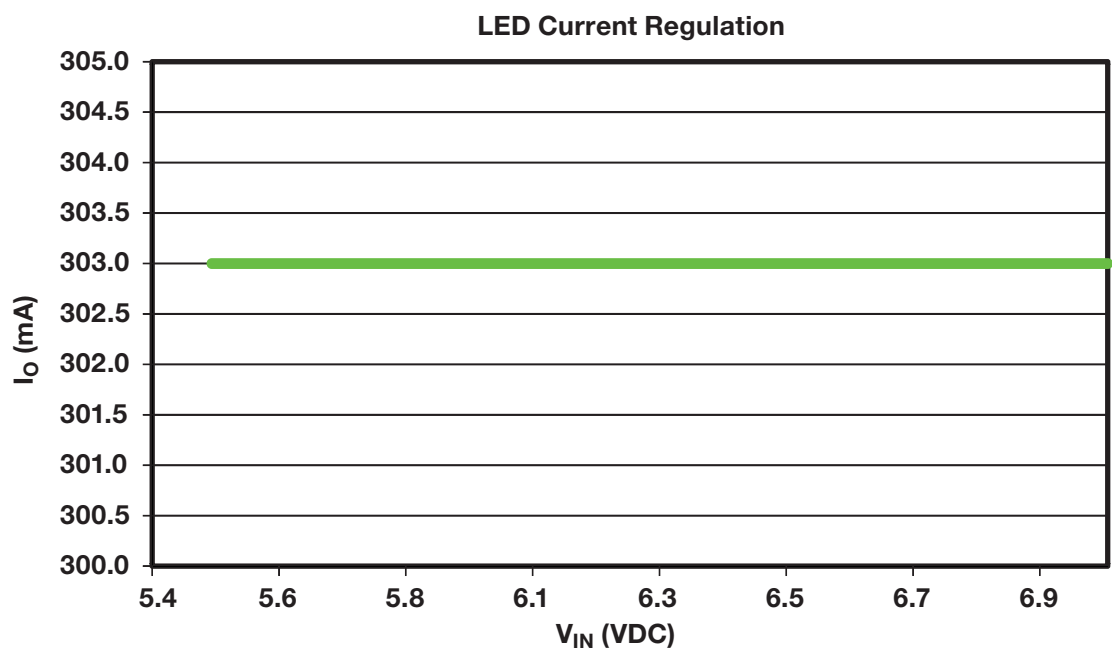
Product	PMP Number	Input	LED Configuration	LED Current	Number of LEDs
Solar Lantern	PMP3578/79 PMP3676	5 to 7VDC	Series	300 to 450mA	1W and 3W options Also can be used for up to 10 LED lanterns with 3W maximum power
Solar Street Light	PMP3543	10 to 28VDC	Series-Parallel 9S(22S)2P	700mA	Can support up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

