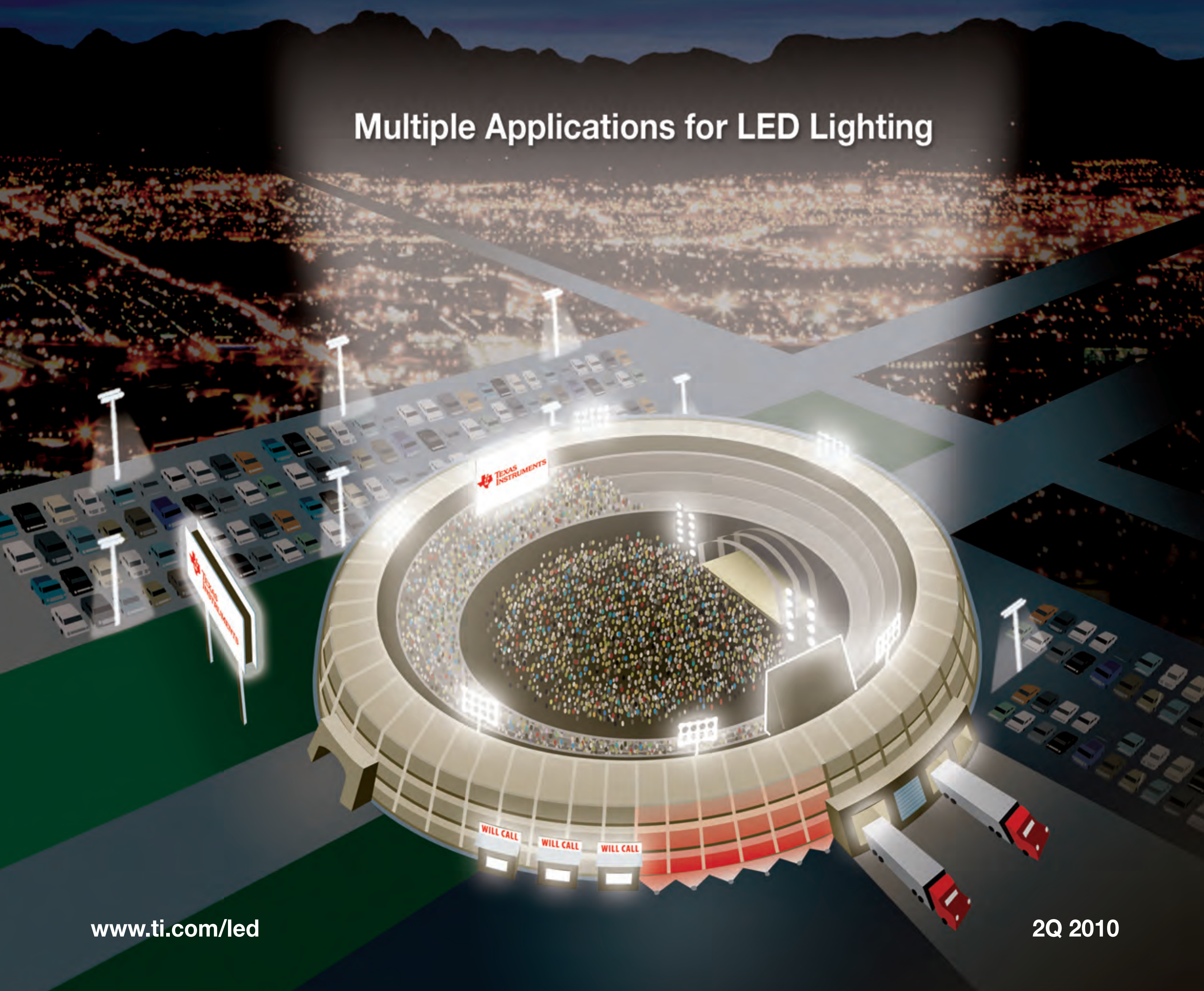
LED Reference Design Cookbook

Texas Instruments

Multiple Applications for LED Lighting



www.ti.com/led

2Q 2010

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LED Drivers							
Medium-Size LCD Backlight	3 series	Digital or PWM	3 to 12 V_{DC}	5 typical	820 max	TPS61165	54
Large-LCD Backlight Driver	Up to 96 (12 series, 8 strings)	Analog or PWM	4 to 24 V_{DC}	16 to 48	320	TPS61195	56
NEW! 24-Channel, 12-Bit PWM LED Driver	24 parallel	Digital or PWM	3.0 to 5.5 V_{DC}	2.0 to 17.0 V	40 per channel	TLC5951	58
NEW! 24-Channel, Constant-Current LED Driver with Global Brightness Control	24 parallel	Digital	3.0 to 5.5 V_{DC}	2.0 to 17.0 V	35 per channel	TLC5952	60
NEW! 16-Channel LED Driver with Load-Switch Dimming Control	16 parallel	PWM or Analog	3.0 to 5.5 V_{DC}	17 max	100 per channel	TLC59116	62

LED Reference Design Cookbook

Helping You Solve Your Lighting Design Challenges

The LED 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

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 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

TPS92010 NEW!

Description

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 lightbulbs 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 TPS92010 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
- High efficiency
- TI lossless dimming circuit for a cooler, lower-power system during deep dimming

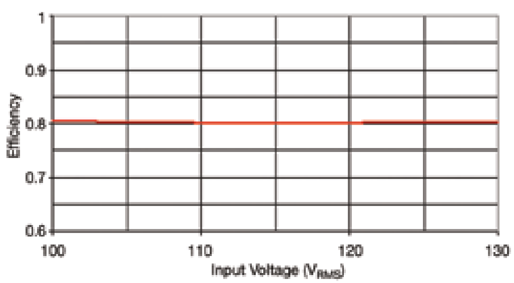
Web Links

Datasheets, user's guides, samples:
www.ti.com/sc/device/**TPS92010**

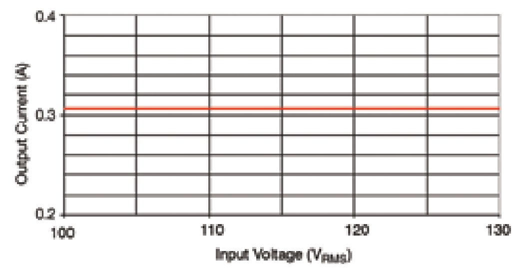
Design Specifications

Parameter	Minimum	Typical	Maximum
Input voltage (V_{AC})	100	120	130
Output voltage (V_{DC})	9	—	18
Output current (A)	—	0.35	—
Efficiency (%)	—	80	—

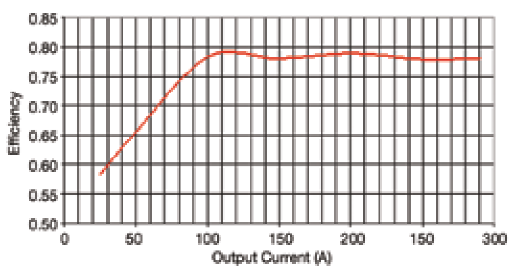
Efficiency without Dimmer



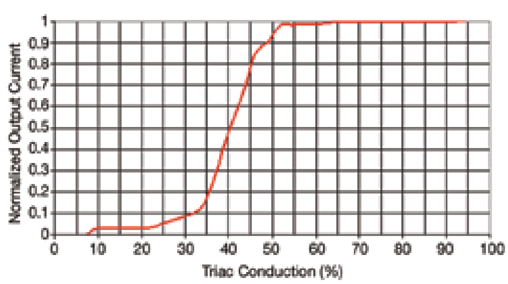
Output Current Regulation



Efficiency with Dimmer



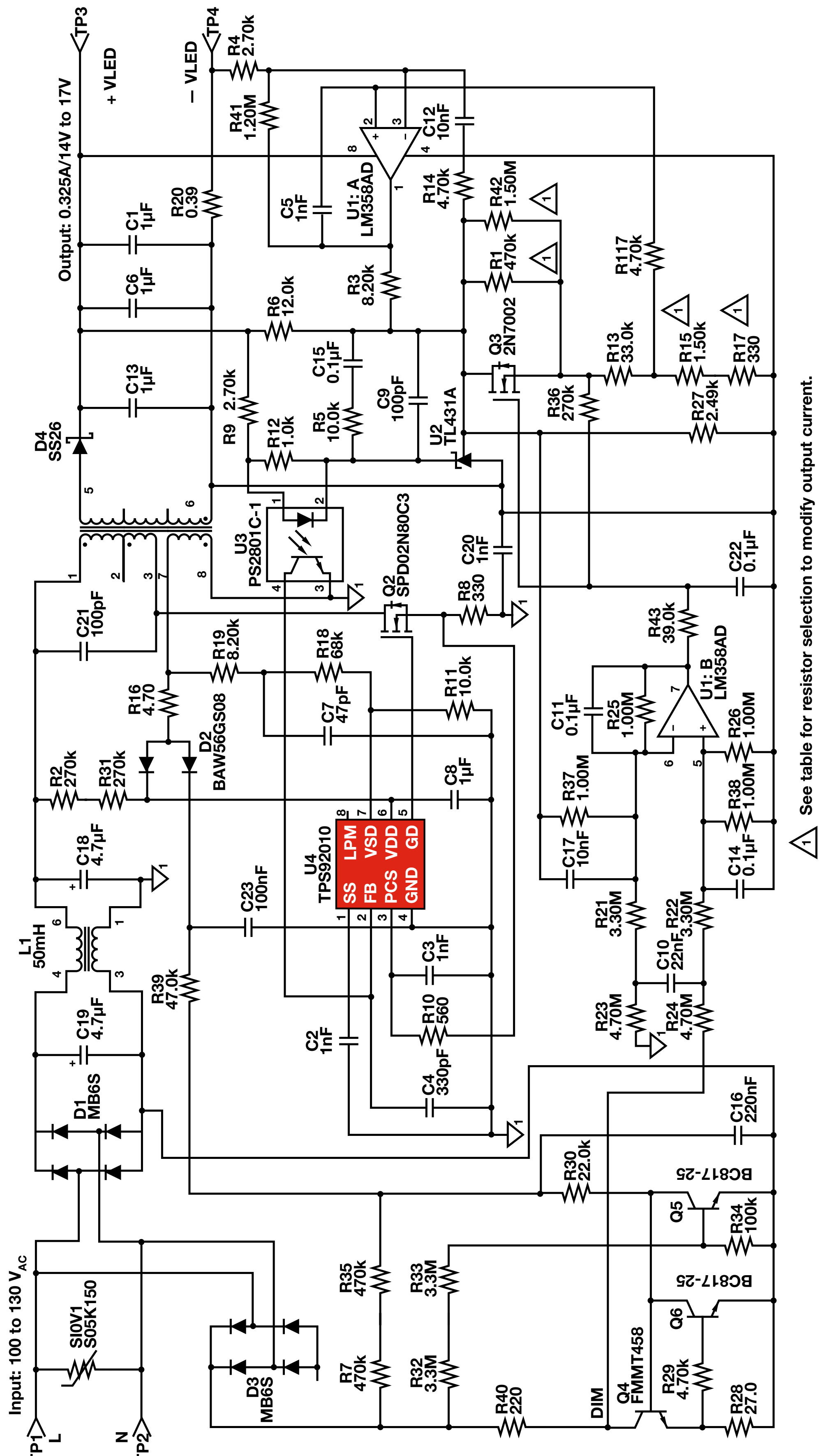
Dimming Performance



Adjusting the Output Current

Output Current (A)	R15 (Ω)	R17 (Ω)	R1 (Ω)	R42 (Ω)
0.20	1000	150	330	1000
0.225	1200	86	390	1000
0.25	1200	220	470	1000
0.275	1000	560	680	680
0.30	1500	220	680	680
0.325	1500	330	470	1500
0.35	1000	1000	820	1000
0.40	1800	470	1000	1000
0.45	2200	390	1500	1000
0.50	2700	220	1500	1000
0.60	3300	150	1500	1500
0.70	3900	270	2200	1500

TPS92010



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

TPS92010 PMP3522

Description

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

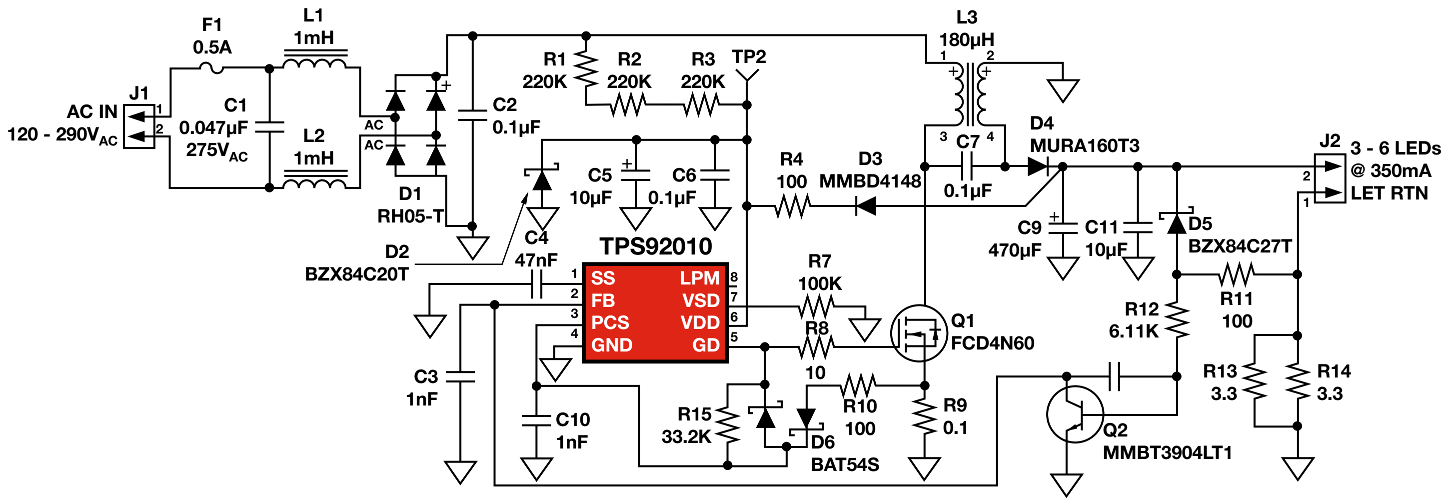
Web Links

Datasheets, user's guides, samples:
www.ti.com/sc/device/**TPS92010**

Design Specifications

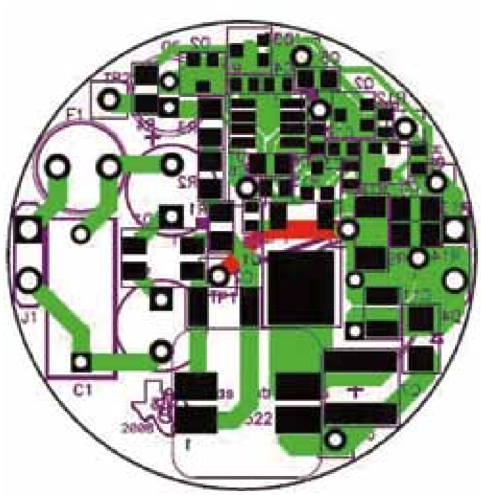
Parameter	Minimum	Typical	Maximum	Unit
Input voltage	120	—	290	V_{AC}
Output voltage	—	—	24	Volts
Output current	—	0.350	—	Amp

PMP3522 Schematic

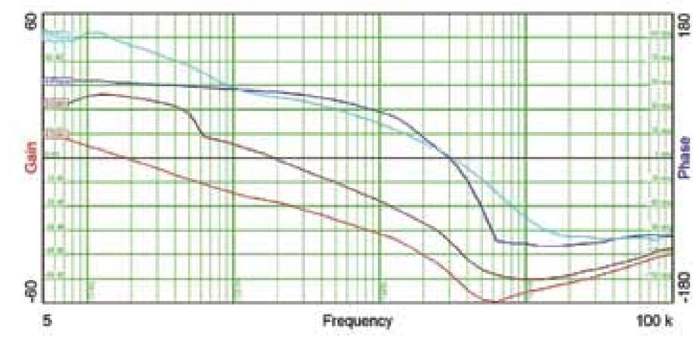


For more reference designs, see: www.ti.com/powerreferencedesigns

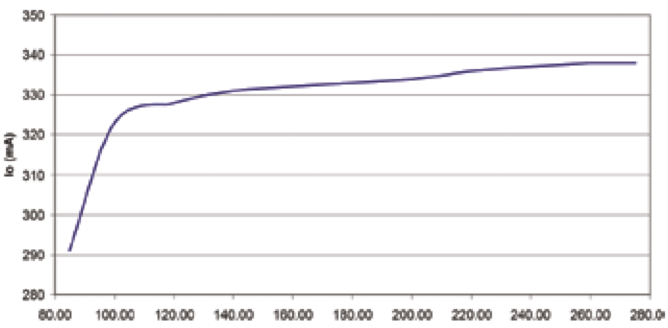
Laid Out for Bulb Replacement



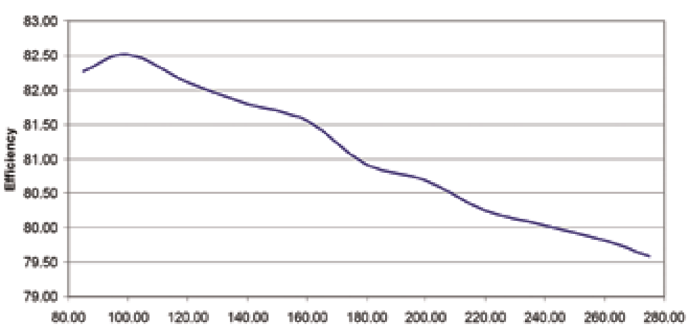
Control Loop Frequency



Regulation



Efficiency



TPS92210EVM

NEW!