## → PMP3578 – 1W LED Lantern Driver (TPS54231)



## → PMP3578 – 1W LED Lantern Driver (TPS54231)

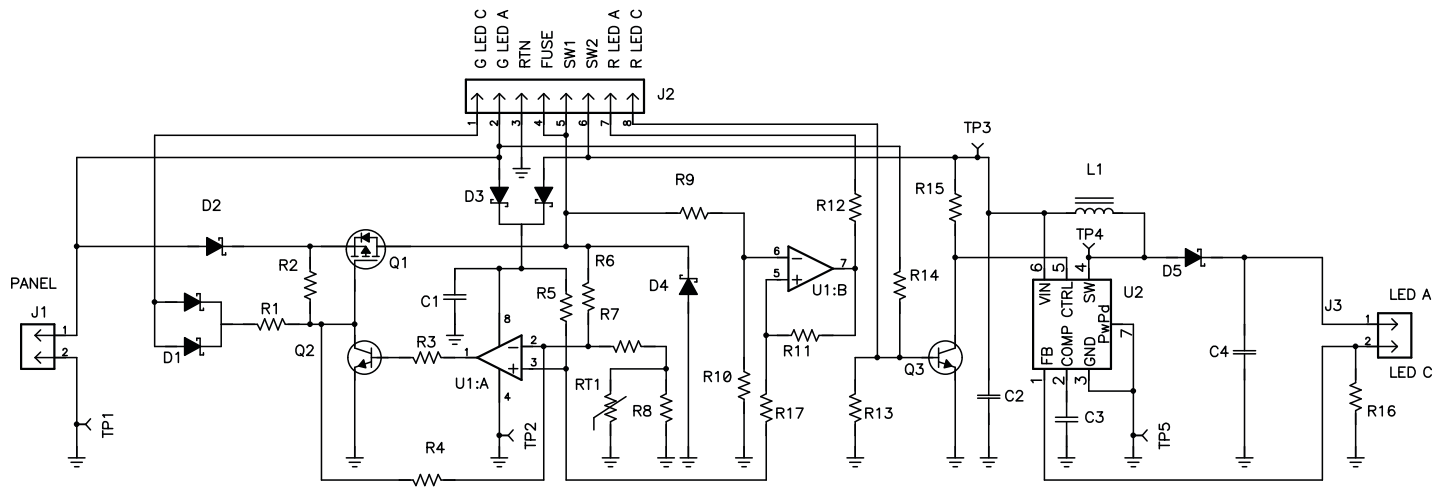
### Performance Data



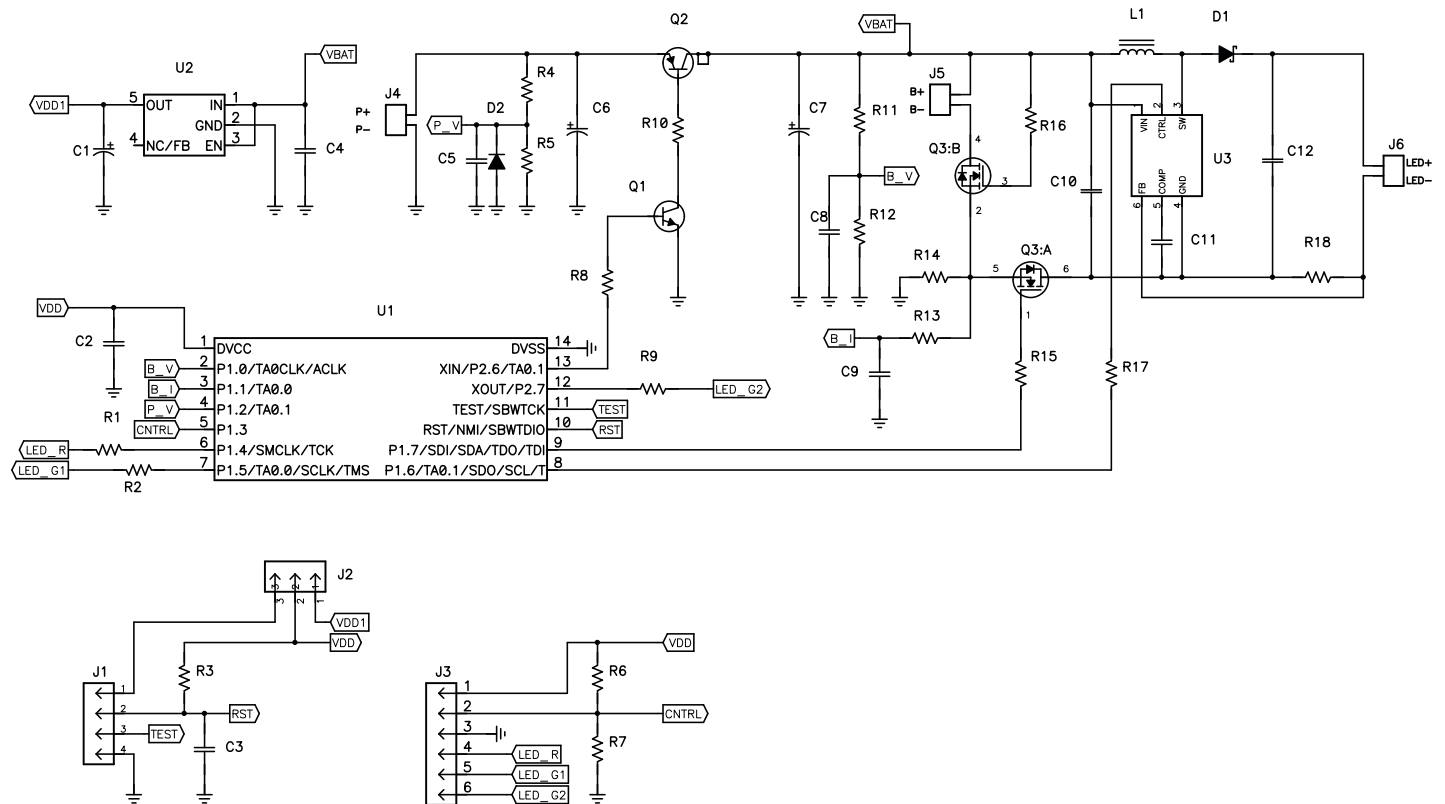


# DC Powered LED Drivers

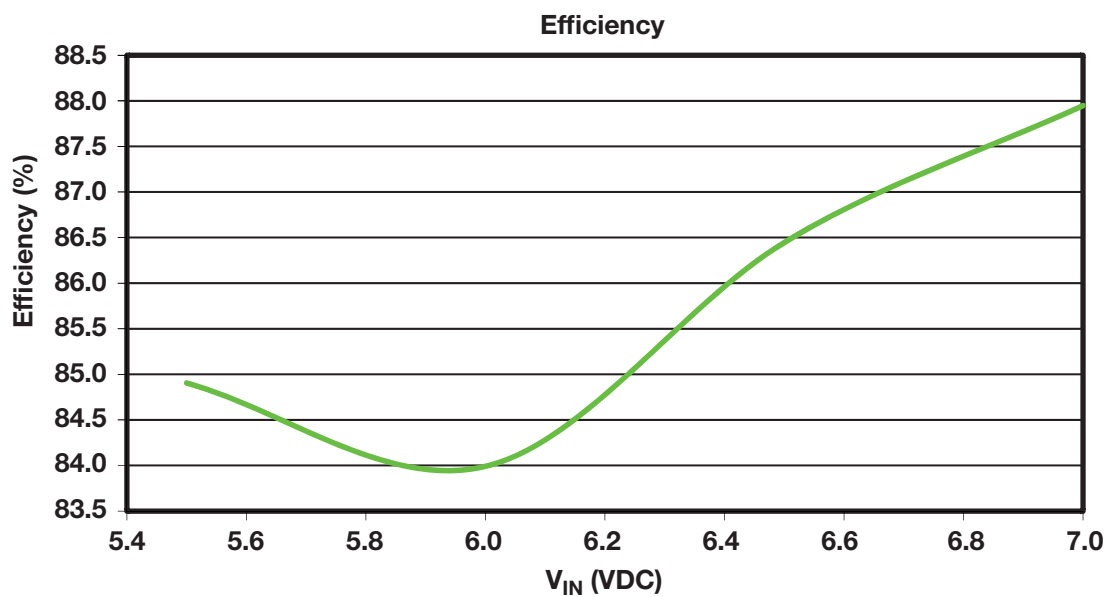
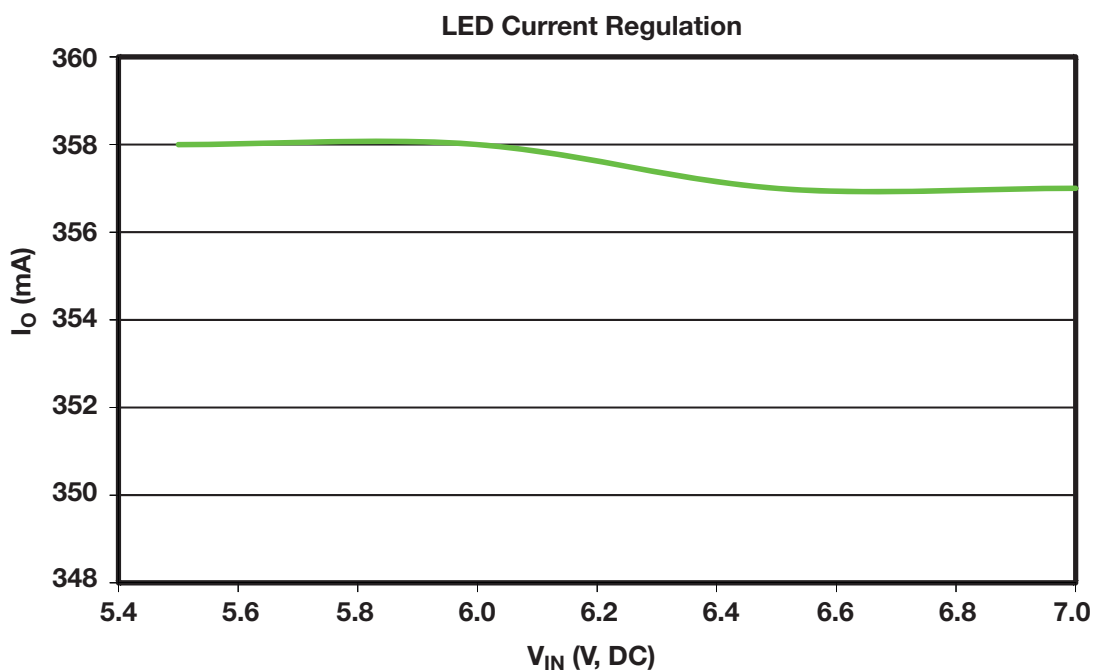
## ➔ PMP3579 – 3W LED Lantern Driver (TPS61165)



## ➔ PMP3676 – 3W LED Lantern Driver Using MSP430™ Controller

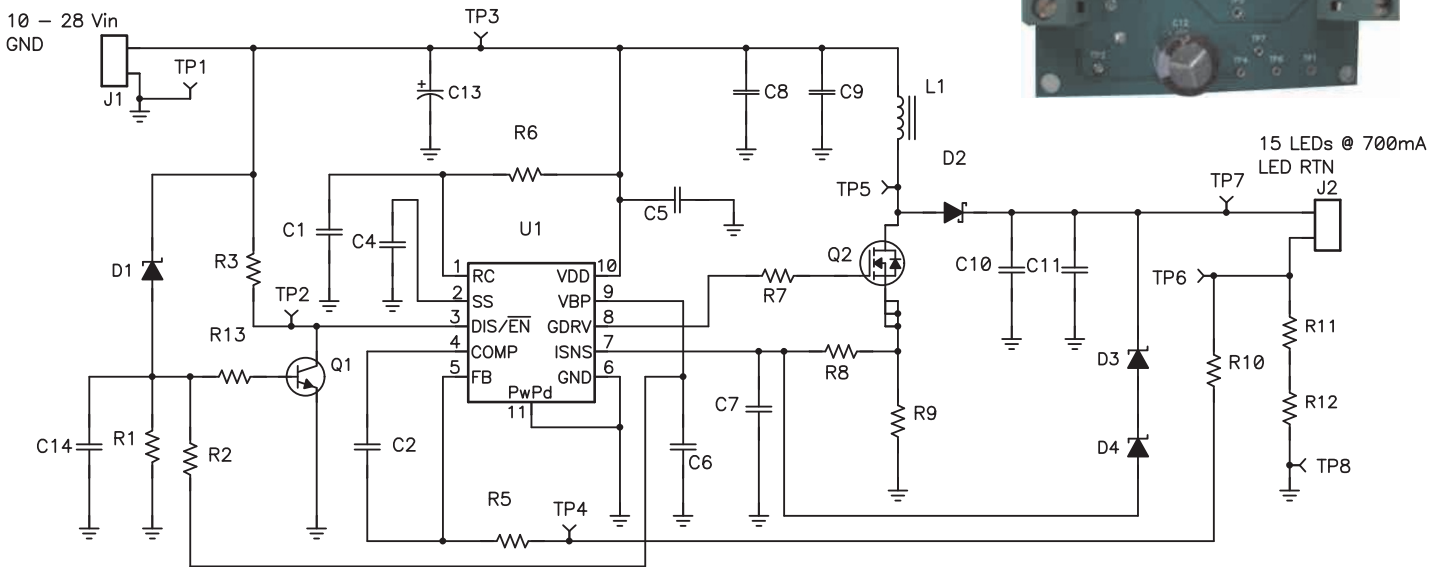


### Performance Data

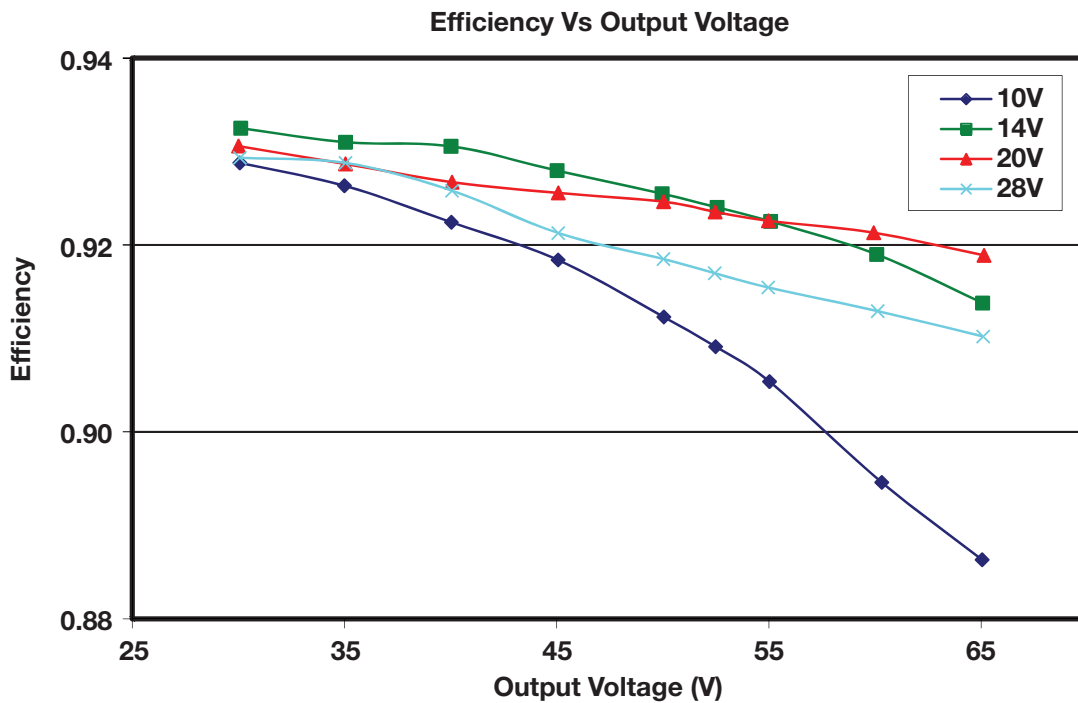


# DC Powered LED Drivers

## ➔ PMP3543 – 18 to 45W Solar-Street-Light Driver (TPS40211)



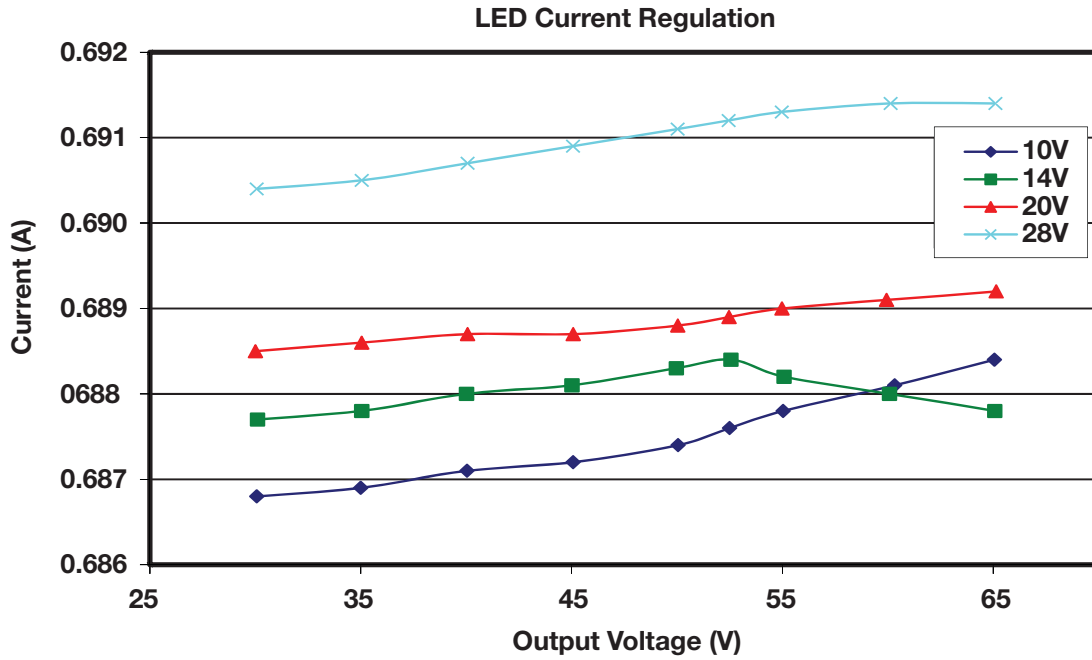