Description

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 quasiconstant "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

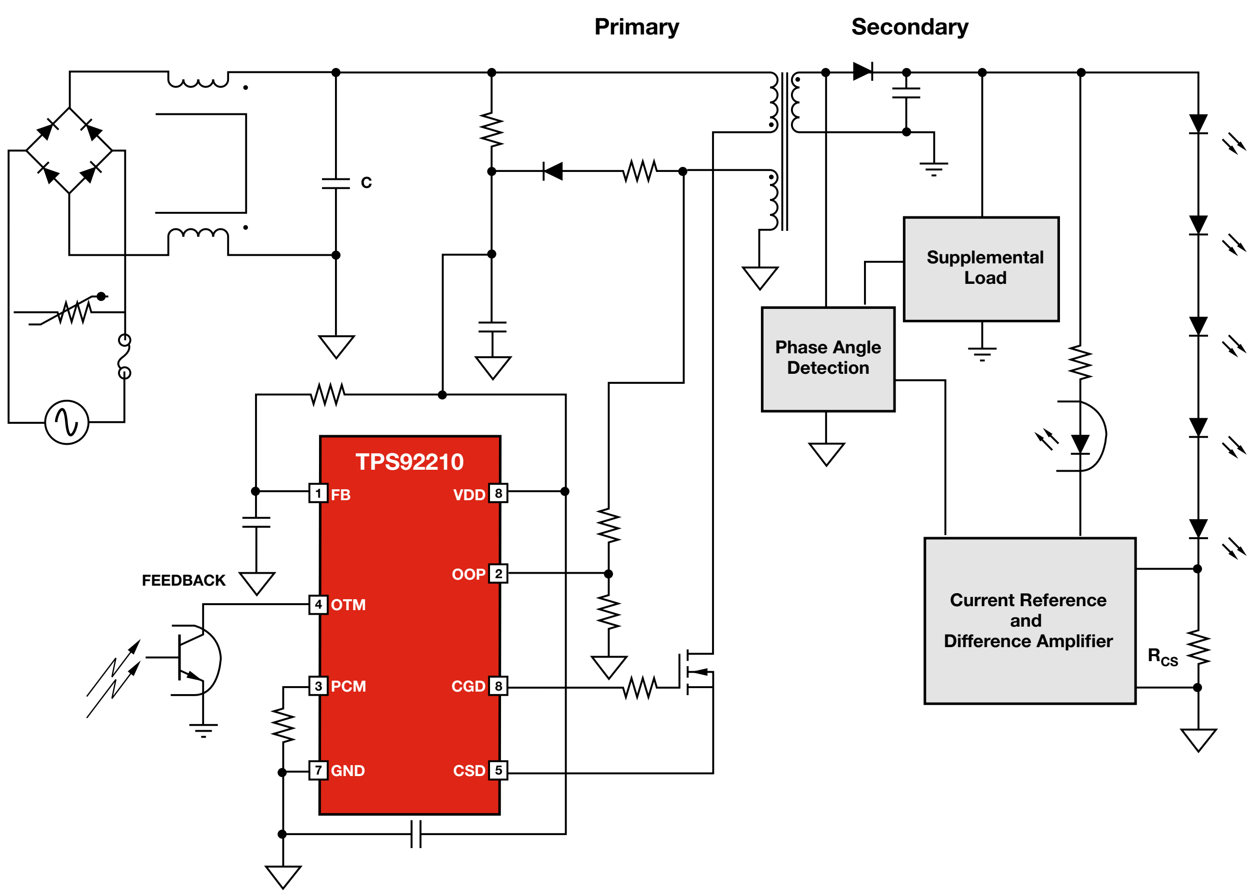
- AC/DC TRIAC dimmable LED driver with PFC
- Ideal for residential lighting
- Single stage (PFC and LED current regulation)
- 12- to 25-W applications
- Deep TRIAC dimming capability

Web Links

www.ti.com/**tps92210evm**

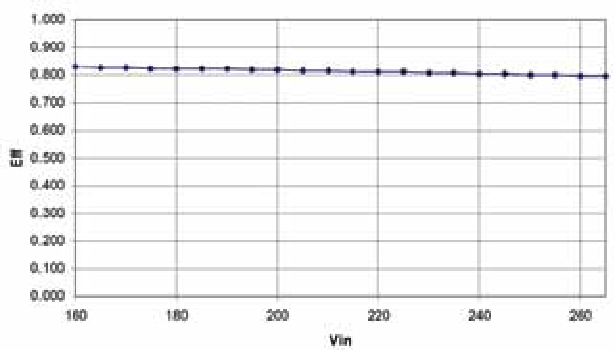
Description	Parts	V_{IN} Range		V_{OUT} (DC) Range		Number of LEDs	I_{OUT} (max)	P_{OUT} (max)	Eff.	PFC	ISO	Dimming In	Dimming Out
TPS92210EVM High efficiency, PFC and TRIAC dimmable LED lighting driver	TPS92210	180 V	265 V	17 V	21 V	6	350 mA	11 W	83%	Yes	Yes	TRIAC	Linear

TPS92210EVM Block Diagram

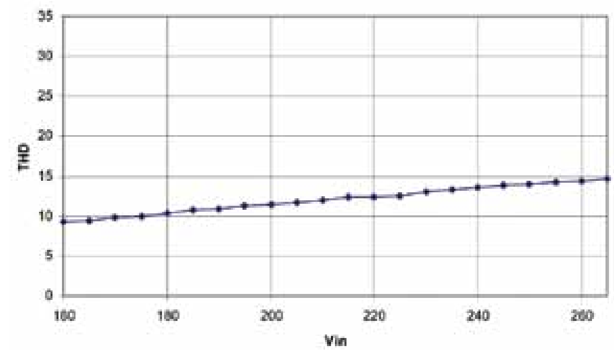


For more reference designs, see: www.ti.com/powerreferencedesigns

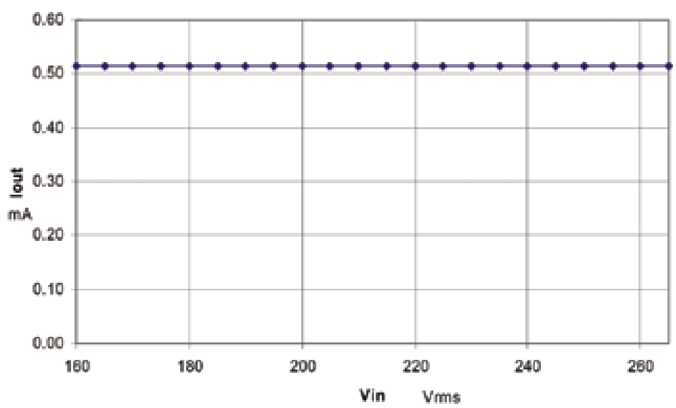
LED Lighting Driver's Efficiency



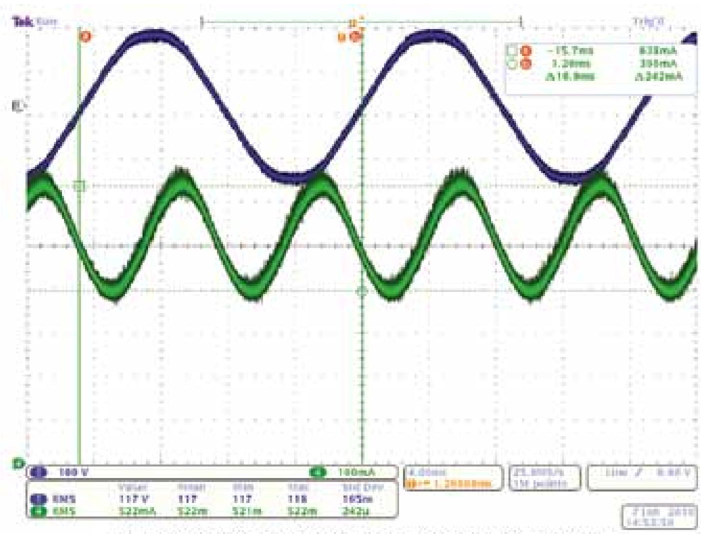
LED Lighting Driver's Total Harmonic Distortion



LED Lighting Driver's Current Regulation

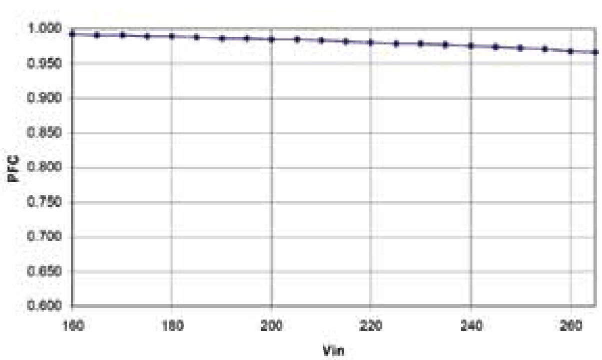


LED Lighting Driver's Current Ripple



Blue is VIN: 100V/div, Green is IOUT: 100mA/div, Time base: 4ms/div

LED Lighting Driver's PFC



TPS92001 PMP4981

Description

The PMP4981 is a reference design for an LED driver in a lightbulb-replacement circuit. The design is optimized to function with AC input sources that may be fed through an industry-standard TRIAC-based phase-cut dimmer.

The PMP4981's dimming function allows the string of LEDs to be dimmed to very low levels without flickering or stroboscopic effects. Current is drawn from the TRIAC only when needed, providing high efficiency with a non-isolated driver for a very-low-cost solution. This single stage provides high reliability, long life and high performance.

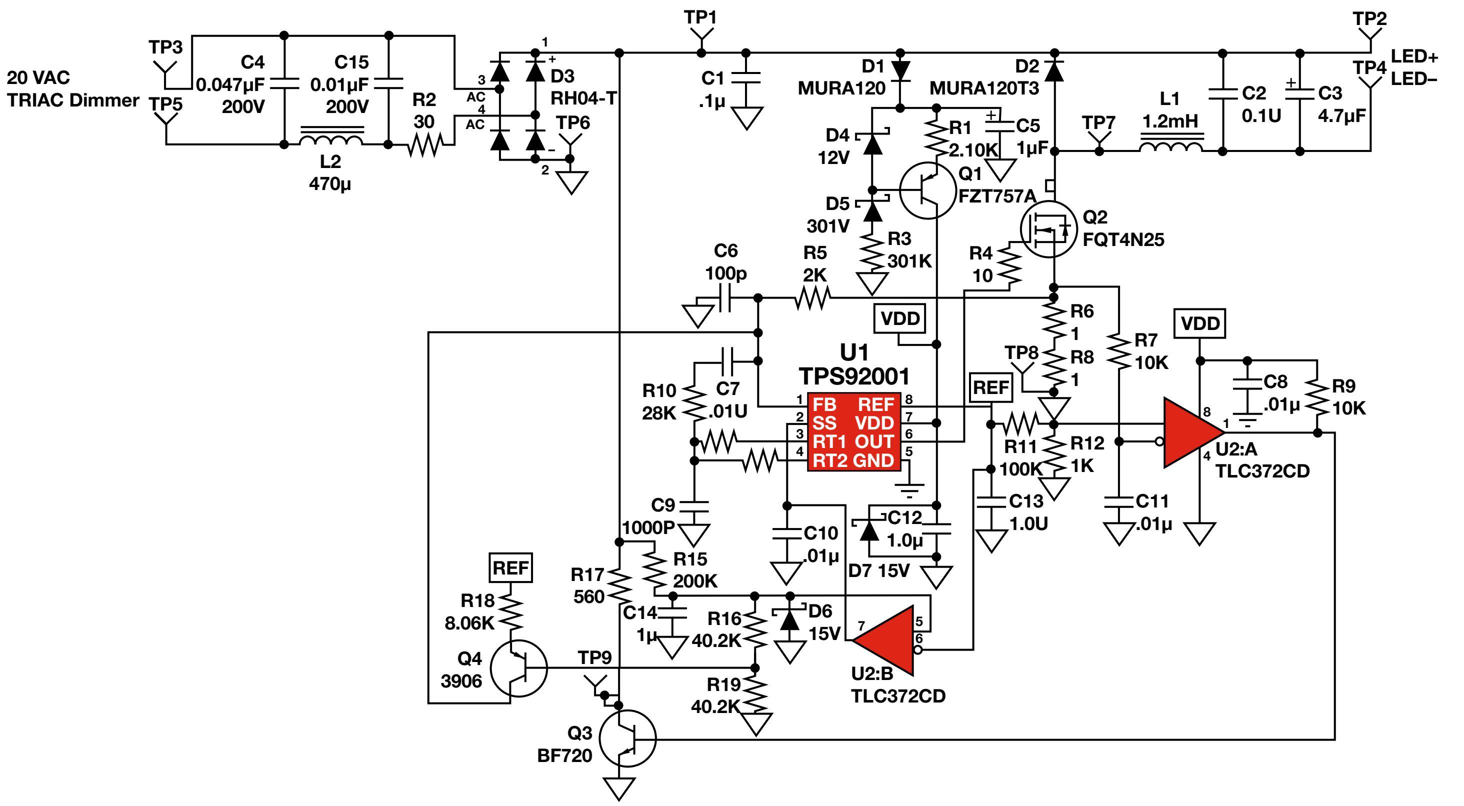
Key Features

- Low-cost, AC/DC TRIAC dimmable LED driver lighting reference design
- Ideal for residential lighting
- LED ripple current 100% (120 Hz)
- 6- to 11-W applications
- Deep TRIAC dimming capability
- No electrolytic capacitors option

Design Specifications

Description	Parts	V_{IN} (AC) Range	V_{OUT} (DC) Range	Number of LEDs	I_{OUT} (max)	P_{OUT} (max)	Eff.	PFC	ISO	Dimming In	Dimming Out	EVM
PMP4885 low-cost offline LED lighting driver	TPS92001 TLC372	90 130	24 32	7 to 9	450 mA	12 W	79%	No	No	TRIAC	PWM	Paper

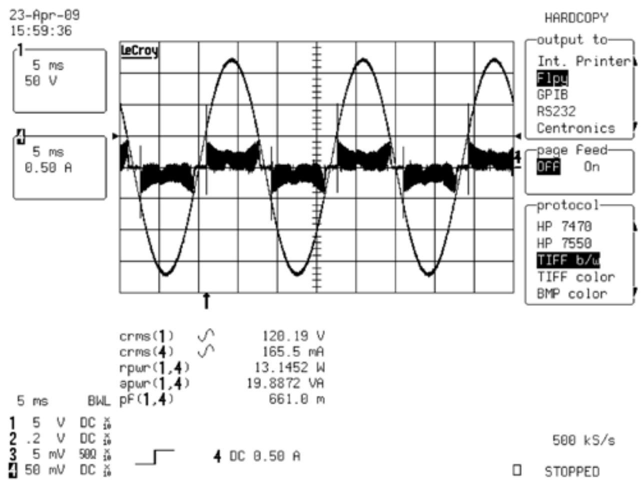
PMP4981 Schematic



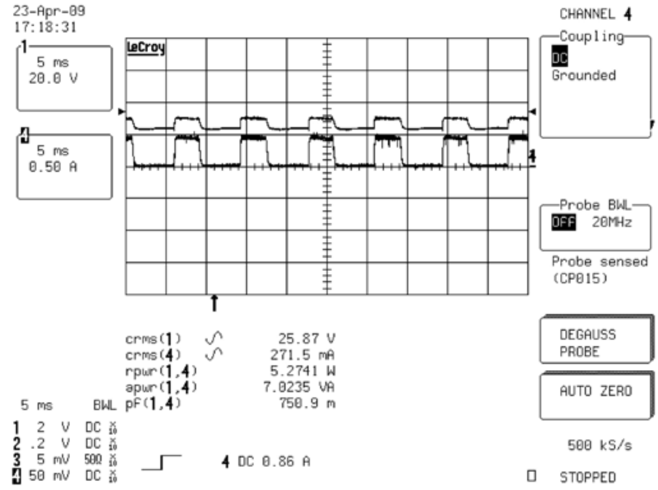
For more reference designs, see: www.ti.com/powerreferencedesigns

TPS92001 PMP4981

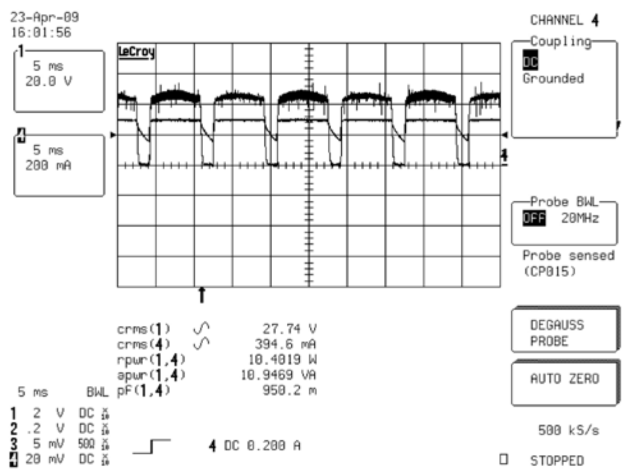
Line Current and Voltage – Dimmer at Full Power Position



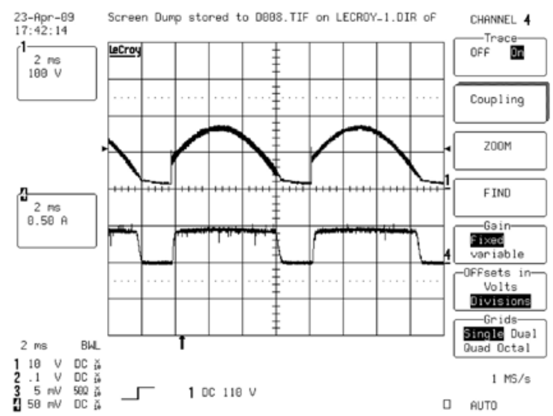
LED Current and Voltage – Dimmer at Half Power Position



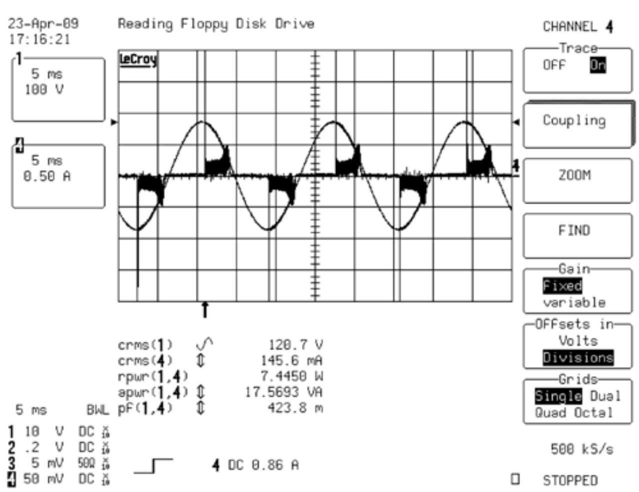
LED Current and Voltage – Dimmer at Full Power Position



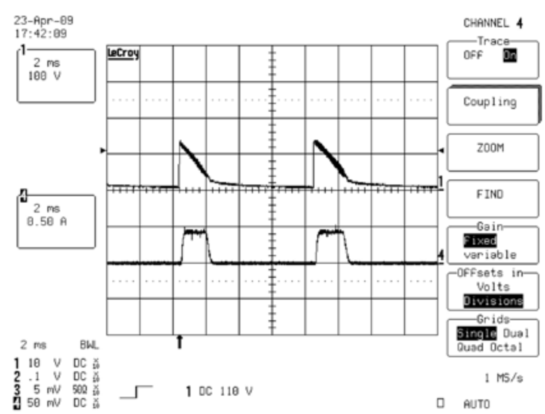
Rectified AC (Top) and LED Current (Bottom) — High Conduction Angle



Line Current and Voltage – Dimmer at ~ Half Power Position



Rectified AC (Top) and LED Current (Bottom) — Low Conduction Angle



UCC28810/UCC28810EVM-002

Description

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_{RMS}) 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_{DC}. 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

Datasheets, user's guides, samples:
www.ti.com/sc/device/**UCC28810**

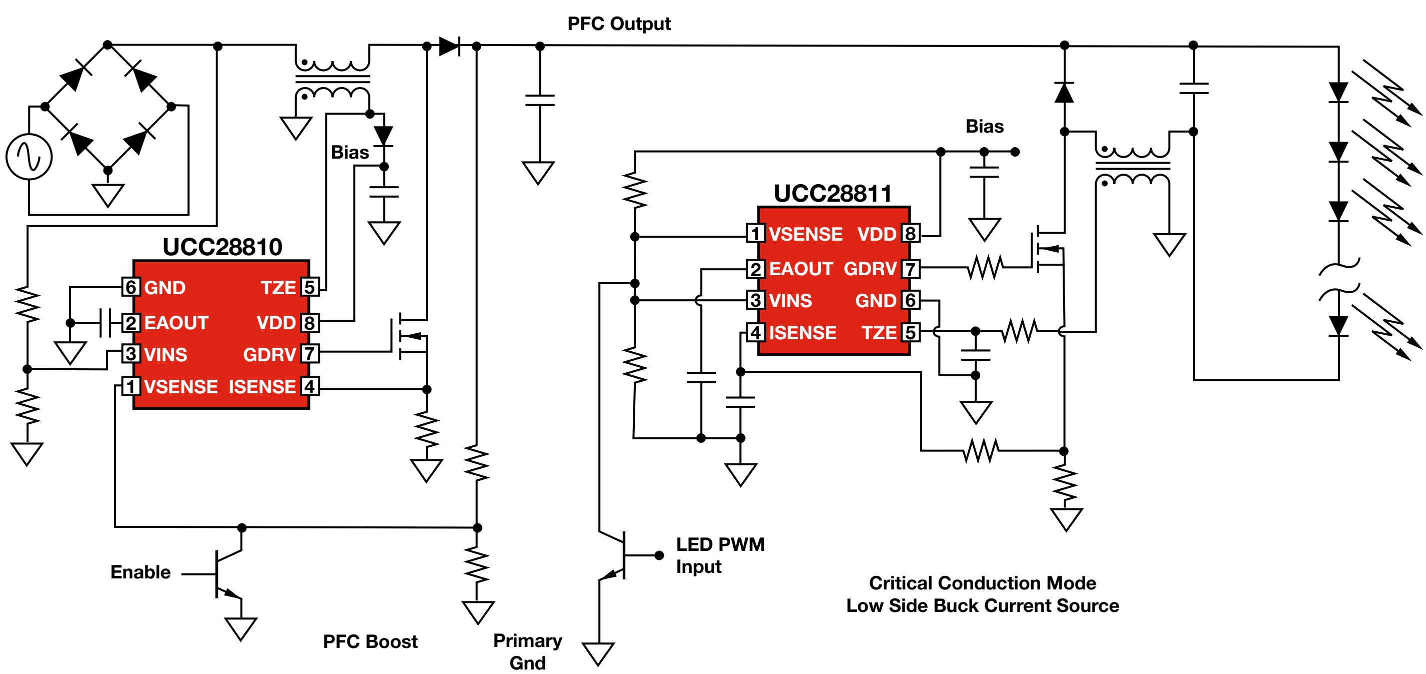
Reference designs:
www.ti.com/**powerreferencedesigns**

EVM:
www.ti.com/**ucc28810evm-002**

Design Specifications

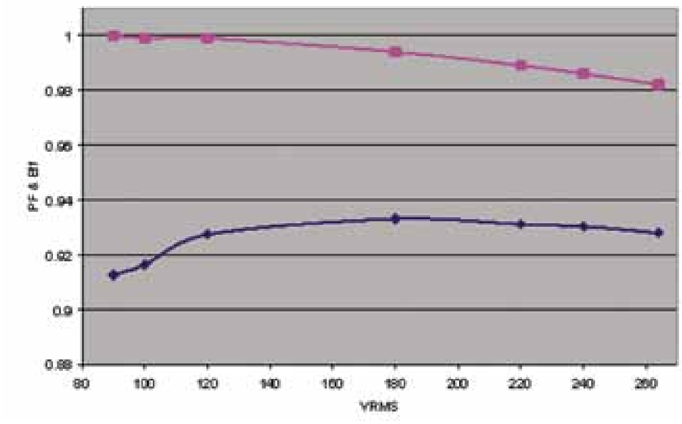
Description	Parts	V_{IN} (AC) Range	V_{OUT} (DC) Range	Number of LEDs	I_{OUT} (max)	P_{OUT} (max)	Eff.	PFC	ISO	Dimming In	Dimming Out	EVM
UCC28810 EVM002 100-W LED lighting driver	UCC28810 UCC28811	90 265	55 100	15-30	900 mA	100 W	93%	Yes	No	PWM	PWM	Yes

UCC28810EVM-002 Block Diagram



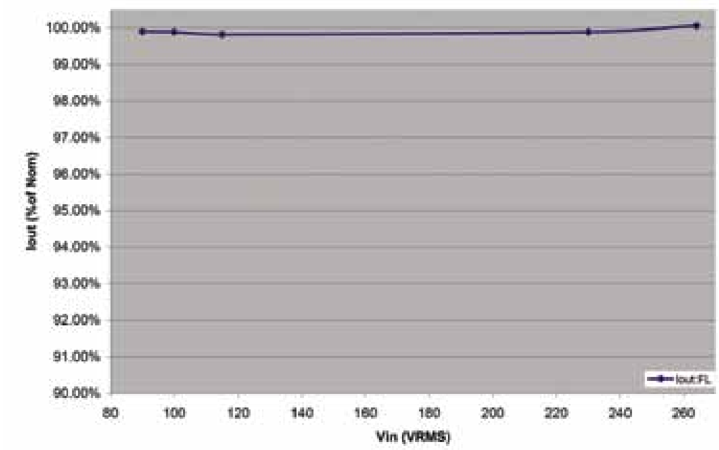
UCC28810/UCC28810EVM-002

Efficiency and Power Factor vs. Line Voltage



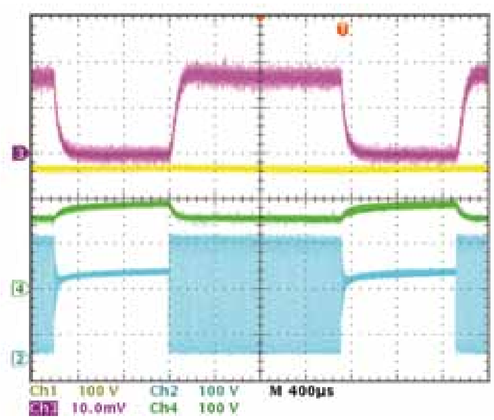
UCC28810EVM-002 efficiency and power factor vs. line voltage 30 Cree XRE LED's at 900 mA.

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



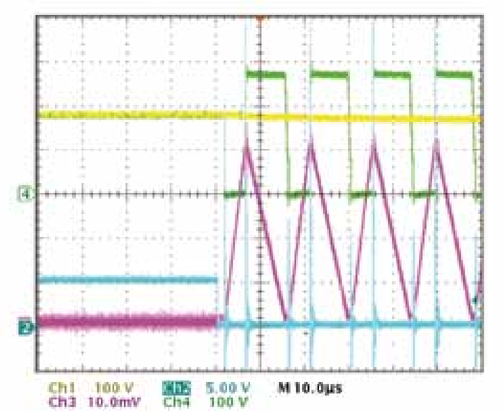
LED current regulation as a function of line voltage.

PWM Dimming Waveforms



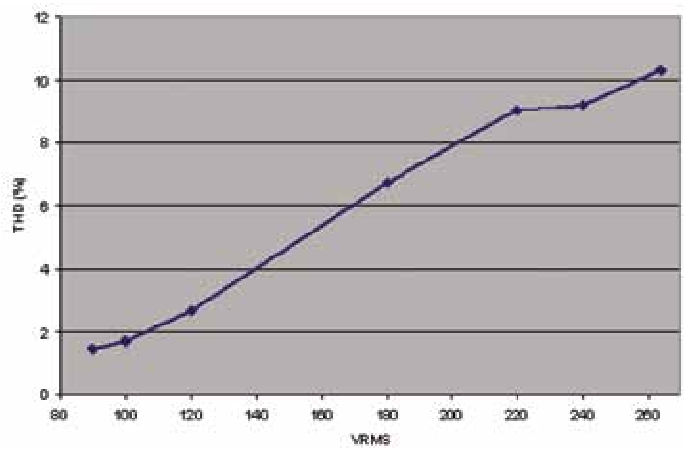
UCC28810EVM-002 transition mode buck PWM response. Ch1: Buck V_{IN}, Ch2: Buck V_{DS}, Ch3: LED current (0.5 A/Div), Ch4: LED voltage. Ch1 and Ch4 share GND reference.

PWM Dimming Response



UCC28810EVM-002 transition mode buck PWM response (expanded). Ch1: LED V_{OUT}, Ch2 PWM, Ch3 buck inductor current 500 mA/Div, Ch4 V_{DS} 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.

UCC28810/UCC28810EVM-003: Simp*LED*Drive™

Description

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

- Simp*LED*Drive™ 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

Reference designs:
www.ti.com/**powerreferencedesigns**

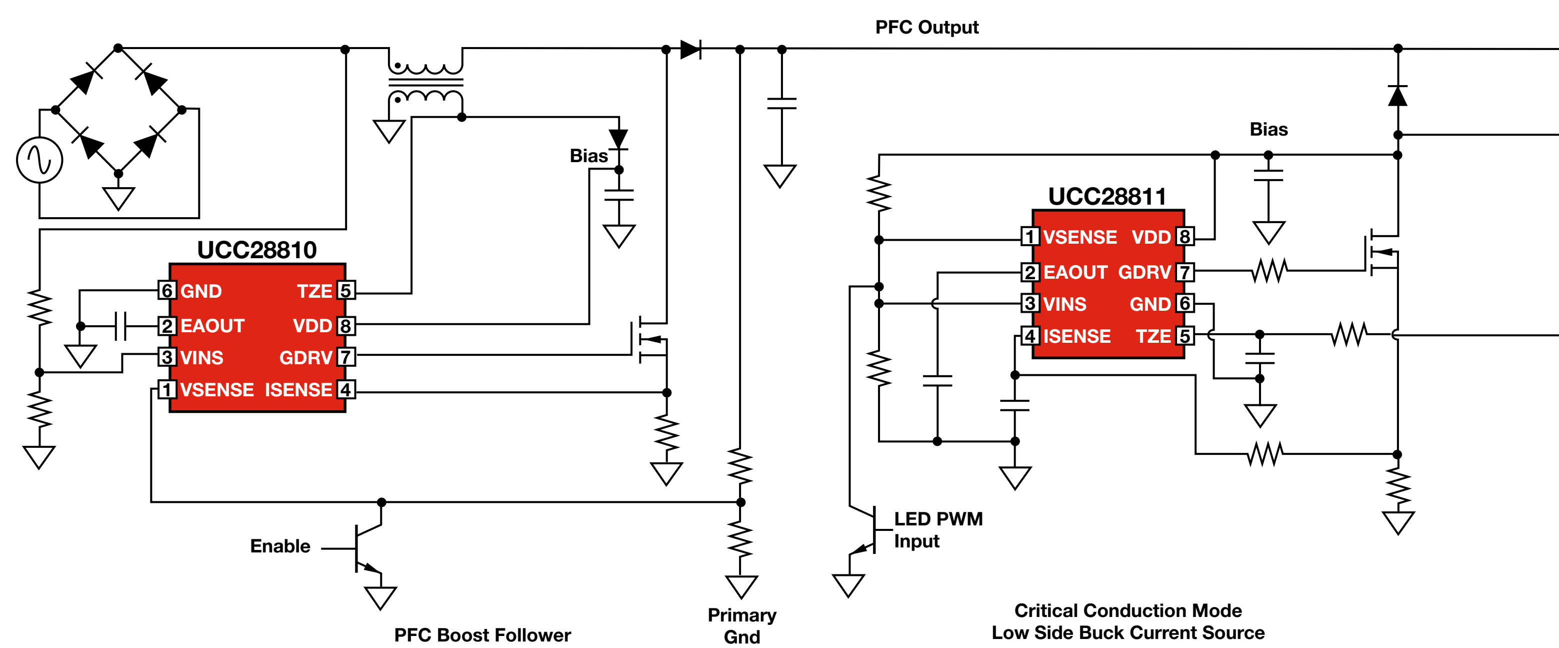
Datasheets, user's guides, samples:
www.ti.com/sc/device/**UCC28810**