### Performance Data



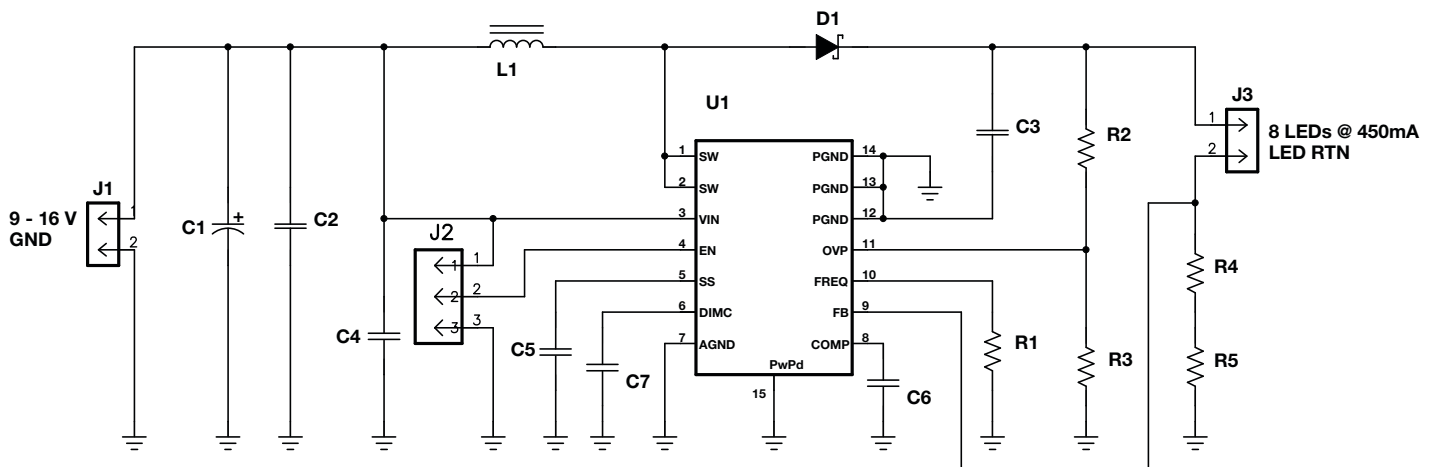
# DC Powered LED Drivers

## → PMP3543 – 18 to 45W Solar-Street-Light Driver (TPS40211)

### Performance Data



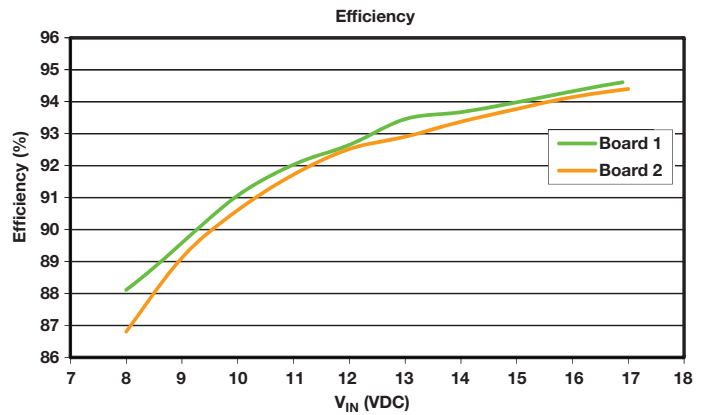
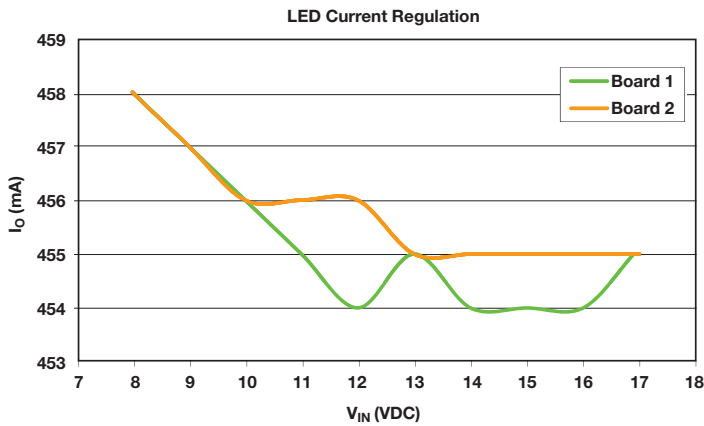
## → PMP3588 – Solar-Powered Down-Lighting Driver (TPS61500)