EVM:
www.ti.com/**ucc28810evm-003**

Design Specifications

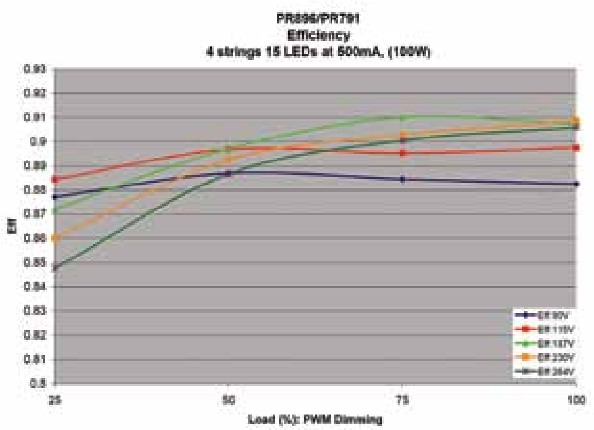
Description	Parts	V_{IN} (AC) Range	V_{OUT} (DC) Range	Number of LEDs	I_{OUT} (max)	P_{OUT} (max)	Eff.	PFC	ISO	Dimming In	Dimming Out	EVM
UCC28810 EVM003 100-W isolated multi-string LED lighting driver w/multiple transformers	UCC28810 UCC28811 TPS92020	90, 265	22 V, 60 V	4X (7 - 15)	500 mA	110 W	91%	Yes	Yes	PWM	PWM	Jul-09

UCC28810EVM-003 Block Diagram



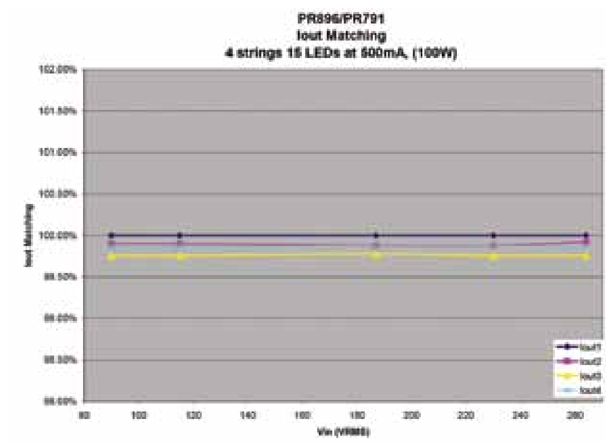
UCC28810/UCC28810EVM-003

Efficiency vs. Line Voltage



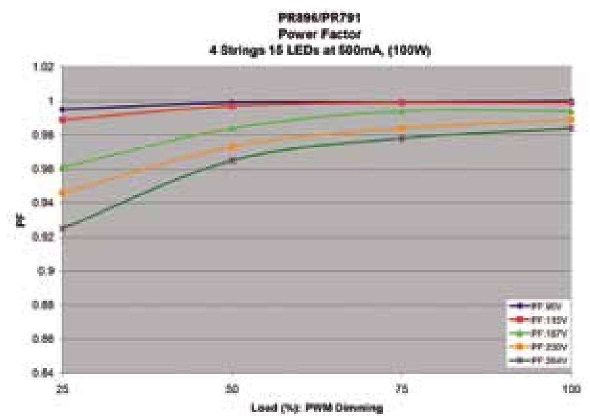
UCC28810EVM-003 efficiency vs. line voltage and load 4 x 15 Cree XRE LED's at 500 mA.

I_{OUT} Matching vs. Line Voltage



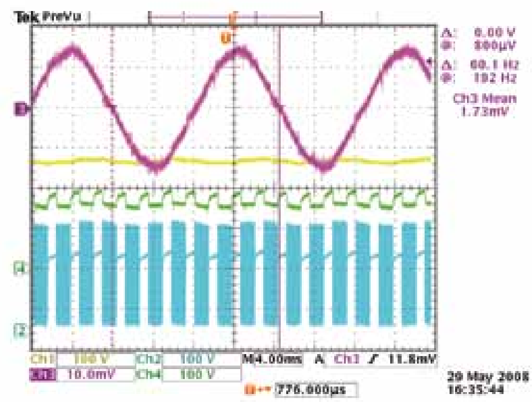
UCC28810EVM-003 I_{OUT} matching vs. line voltage 4 x 15 Cree XRE LED's at 500 mA.

Power Factor vs. Line Voltage

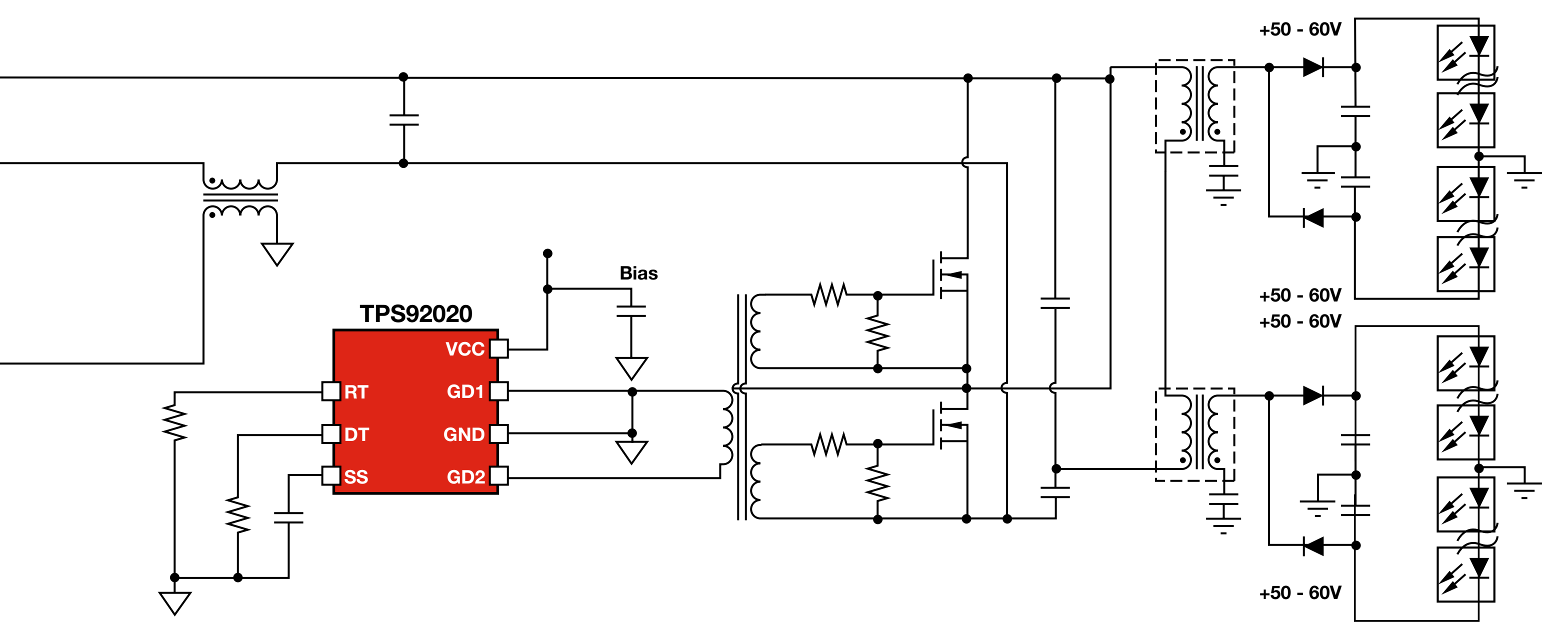


UCC28810EVM-003 power factor vs. line voltage 4 x 15 Cree XRE LED's at 500 mA.

UCC28810EVM-003 AC Input Current During PWM Dimming



Ch1: V_{BUCK}+, Ch2: Buck V_{DS}, Ch3: AC line current 1A/Div, Ch4: V_{BUCK} - Ch1 and Ch 4 share GND reference.



TPS92020, UCC28810/1 NEW!

Description

This reference design uses the UCC28810, UCC28811 and TPS92020 for an isolated, off-line, 240-W LED driver for high-bay and streetlight applications. The driver has three stages: a power-factor-correction (PFC) stage, a buck stage and an isolation stage. The PFC and buck stages both operate in critical-conduction mode. The isolation stage is a half-bridge converter with an option to adopt a multi-transformer configuration. A constant output current is controlled within the buck stage to provide 3 A to the LED strings, with an output voltage ranging from 70 V to 85 V.

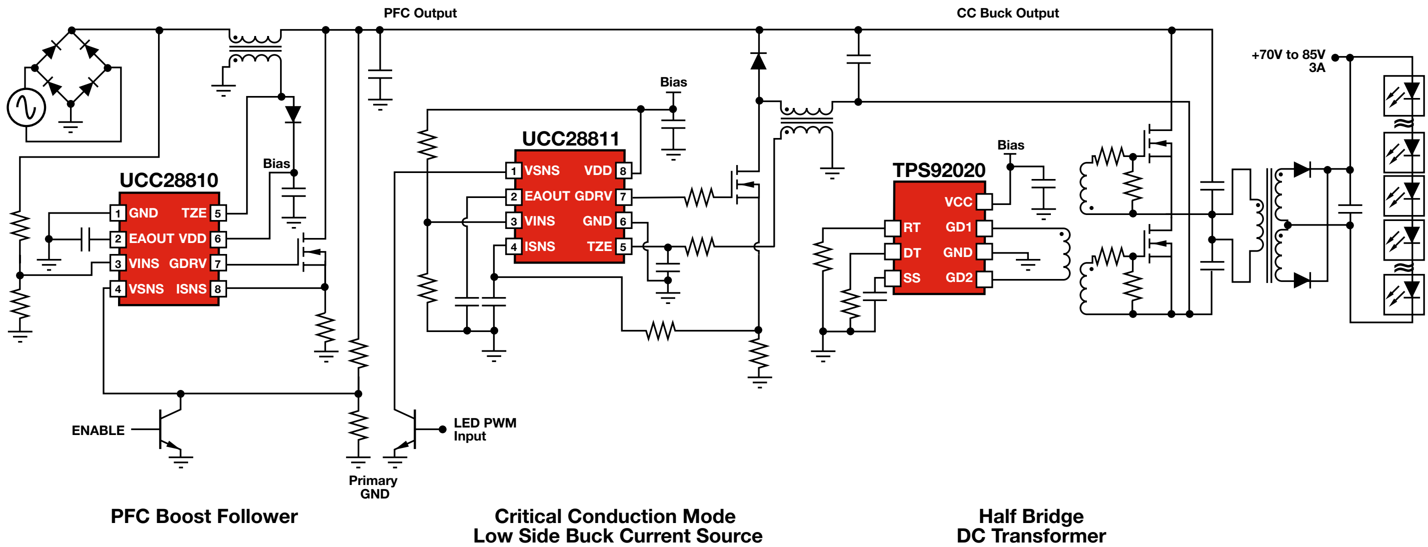
Web Links

Datasheets, user's guides, samples:
www.ti.com/sc/device/**TPS92020**,
www.ti.com/sc/device/**UCC28810** or
www.ti.com/sc/device/**UCC28811**

Design Specifications

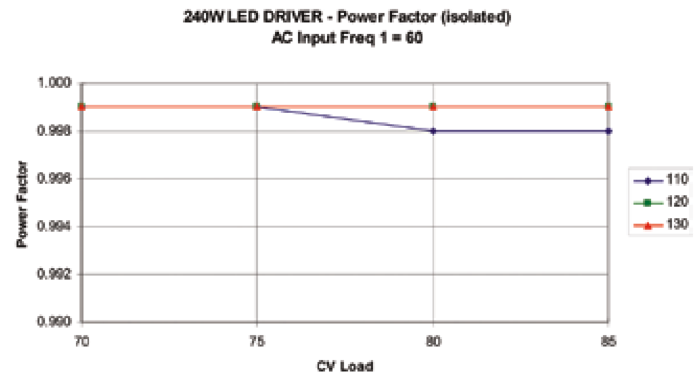
Parameter	Test Conditions	Minimum	Typical	Maximum	Unit
Input voltage	—	108	120/277	305	V_{RMS}
Power factor	—	0.990	—	—	—
Output current	—	—	3	—	Amp
Output ripple	C_{OUT} = 4.4 µF	—	300	—	mA_{PP}
Output voltage	—	70	—	85	Volts
Efficiency	—	87	—	—	%

TPS92020, UCC28810/1 Schematic

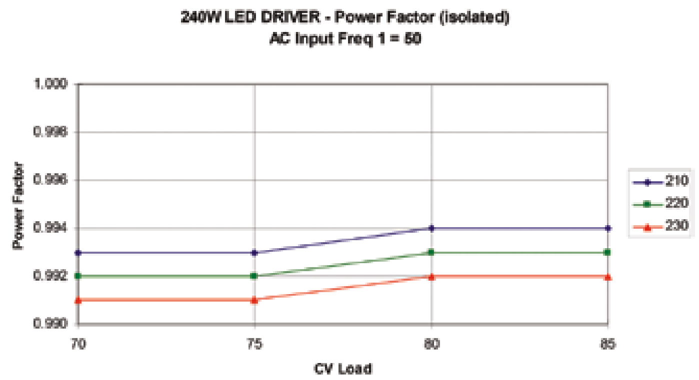


For more reference designs, see: www.ti.com/powerreferencedesigns

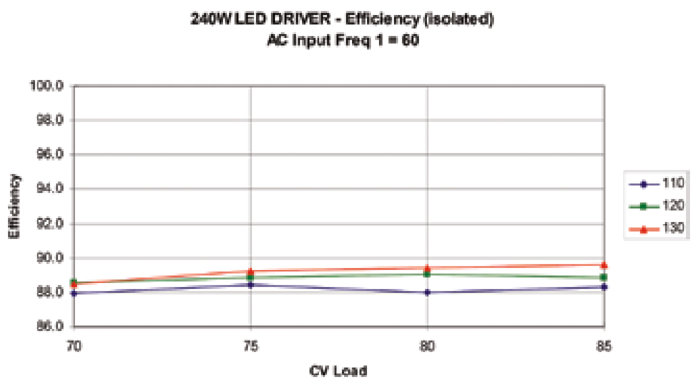
Power Factor



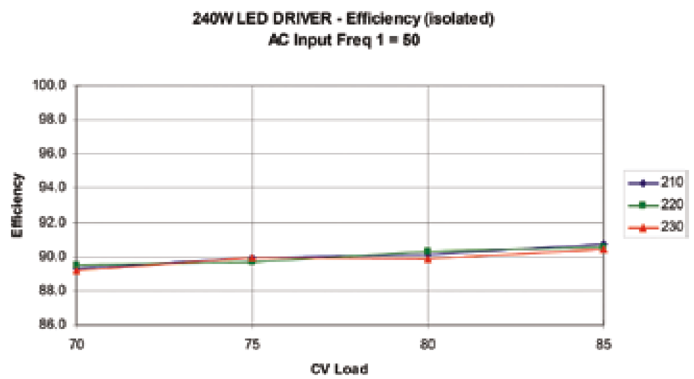
Power Factor



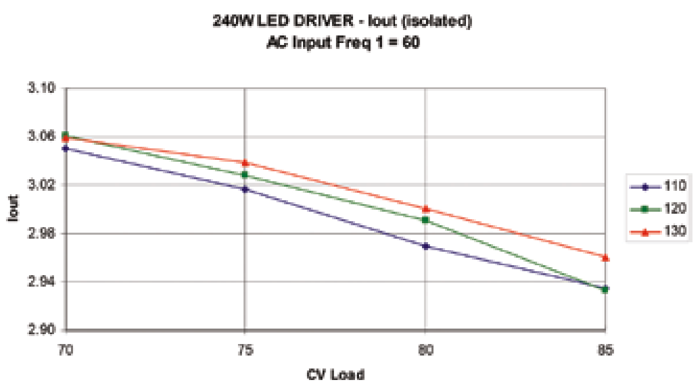
Efficiency



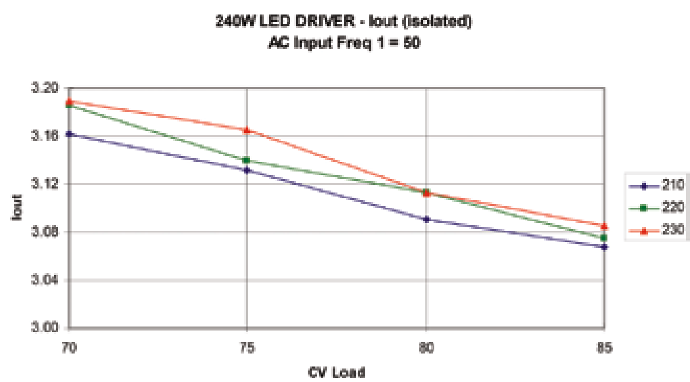
Efficiency



Load Regulation



Load Regulation



UCC28810 PMP4501

Description

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-V_{AC} 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

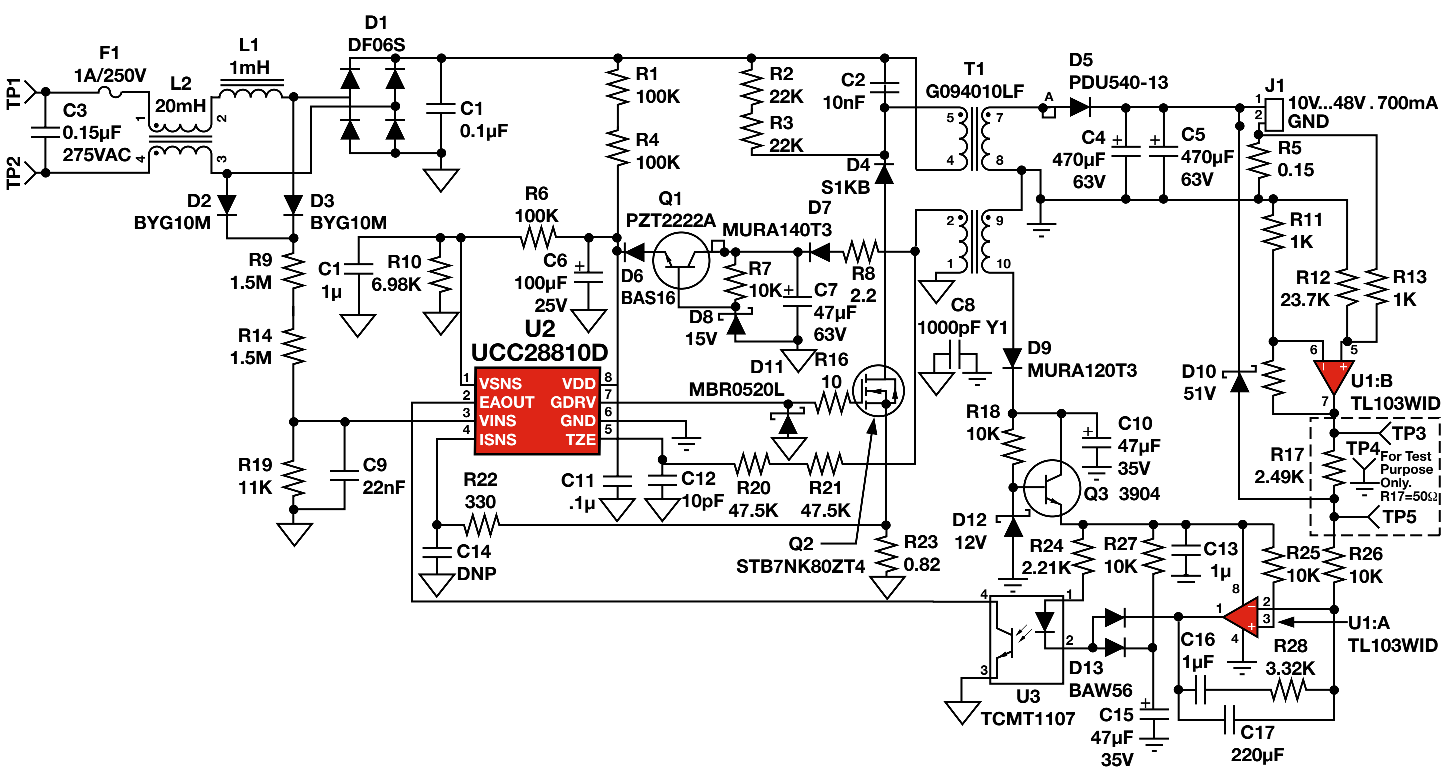
Web Links

Datasheets, user's guides, samples:
www.ti.com/sc/device/UCC28810

Design Specifications

Description	Parts	V_{IN} (AC) Range	V_{OUT} (DC) Range	Number of LEDs	I_{OUT} (max)	P_{OUT} (max)	Eff.	PFC	ISO	Dimming In	Dimming Out	EVM
UCC28810 PMP4501 34-W Secondary side current loop	UCC28810 TL103W	180 265	10 V 48.5 V	3-13	700 mA	34 W	89%	Yes	Yes	No	No	Reference Design

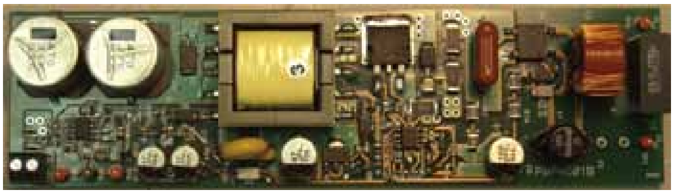
PMP4501 Reference Design Schematic



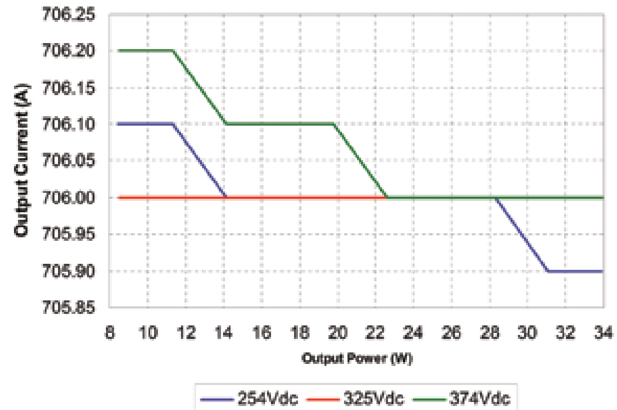
For more reference designs, see: www.ti.com/powerreferencedesigns

UCC28810 PMP4501

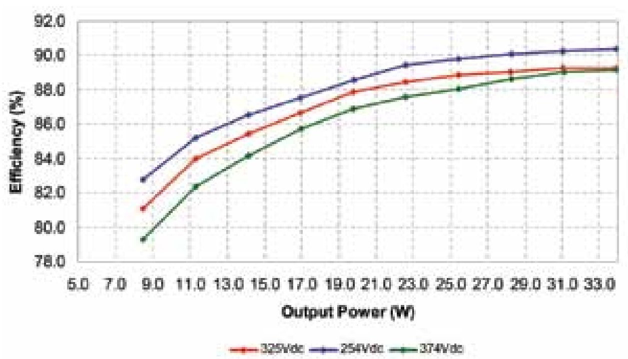
PMP4501 Board



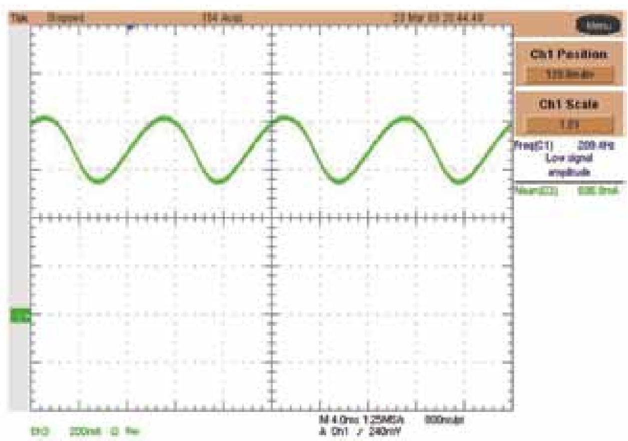
I_{OUT} Regulation vs. Rectified-Equivalent Line Voltage and Output Power



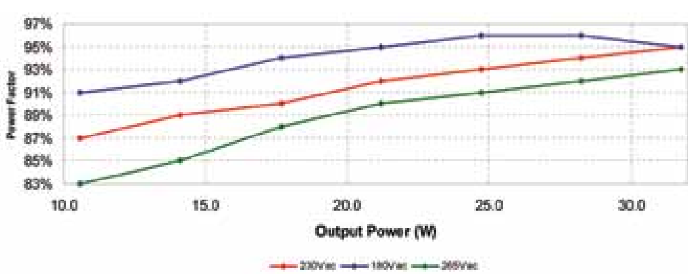
Efficiency vs. Rectified-Equivalent Line Voltage and Output Power



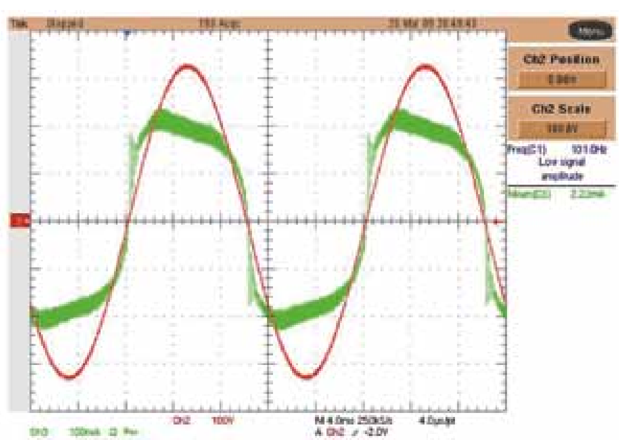
Output Current Ripple. Input Voltage = 230 V_{AC}, Output Voltage = 48 V @ 700 mA



Power Factor vs. Line Voltage and Output Power



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



UCC28810 PMP3976

Description

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.

The LED-lighting circuit uses the UCC28810 transition-mode boost controller to shape the input-current waveform. The circuit starts by charging C6 off the line. Once the controller is running, its power is provided by an auxiliary winding on the SEPIC inductor. A relatively large output capacitor limits LED ripple current to 20% of the DC current. As a side note, the AC flux and currents in the transition-mode SEPIC are quite high, so Litz wire and low-loss core material are required to reduce inductor losses.

The following material presents lab results from a prototype that was built to match the schematic. Efficiency is quite high over the European line range, peaking at 92%. This good efficiency was achieved by limiting the ringing on the power semiconductors. Also, as can be seen from the current waveform, the power factor is quite good at over 96%. Interestingly, the waveform is not purely sinusoidal but shows some steepness on the rising and falling edges. This is because the circuit measures switch current but not input current. However, the waveform is good enough to pass the European requirements for harmonic currents.

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

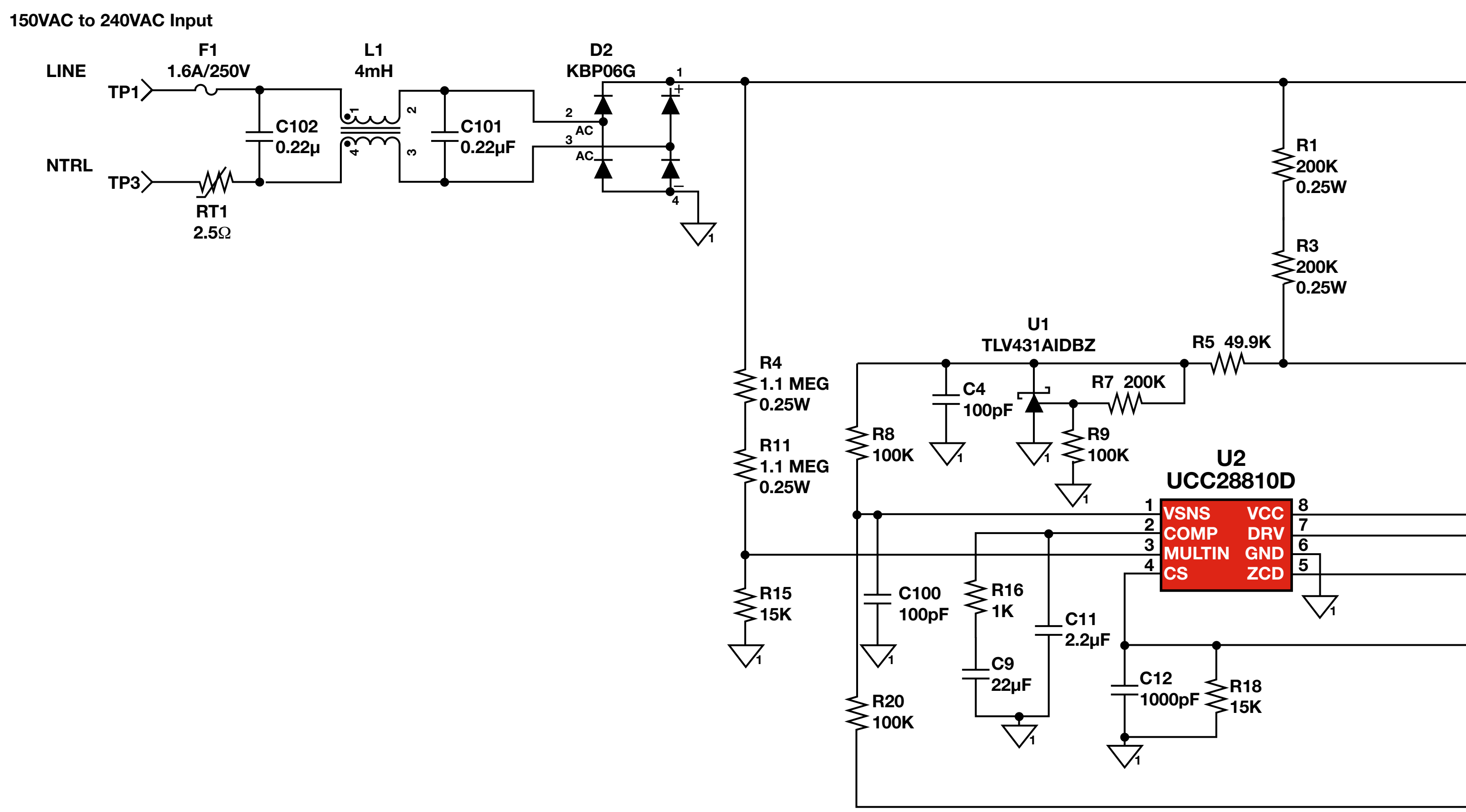
Datasheets, user's guides, samples:
www.ti.com/sc/device/**UCC28810**

Reference designs:
www.ti.com/**powerreferencedesigns**

Design Specifications

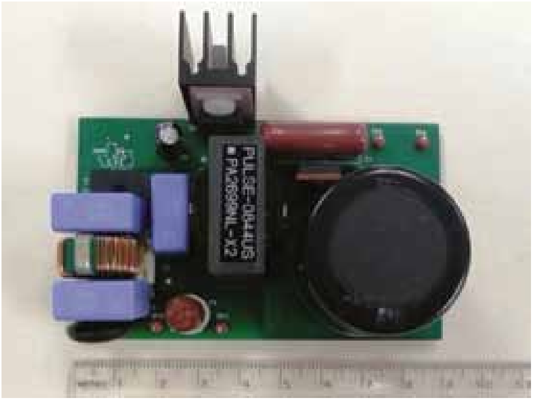
Parameter	Minimum	Typical	Maximum	Unit
Input voltage	150	—	264	V_{AC}
Output voltage	—	—	300	Volts
Output current	—	0.350	—	Amp

PMP3976 Schematic



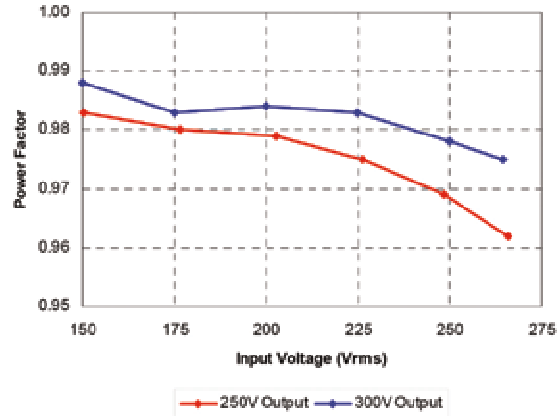
UCC28810 PMP3976

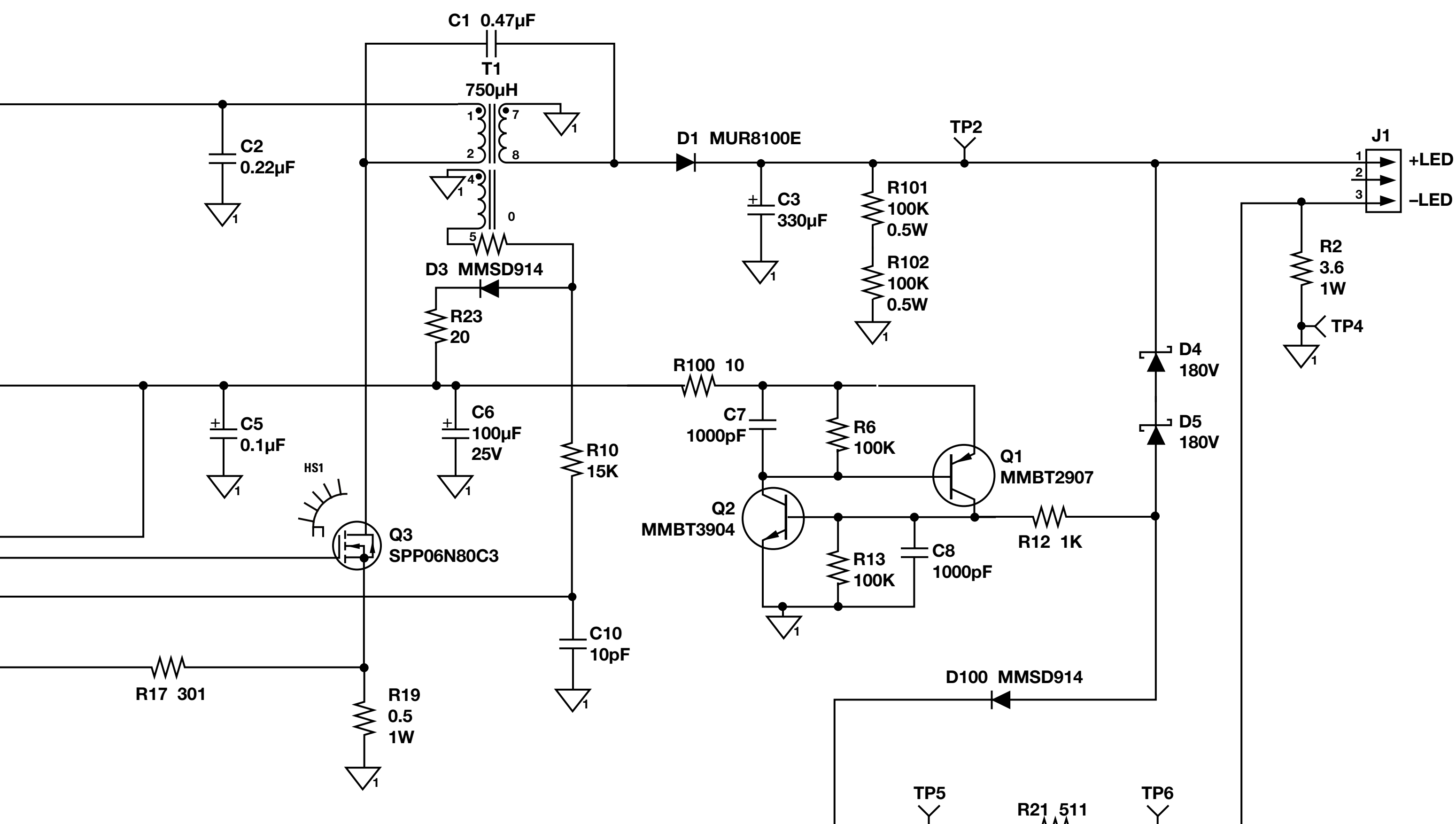
PMP3976 Rev B Demo Board



The circuit is built on a PMP3976 Rev A PWB.