# DC Powered LED Drivers

## ➔ PMP3588 – Solar-Powered Down-Lighting Driver (TPS61500)

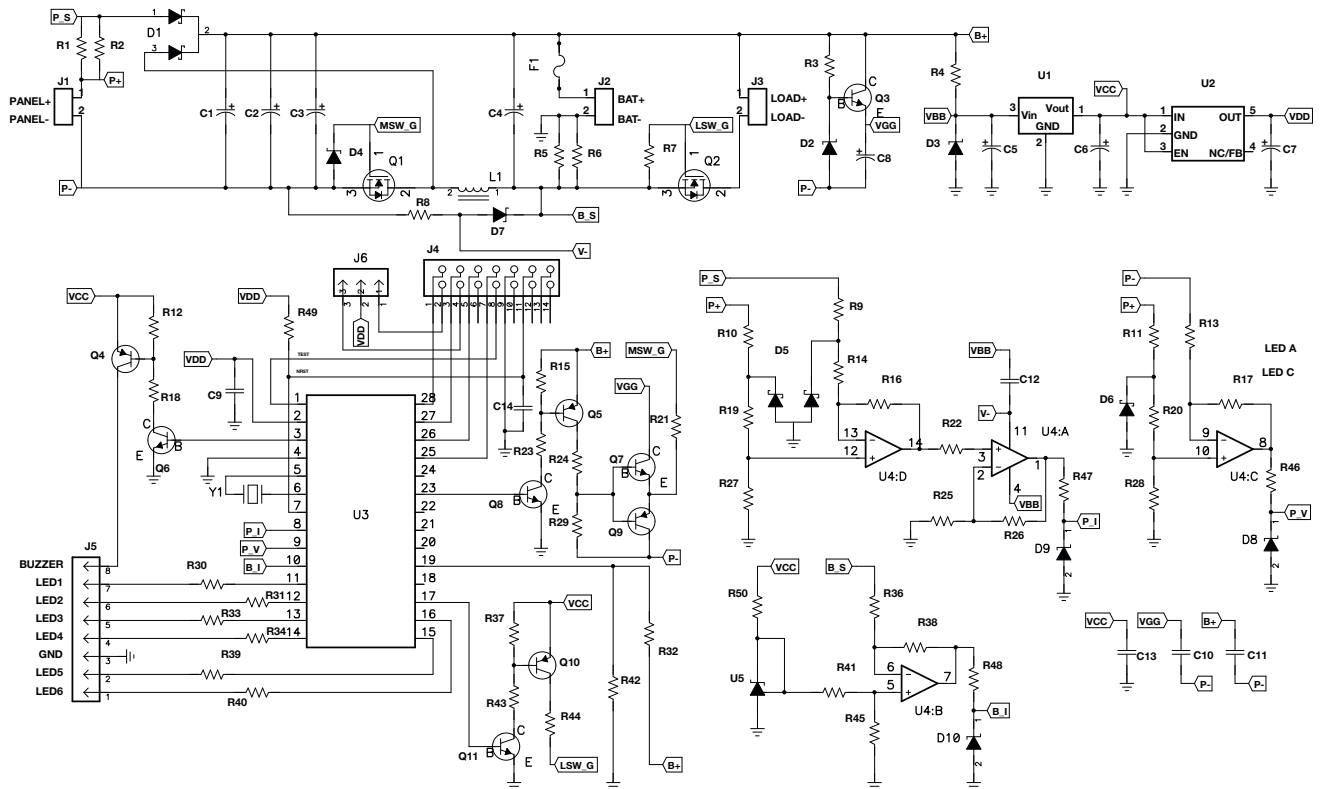
### Performance Data



## ➔ 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

### TPS92001/2

#### Key Features

- Ideal for single stage LED driver designs
- Isolated and nonisolated 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

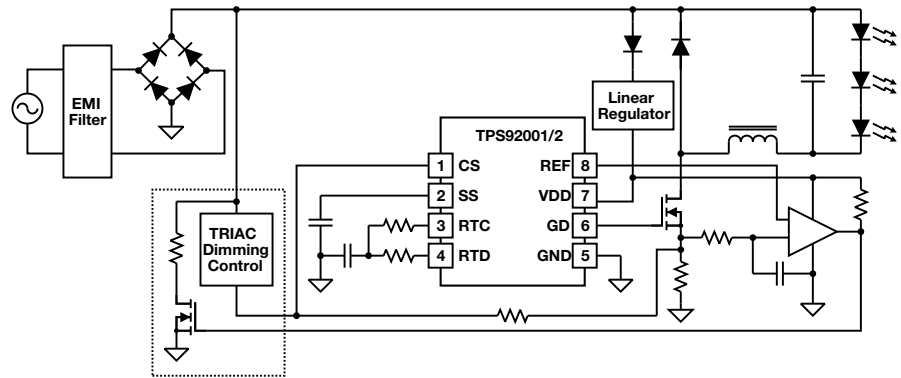
#### Benefits

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

- Power for microcontroller
- Protects driver from abnormal conditions
- Lower switching losses, smaller heat sink

#### 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

### TPS92010

#### 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

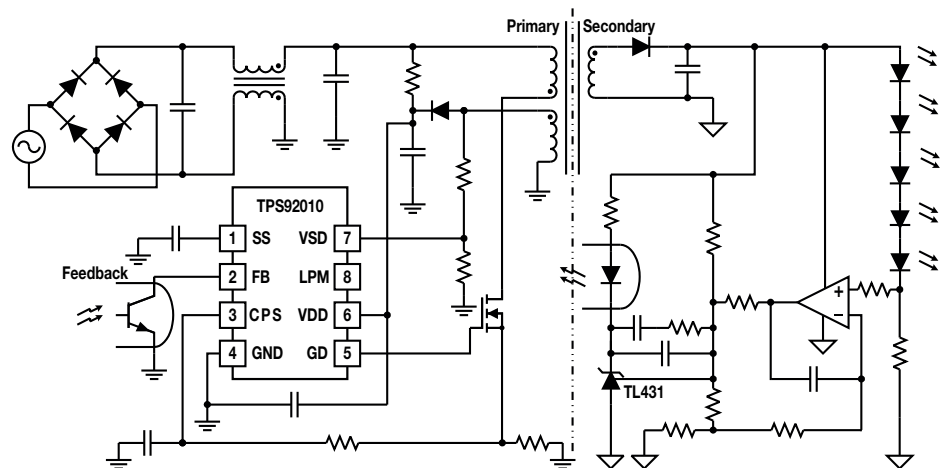
#### Benefits

- 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

- Safely shuts down driver if open-circuit or over-temperature condition is present
- Protects driver from abnormal conditions
- Lower switching losses reducing system cost