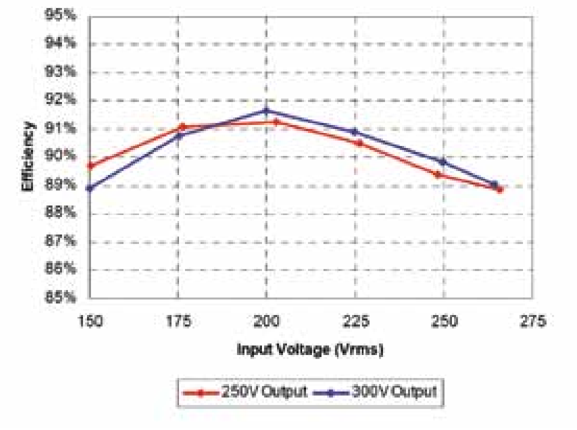
Power Factor



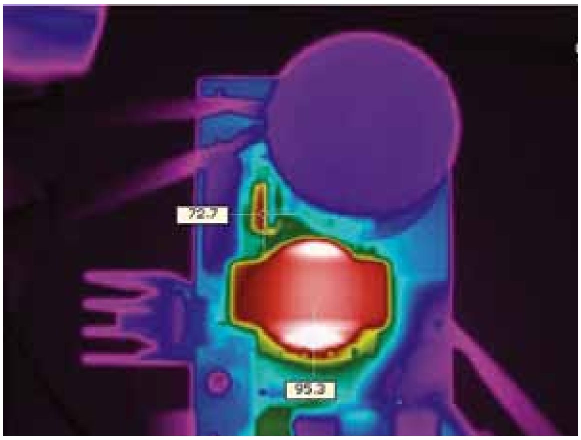


UCC28810 PMP3976

Efficiency



Harmonic Content

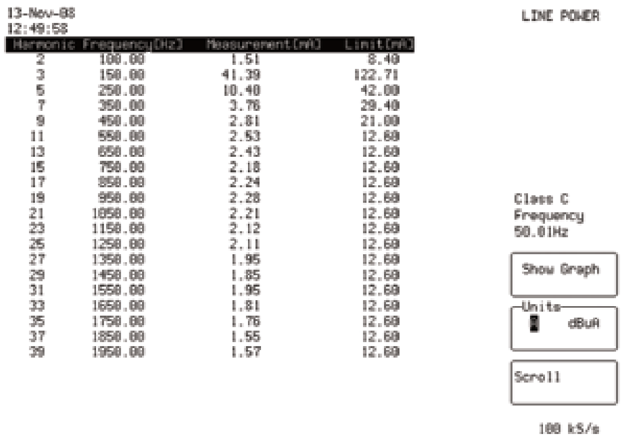


The image above shows a thermal image of the board. The ambient temperature was 26ºC with no forced air flow. The input was 230 V_{AC}.

Efficiency and Power Factor

I_{OUT}	V_{OUT}	V_{IN}	L_{IN}	PF	P_{OUT}	Losses	Efficiency %
0.349	245.5	150.4	0.646	0.983	85.65	9.827	89.7
0.349	245.4	176.4	0.544	0.980	85.64	8.398	91.1
0.349	245.3	202.6	0.473	0.979	85.61	8.208	91.3
0.350	245.3	226.3	0.430	0.975	85.86	9.201	90.5
0.350	245.3	248.4	0.399	0.969	85.86	10.184	89.4
0.350	245.3	265.7	0.378	0.962	85.86	10.763	88.9

Harmonic Content


13-Nov-08
12:49:58

LINE POWER

Harmonic	Frequency(Hz)	Measurement(mA)	Limit(mA)
2	100.00	1.51	8.40
3	150.00	41.39	122.71
5	250.00	10.40	42.00
7	350.00	3.76	29.40
9	450.00	2.81	21.00
11	550.00	2.53	12.60
13	650.00	2.43	12.60
15	750.00	2.18	12.60
17	850.00	2.24	12.60
19	950.00	2.28	12.60
21	1050.00	2.21	12.60
23	1150.00	2.12	12.60
25	1250.00	2.11	12.60
27	1350.00	1.95	12.60
29	1450.00	1.85	12.60
31	1550.00	1.95	12.60
33	1650.00	1.81	12.60
35	1750.00	1.76	12.60
37	1850.00	1.55	12.60
39	1950.00	1.57	12.60

Class C
Frequency
50.01Hz

Show Graph

Units
dBuA

Scroll

100 kS/s

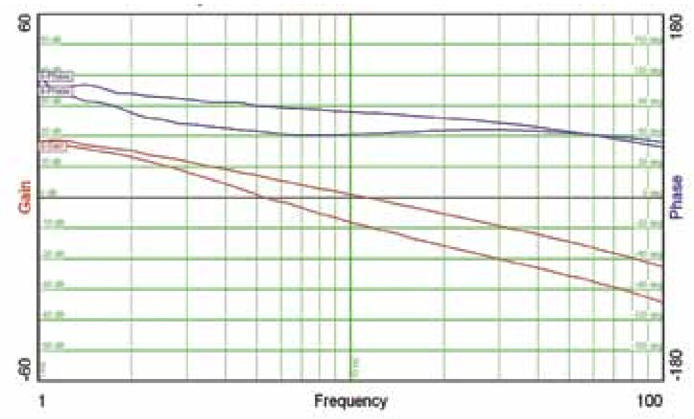
The harmonic content and the EN61000-3-2 Class C (lighting equipments) Limits are shown above; input voltage was set to 230 V_{AC}.

I_{OUT}	V_{OUT}	V_{IN}	L_{IN}	PF	P_{OUT}	Losses	Efficiency %
0.348	303.9	149.9	0.803	0.988	105.75	13.168	88.9
0.349	303.3	175.2	0.677	0.983	105.85	10.742	90.8
0.349	303.8	199.9	0.588	0.984	106.03	9.634	91.7
0.349	303.3	224.8	0.527	0.983	105.85	10.604	90.9
0.349	303.2	249.8	0.482	0.978	105.82	11.938	89.9
0.349	303.0	264.2	0.461	0.975	105.75	13.004	89.0

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

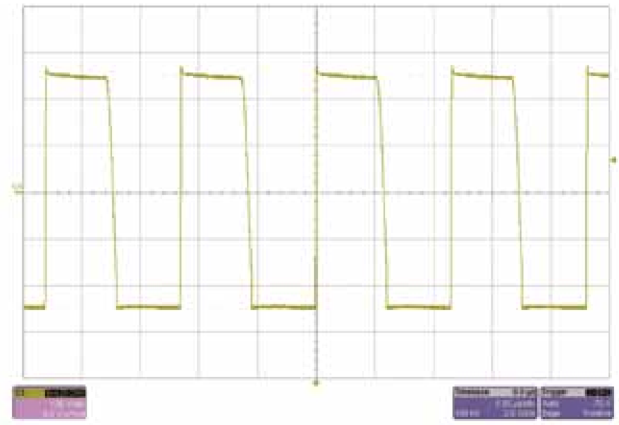
UCC28810 PMP3976

Frequency Response



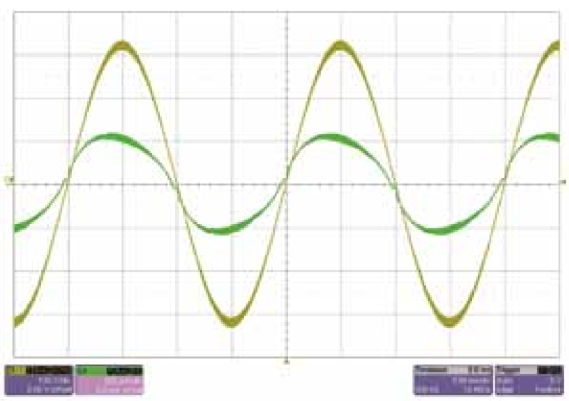
The frequency response of the feedback loop is shown in the plot above. The input was set to 220 V_{AC}. The lower gain plot was taken with a 300 V output. The upper gain plot was taken with a 250 V output.

Diode Voltage Waveform



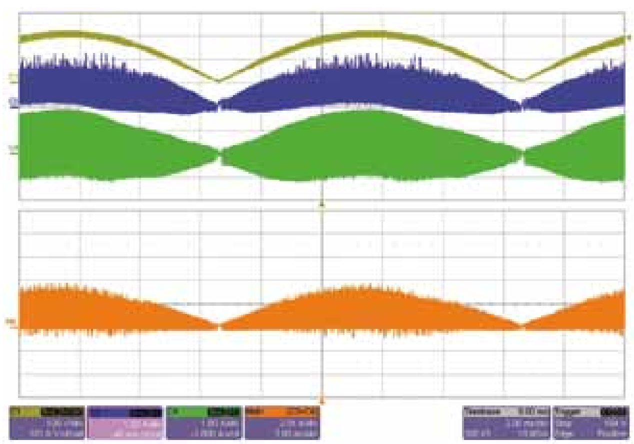
The image above shows the voltage on the anode of D1. The input was set to 250 V_{DC}.

Line Voltage and Current Waveform

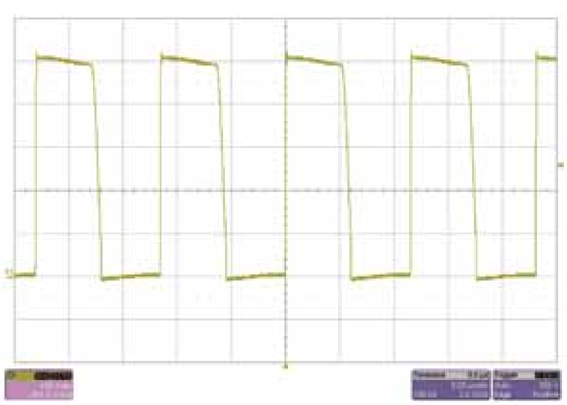


The image above shows the input voltage and current. The input voltage was 230 V_{AC}.

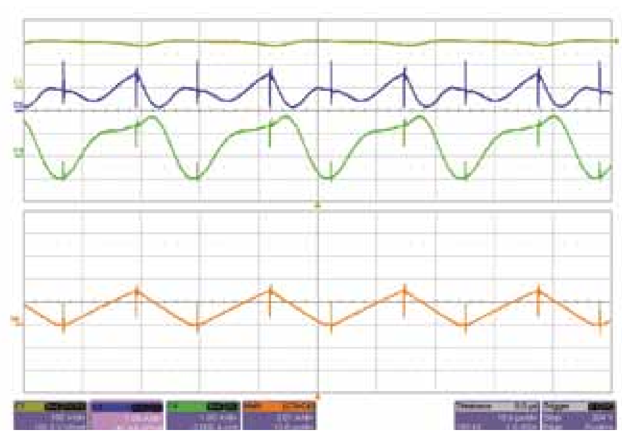
Inductor Winding Currents



MOSFET Voltage Waveform



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



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

UCC28810/UCC28810EVM-001

Description

The UCC28810EVM-001 evaluation module (EVM) is a 25-W TRIAC dimmable and single-stage flyback converter with PFC. The UCC28810EVM-001 provides approximately 36 V at a constant 700-mA (undimmed nominal) load current to power a string of high-brightness LEDs. This EVM allows the evaluation of the UCC28810 LED lighting controller in an application where LEDs can be used for general illumination applications that require dimming.

Using the UCC28810 transition-mode boost IC with PFC in a flyback converter yields a valley-switching design that can achieve 90% efficiency and a high power factor over a universal wide input-voltage range. The UCC28810EVM-001 also operates over a universal wide input-voltage range. High-performance TRIAC dimming detection and regulation adjustment are achieved with minimal impact on efficiency.

An input-filter damping network ensures operations with most TRIAC-based wall dimmers. No extra resistance is used across the line or in series that would reduce efficiency. Valley switching is implemented in the UCC28810EVM-001 to improve efficiency. A fast start-up circuit is also implemented, so there is no perceived delay from switching to illumination.

Web Links

Reference designs:
www.ti.com/**powerreferencedesigns**

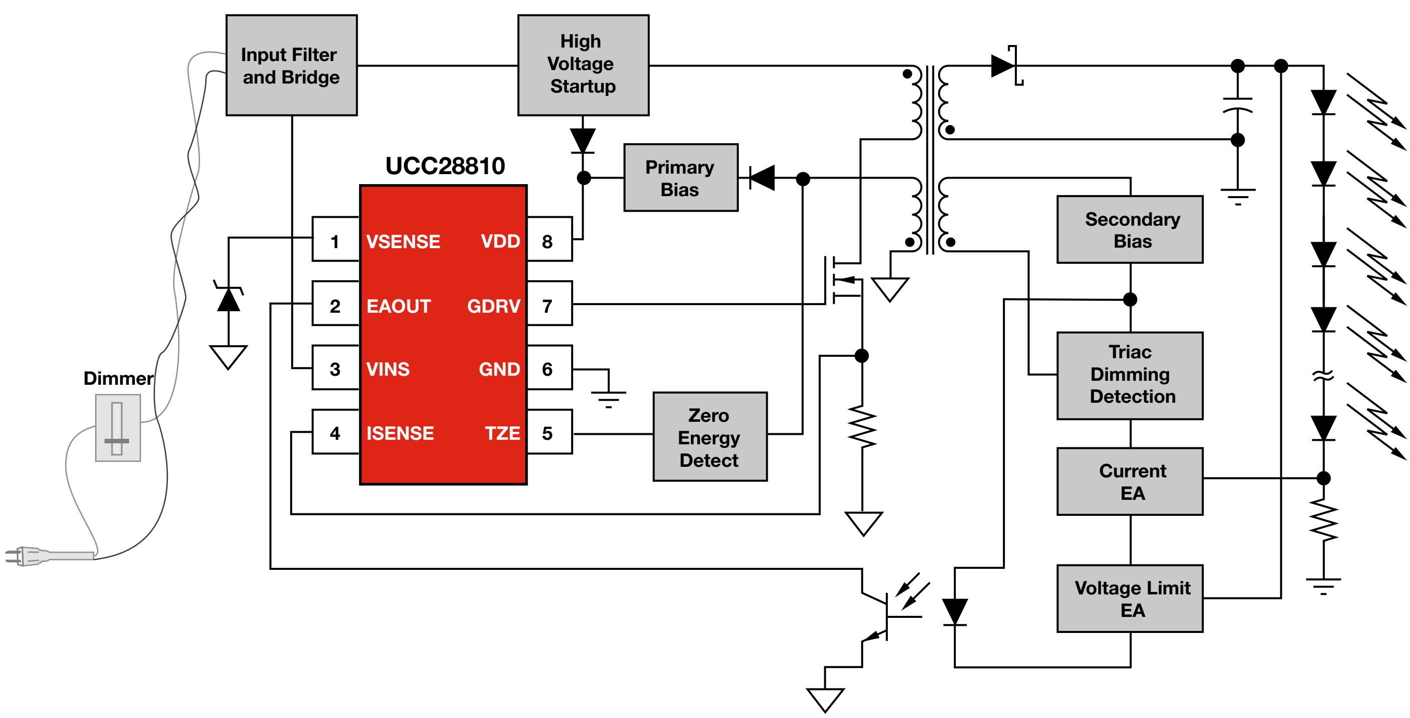
Datasheets, user's guides, samples:
www.ti.com/sc/device/**UCC28810**

EVM:
www.ti.com/**ucc28810evm-001**

Design Specifications

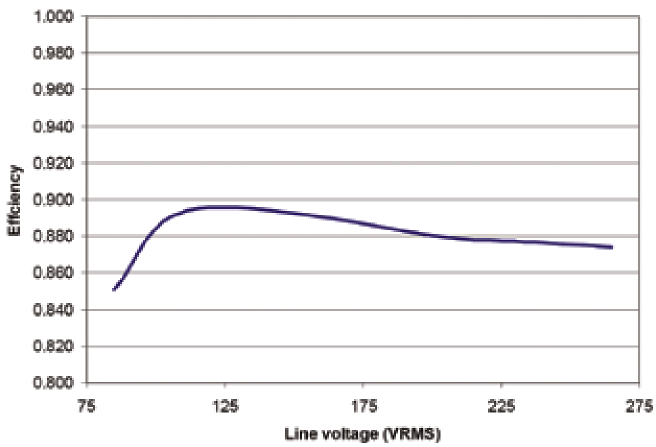
Description	Parts	V_{IN} (AC) Range	V_{OUT} (DC) Range	Number of LEDs	I_{OUT} (max)	P_{OUT} (max)	Eff.	PFC	ISO	Dimming In	Dimming Out	EVM
UCC28810 EVM001 25-W PFC dimmable LED driver	UCC28810 TPS3808	85 305	33	10	700 mA	25 W	89%	Yes	Yes	TRIAC	Linear	Yes

UCC28810EVM-001 Block Diagram



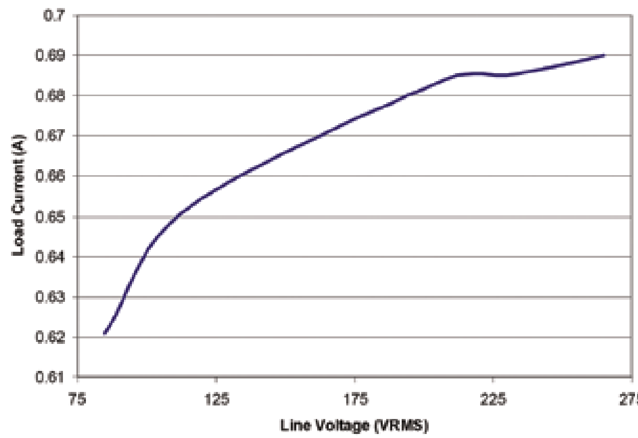
UCC28810/UCC28810EVM-001

Efficiency vs. Line Voltage



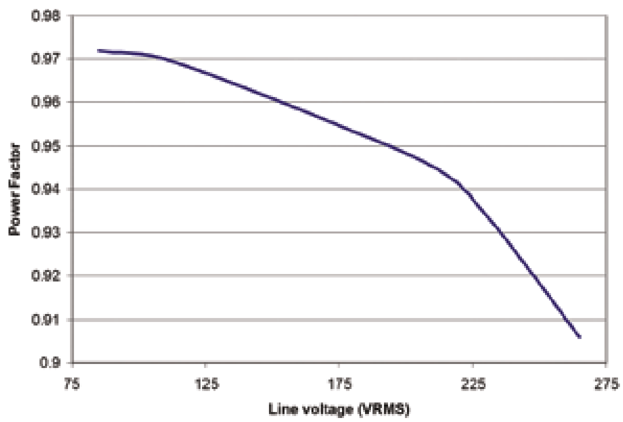
Efficiency as a function of line voltage. 10 Cree XLamp® 7090 XR-E, white, 700 mA LEDs connected in series was used for the load.

Output Current vs. Line Voltage



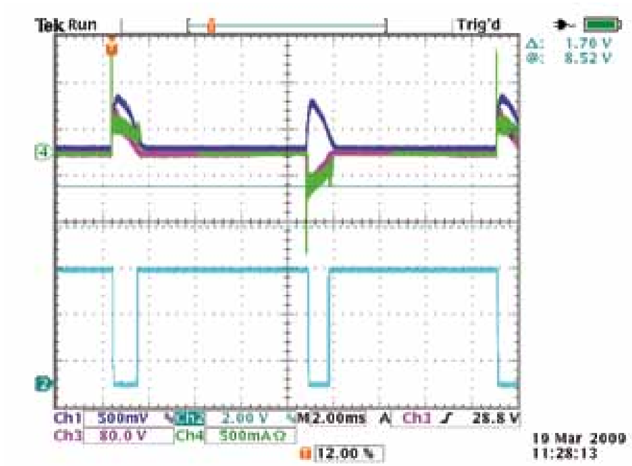
Load current as a function of line voltage. 10 Cree XLamp® 7090 XR-E, white, 700 mA LEDs connected in series was used for the load.

Power Factor vs. Line Voltage

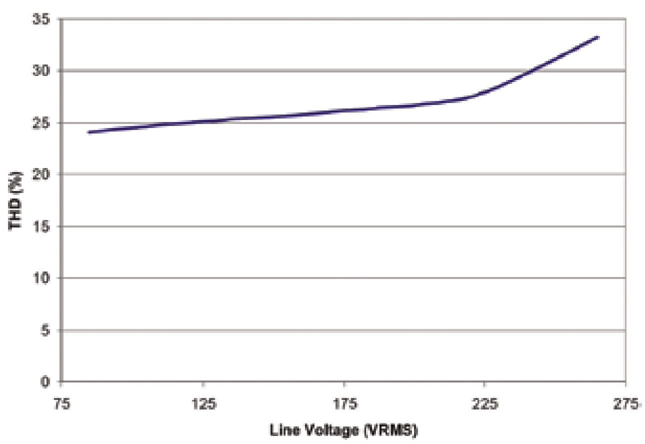


Power factor as a function of line voltage. 10 Cree XLamp® 7090 XR-E, white, 700 mA LEDs connected in series was used for the load.

Triac Dimming Detection Circuit Waveforms – Deep Dimming

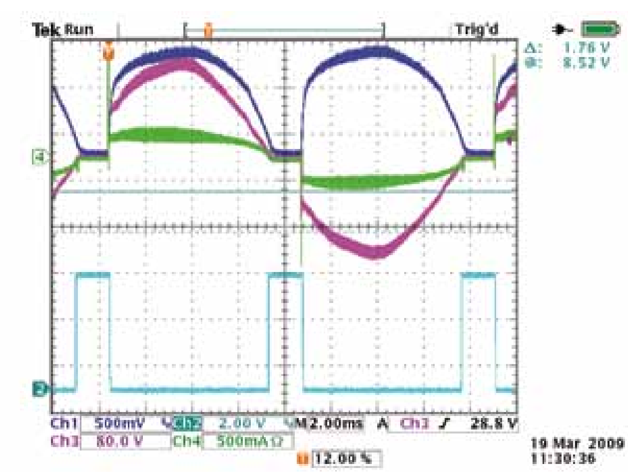


Total Harmonic Distortion vs. Line Voltage



Total harmonic distortion as a function of line voltage. 10 Cree XLamp® 7090 XR-E, white, 700 mA LEDs connected in series was used for the load.

Triac Dimming Detection Circuit Waveforms – Light Dimming



TPS40211 PMP4026

Description

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 PMP4026 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 TPS40211 was chosen for this application due to its low feedback voltage and wide input-voltage range. 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. It can be found along with a demonstration board at:

http://**focus.ti.com/docs/toolsw/folders/print/tps40211evm-352.html**

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

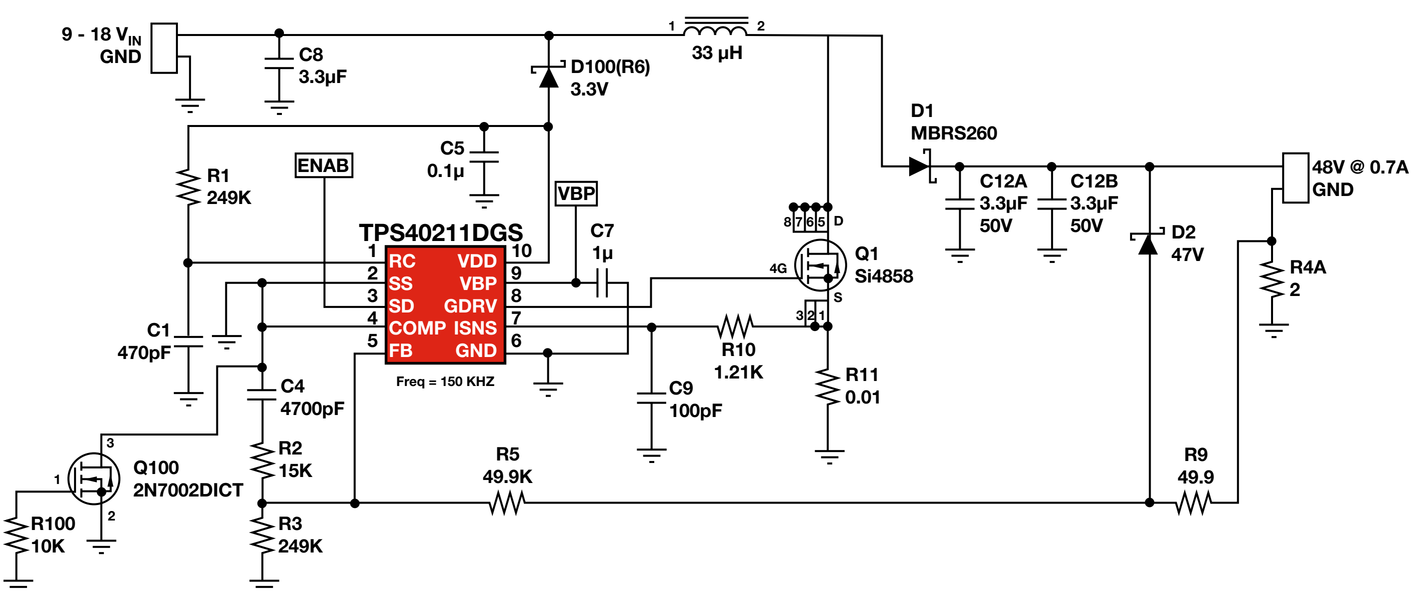
Web Links

Datasheets, user's guides, samples:
www.ti.com/sc/device/**TPS40211**

Design Specifications

Parameter	Minimum	Typical	Maximum	Unit
Input voltage	9	—	16	V_{DC}
Output voltage	—	—	40	Volts
Output current	—	0.700	—	Amp
Switching frequency	—	150	—	kHz

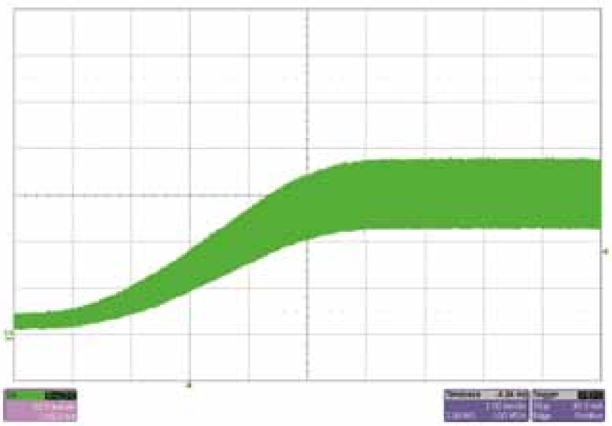
PMP4026 Schematic



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

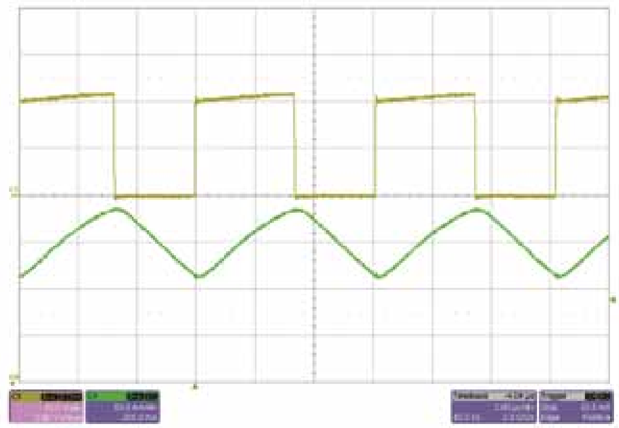
TPS40211 PMP4026

Startup



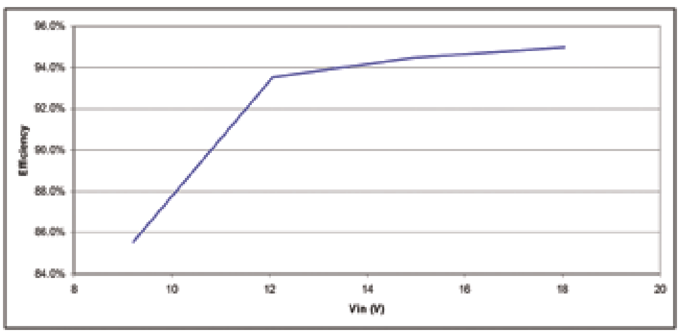
The input voltage was set at 12 V, with 0.15 (LED) + 1 (resistor) A load on the outputs.

Output Ripple Current



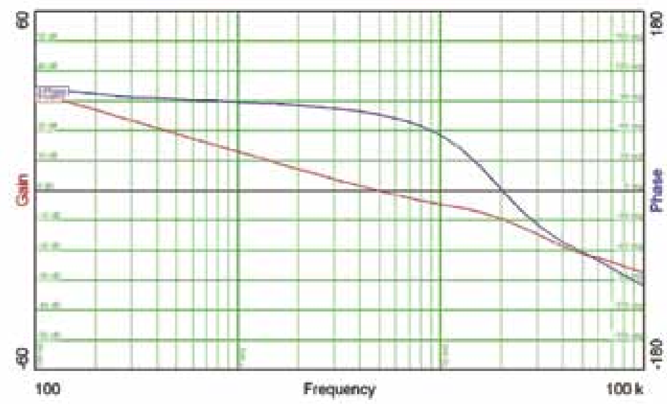
The image was taken with a 1.15 A/20 V load. Top waveform is FET drain, bottom is LED current.

Efficiency

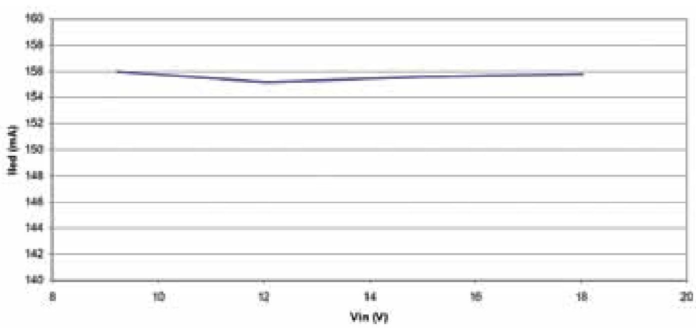


Total output current was 1.15 A, output voltage was 20 volts.

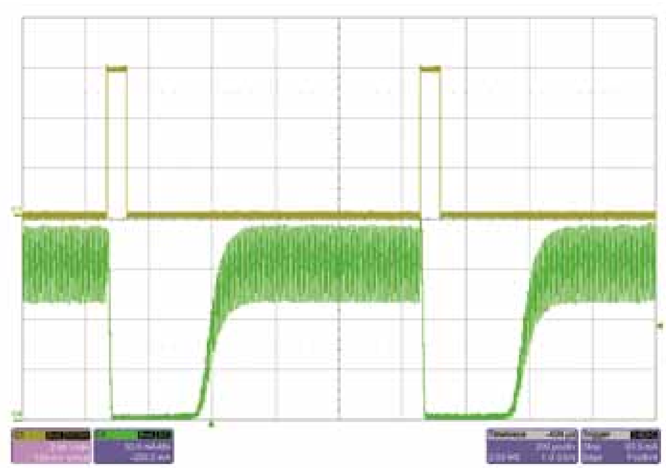
Control Loop Frequency Response: 12 V input; 1.15 A Load



Load Regulation of Outputs



Load Transients



Output response to driving TP%. The input voltage was set to 12 V.