#### 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

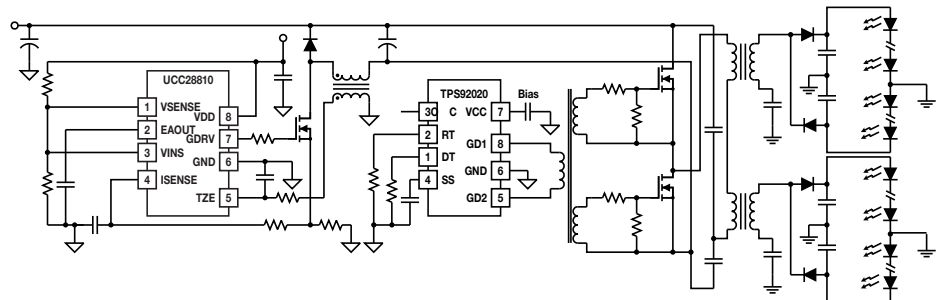
#### Benefits

- 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

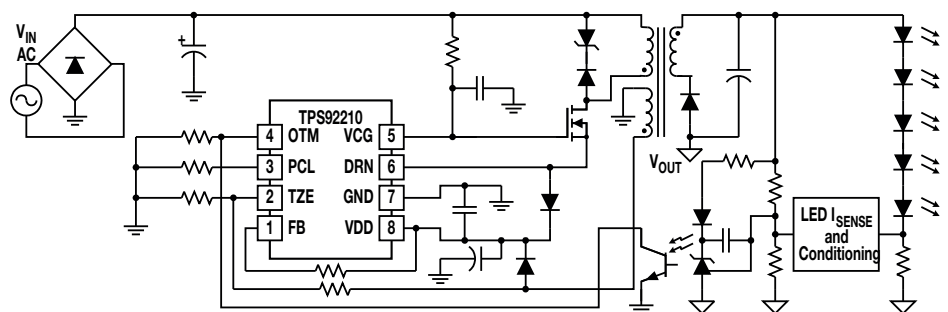
- Flexible operation modes: peak primary current, constant ON-time or both
- Cascoded MOSFET configuration
- Works with TRIAC dimmers
- DCM or transition-mode operation
- Advanced overcurrent protection

#### 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 Driver Controllers

## LED Lighting Power Controller

### UCC28810/1

#### Key Features

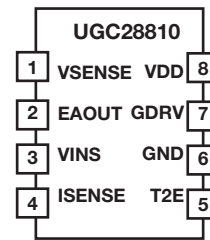
- Transformer zero-energy detection (transition-mode control)
- Implements single-stage power-factor correction and LED current regulation
- Application circuit implements industry standard TRIAC phase-angle dimming
- Improved transient response
- UVLO, OVP and open feedback
- Low startup current and accurate internal  $V_{REF}$
- 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

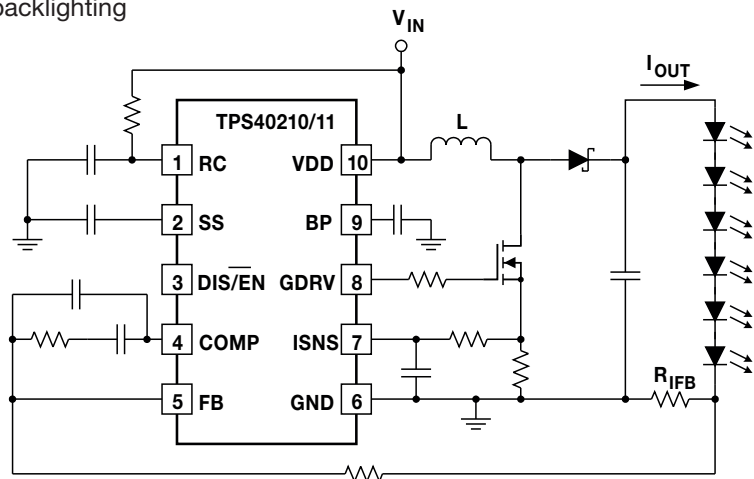
- Design and implementation flexibility
- Fewer external components
- Protects the device upon string short

#### Applications

- High-current LED drivers
- LED lighting solutions
- LED backlighting

#### Benefits

- Number of LEDs in series is limited by external MOSFET and boost ratio
- Enables use of small  $I_{SENSE}$  resistors with lower power dissipation



# LED Driver Controllers

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

### TPS61165

#### Key Features

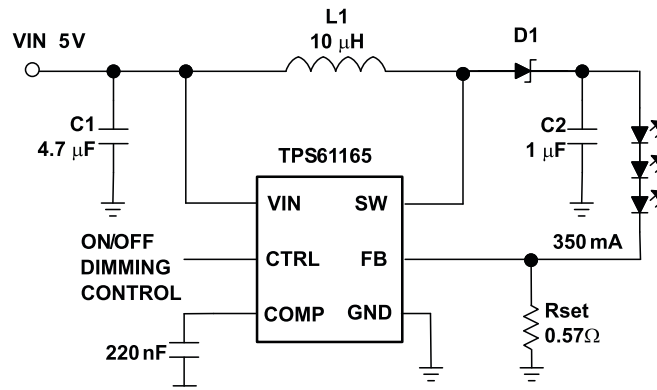
- 3 to 18 V input voltage range
- Multi-function digital pin (CTRL)
- 2x2 mm QFN or SOT-23 package

#### 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 for example)



L1: TOKO #A915\_Y-100M  
 C1: Murata GRM 188R61A475 K  
 C2: Murata GRM 188R61E105K  
 D1: ONsemi MBR0540T1  
 LED: OSRAM LW-W5SM

**Digital dimming with up to 32 steps - no audible noise**

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

### TPS61500

#### Key Features

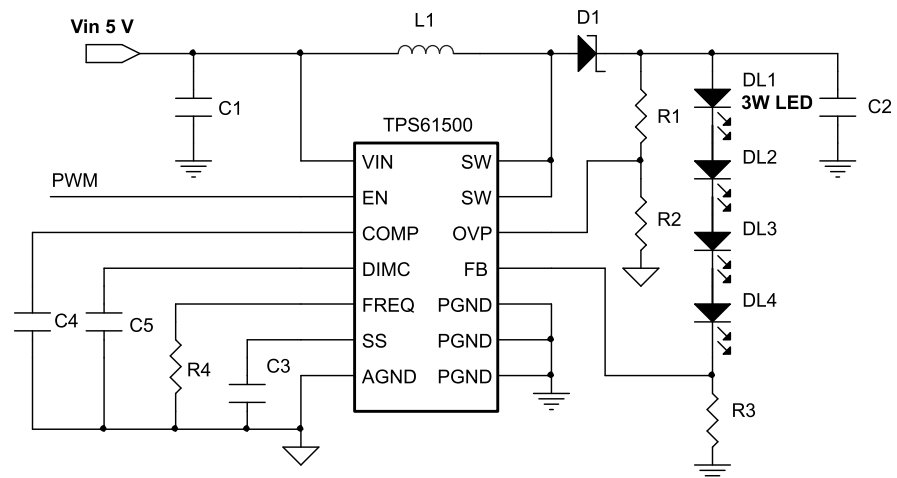
- 2.9V to 18V input voltage range
- 3.0A current switch (integrated FET)
- Four 3W LEDs from 5V<sub>IN</sub>
- Eight 3W LEDs from 12V<sub>IN</sub>
- 200kHz to 2.2MHz switching frequency
- Analog and PWM brightness dimming
- User defined softstart
- Up to 93% efficiency
- 14-pin HTSSOP package

#### 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



## 3.5 to 28V Input 2-A DC/DC Converters

### TPS54231, TPS54233

#### 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

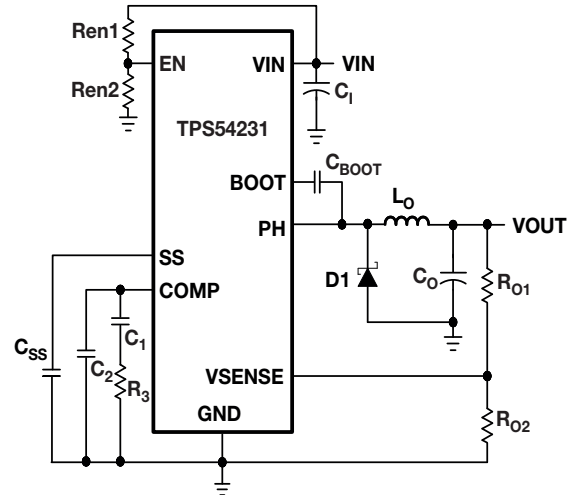
#### Benefits

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

- 570kHz allows smaller L & C; 285kHz allows higher  $V_{IN}$  with lower  $V_{OUT}$  (small duty cycle)
- Supports low voltage DSP/FPGA processors
- Reduces inrush currents during startup
- Stable with many capacitor types, including ceramic or electrolytic

#### 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

### bq24650

#### 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 LiFePO<sub>4</sub> cells or 6 Li-Ion/polymer cells
- ±0.5% charge voltage regulation accuracy over 0 to 85°C

#### Benefits

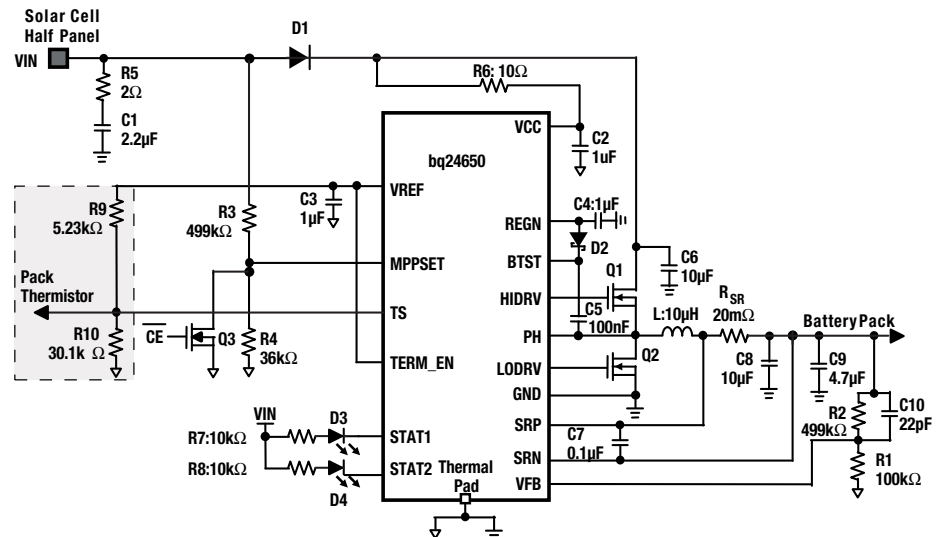
- Simple resistor programmable MPPT vs. software/MCU-based solution – “Set it and forget it”
- 5X the charging current vs. competing solution for the max battery capacity
- Supports 2 additional cells in series vs. competing solar charging solution

- Maximize capacity after 100's of charge cycles with 10+% more capacity than competing solution

#### Applications

- Solar powered applications
- Remote monitoring stations

- LiFePO<sub>4</sub> applications
- Portable handheld instruments
- 12V to 24V automotive systems
- Current limited power source



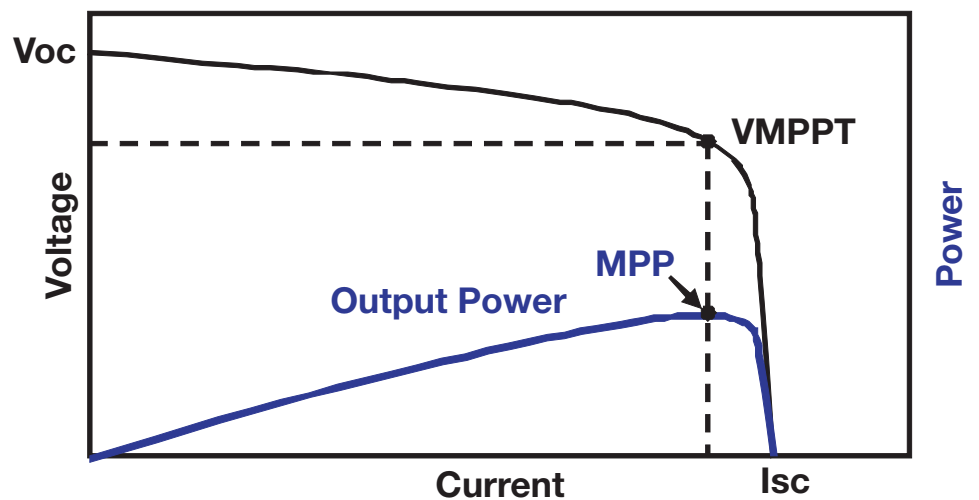
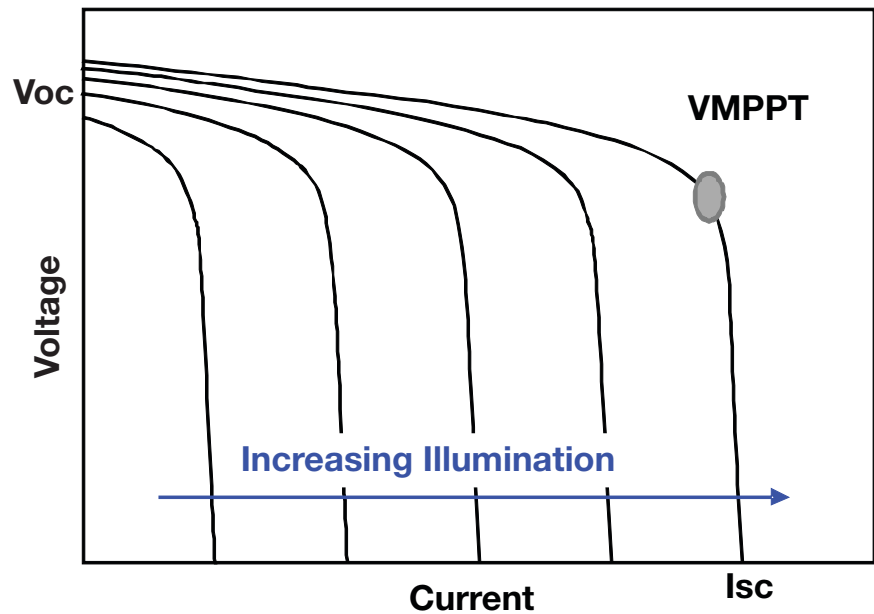
# LED Driver Controllers

## 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

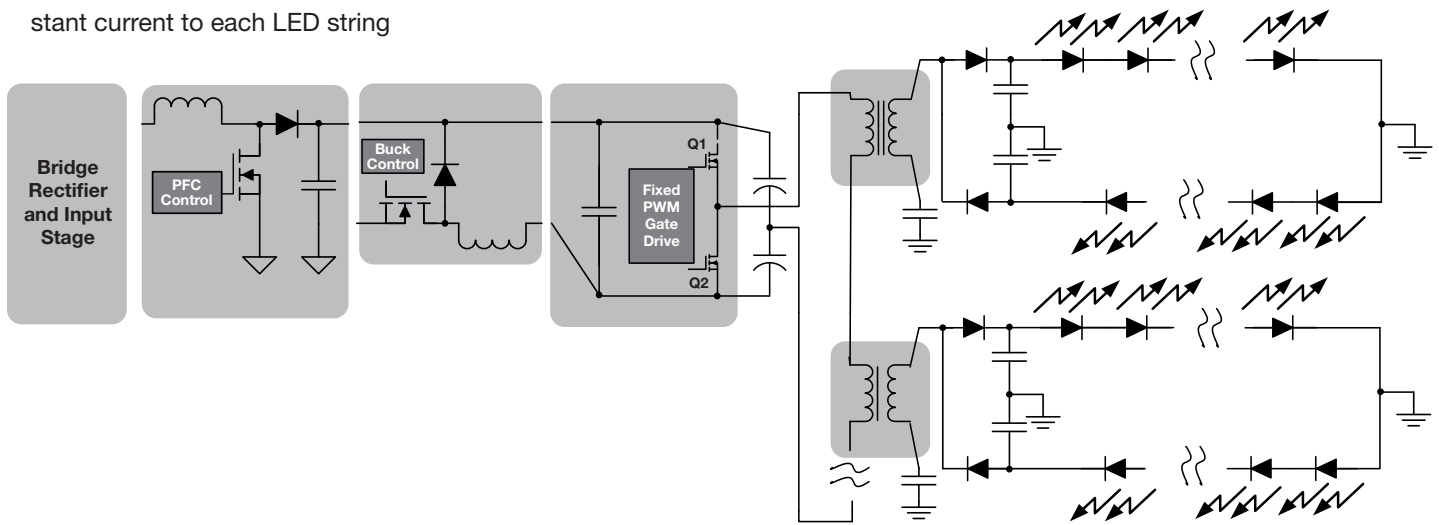
- PFC Stage: Required in any implementation
- Low-Side Buck: Provides constant LED current and main control
- Series Transformers: Provides constant current to each LED string

### Benefits

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

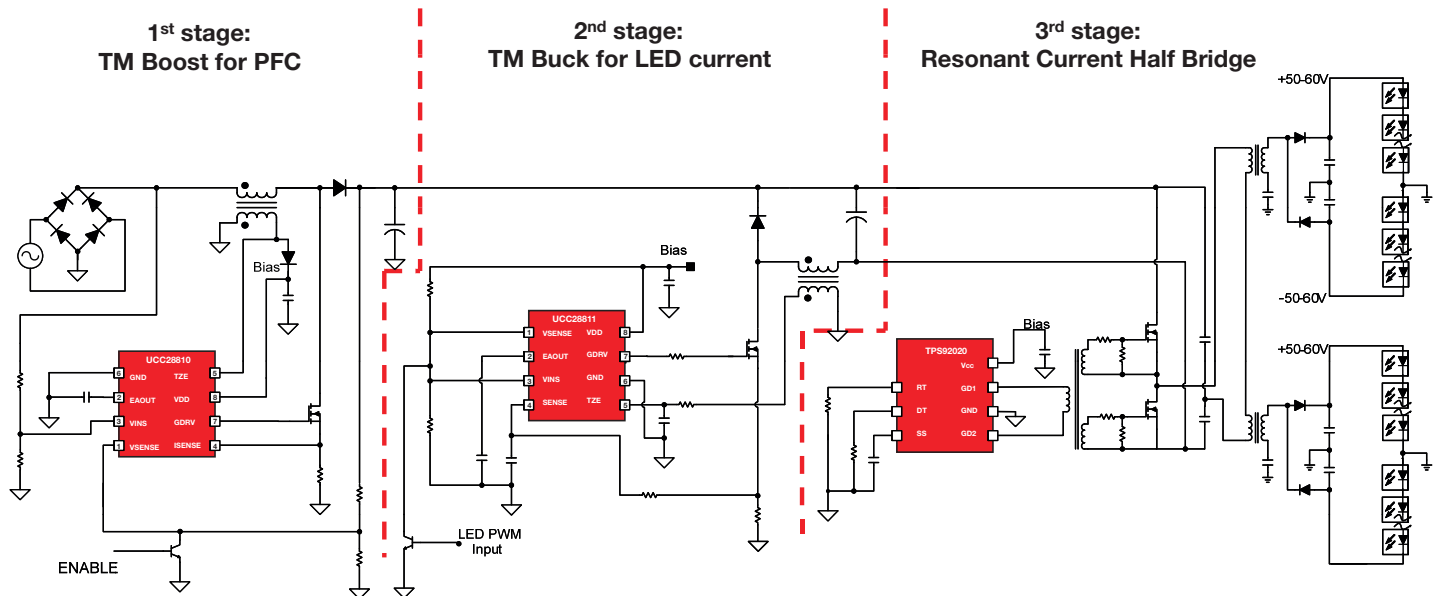
### Drawback

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



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

### UCC2810EVM-003 Evaluation Module





# Evaluation Modules (EVMs)

## 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

Parameter	Minimum	Typical	Maximum	Units
Input Voltage Range	185	–	265	V <sub>rms</sub>
Maximum Input Current	–	0.52	–	A <sub>rms</sub>
Output Voltage, V <sub>OUT</sub>	14	–	17	VDC
Output Load Current, I <sub>OUT</sub>	0.31	0.325	0.34	ADC
System Efficiency	–	85%	–	–

## 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

Parameter	Minimum	Typical	Maximum	Units
Input Voltage Range	185	–	265	V <sub>rms</sub>
Maximum Input Current	–	0.52	–	A <sub>rms</sub>
Output Voltage, V <sub>OUT</sub>	14	–	17	VDC
Output Load Current, I <sub>OUT</sub>	0.31	0.325	0.34	ADC
Output Current Ripple at V <sub>IN</sub> = 230 VAC	–	36	–	mA <sub>pp</sub>
Switching Frequency	–	115	–	kHz
Peak Efficiency	–	87.3%	–	–
Full-Load Efficiency	–	87%	–	–
Power Factor at V <sub>IN</sub> = 230 VAC	–	>0.95	–	–

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