TPS40211 PMP3943

Description

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. It can be found along with a demonstration board at:

www.ti.com/sc/device/**TPS40211evm**

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

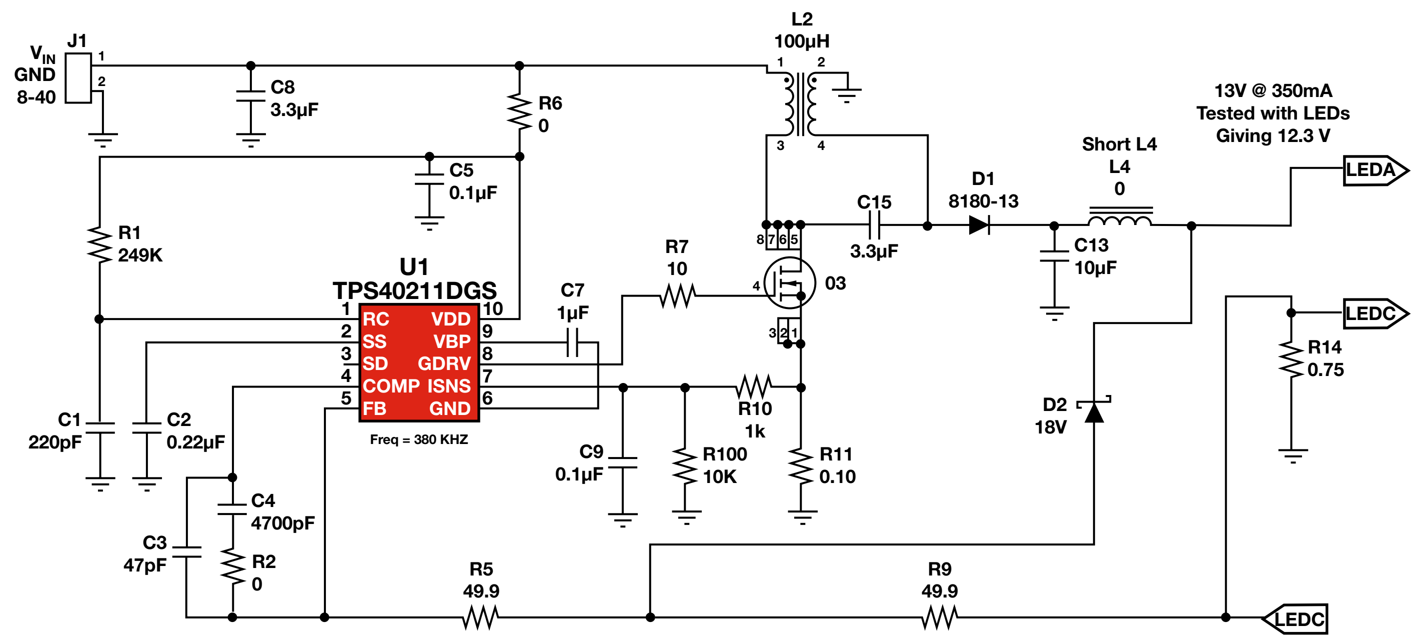
Web Links

Datasheets, user's guides, samples:
www.ti.com/sc/device/**TPS40211**

Design Specifications

Parameter	Minimum	Typical	Maximum	Unit
Input voltage	8	—	40	Volts
Output voltage	—	13	—	Volts
Output current	—	0.350	—	Amp
Switching frequency	—	300	—	kHz

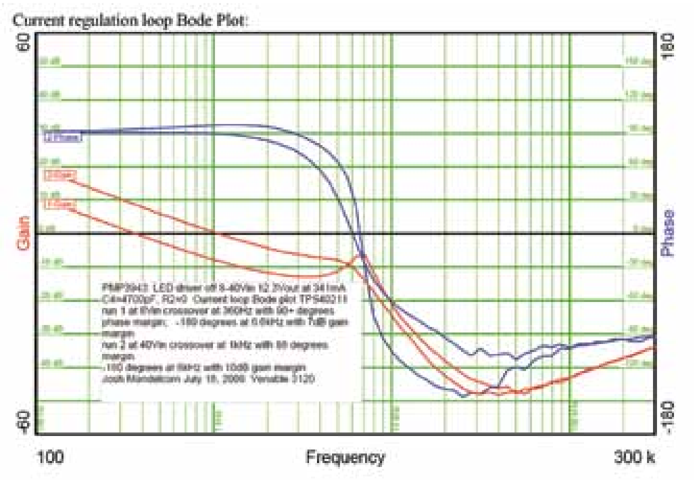
PMP3943 Schematic



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

TPS40211 PMP3943

Current Loop Frequency Response



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

V_{IN} Volts	I_{IN} mA	V_{OUT1} Volts	I_{OUT1} mA	Efficiency %
40.22	123.6	12.27	341.8	84.4
20.11	238.5	12.27	341.3	87.3
7.93	619.4	12.27	341.3	85.3

Regulation and efficiency: 25 degrres Celsius ambient. Target I_{OUT} was 350mA, hence actual current is 2.5% low.

When Diode Load is Opened, V_{OUT} Goes to About 18 V

V_{IN} Volts	I_{IN} mA	V_{OUT1} Volts	I_{OUT1} mA
40.42	8.79	18.44	0
20.08	10.75	18.41	0
8.00	19.12	18.40	0

Short Circuit: Output Current Holds Steady

V_{IN} Volts	I_{IN} mA	V_{OUT1} Volts	I_{OUT1} mA
40.14	21.24	0.694	341.6
20.06	34.20	0.694	341.5
8.00	77.70	0.694	341.4

TMDSPLCKIT-V1 NEW!

Description

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

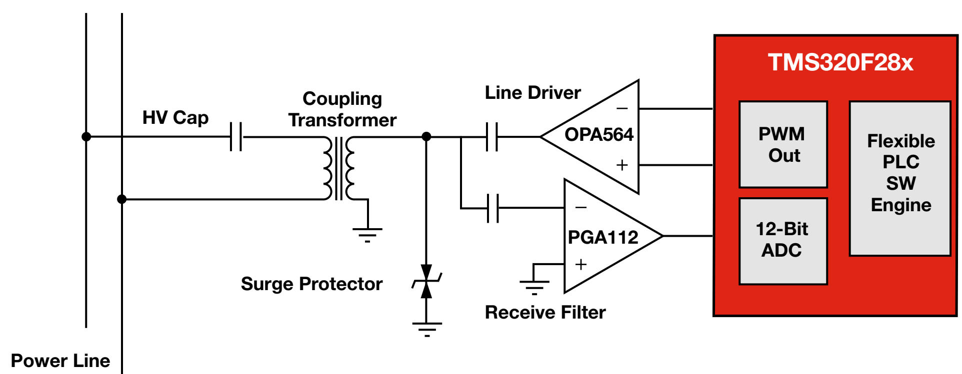
- OFDM and S-FSK modulation schemes
- Data rates of up to 76.8 kbps for one phase (phase selection is provided)
- PLC system on module (SoM) with interface to host controller (I^2C, SPI, SCI)
- Compatible with CENELEC EN50065 and IEC 6100-3 standards
- Operating frequency range: 24 to 94.5 kHz (CENELEC 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:
www.ti.com/sc/device/**OPA564** or
www.ti.com/sc/device/**PGA112**

TMDSPLCKIT-V1 Block Diagram

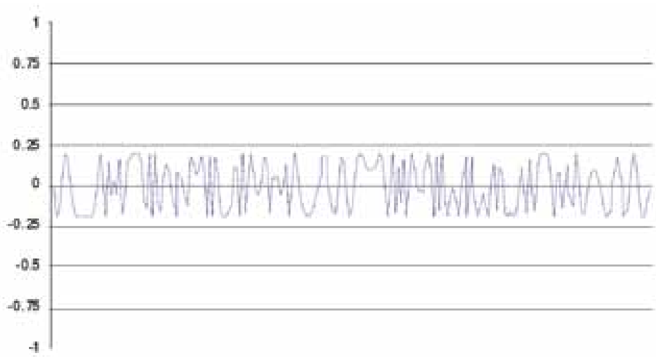


PLC Modem Implementation on TMS320F28x 32-Bit MCU - Simplified Block Diagram

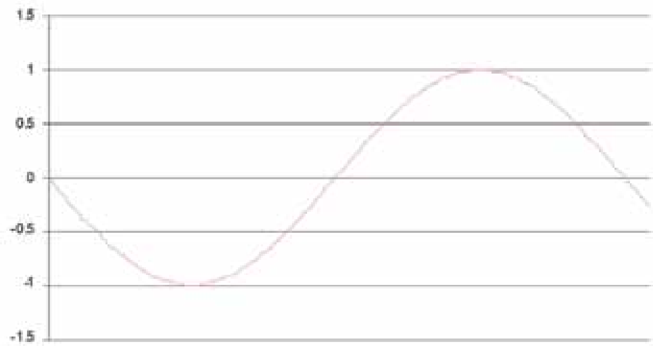
For more reference designs, see: www.ti.com/powerreferencedesigns

TMDSPLCKIT-V1

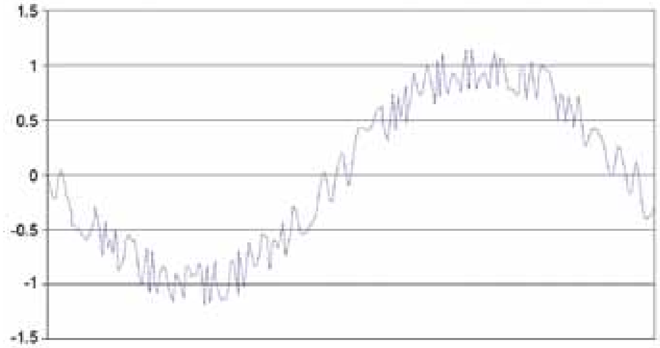
PLC Data Signal



50- or 60-Hz Power Line



PLC Signal Modulated Onto the Power Line 50/60Hz



DALI Implementation with the MSP430™ MCU

NEW!

Description

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.

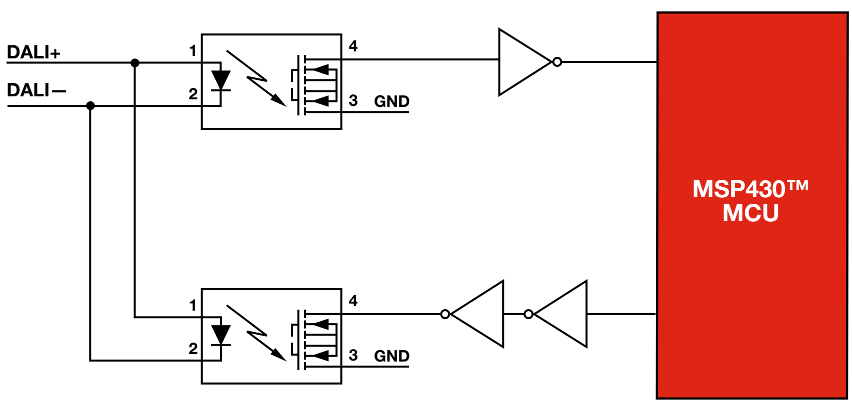
Specifications

- 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

NEW!

TMDSDCDCLEDKIT

Description

The DC/DC LED Developer's Kit includes all of the hardware and software to start experimenting with and developing a digitally controlled LED backlighting system. The kit is based on the Piccolo™ microcontroller and the controlCARD™ development platform. One Piccolo MCU is able to directly control the DC/DC power stage as well as eight LED strings. The development board takes 12 to 48 V_{DC} of input and uses a SEPIC DC/DC topology to buck or boost the input voltage to a desired level. This voltage is then fed to four LED-driving stages, each capable of driving two LED strings at up to 30 W each. The kit includes closed-loop, open-source software for both the DC/DC stage and the LED-lighting stage. The kit hardware is also completely open-source, with the Gerber files, schematics and BOMs all available for free. For more information, please see the quick-start guide for the kit. To download the LED software, please visit: www.ti.com/**c2000tools**

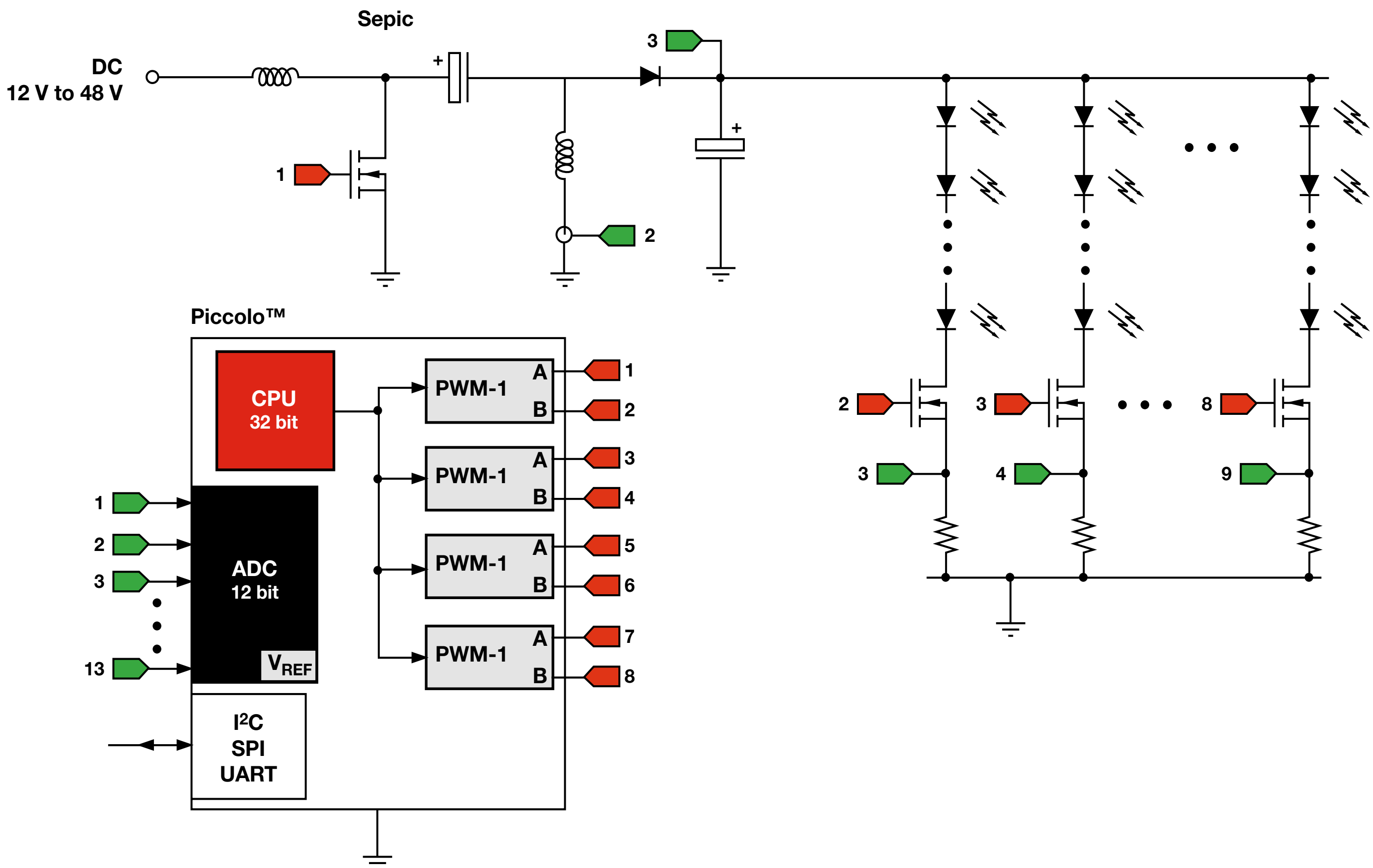
Key Features

- 12- to 24-V_{DC} input to SEPIC DC/DC stage, 12- to 40-V_{DC} output
- Four LED-driver stages, each capable of driving two strings at 30 W
- LED-driver stages can be externally powered
- Piccolo-based controlCARD development platform
- Open-source hardware, including Gerber files, schematics and BOMs
- Closed-loop DC/DC and LED-driving software, complete with source code and documentation

Web Links

Datasheets, user's guides, samples:
www.ti.com/**c2000tools**

Typical Application Schematic



TPS61165 PMP3598

Description

The TPS61165 operates over a 3- to 18-V input supply and delivers an output voltage up to 38 V. With its 40-V rated integrated switch FET, the device drives up to 10 LEDs in series. It operates at a 1.2-MHz fixed switching frequency to reduce output ripple, improve conversion efficiency, and allow for the use of small external components. The default white-LED (WLED) current is set with the external sensor resistor R_{SET}, and the feedback voltage is regulated to 200 mV. In either digital or PWM dimming, the output ripple of TPS61165 at the output capacitor is small and does not generate audible noises associated with common on/off control dimming. For protection during open-LED conditions, the TPS61165 disables switching to prevent the output from exceeding the absolute maximum ratings.

The PMP3598 uses the TPS61165 in a nonsynchronous boost configuration. An additional circuit built around the op amp provides the battery under-voltage/charging indications and also provides ORing between the solar panel and battery inputs. The circuit also incorporates the necessary thermal and overcurrent protections and has load-disconnect feature.

Key considerations for this design are high efficiency and good LED-current regulation. The TPS61165 operates in a constant-current mode to regulate the LED current. The CTRL pin is used for the control input for both digital and PWM dimming. The dimming mode for the TPS61165 is selected each time the device is enabled. Analog dimming has been implemented by varying the feedback reference. A 20-kΩ variable resistor can be used to vary the LED current to achieve dimming. The converter boosts 6 to 10.5 V at 350 mA and has minimum conversion efficiency of 85%. This circuit is used for driving three 1-W LEDs or multiple 50-mA LEDs whos total power input does not exceed 3 W.

Key Features

- Boost output up to 38 Vout
- Wide supply voltage 3 V to 18 V
- High efficiency from 200-mV threshold
- PWM dimming
- LED open protection
- 350-mA LED current

Web Links

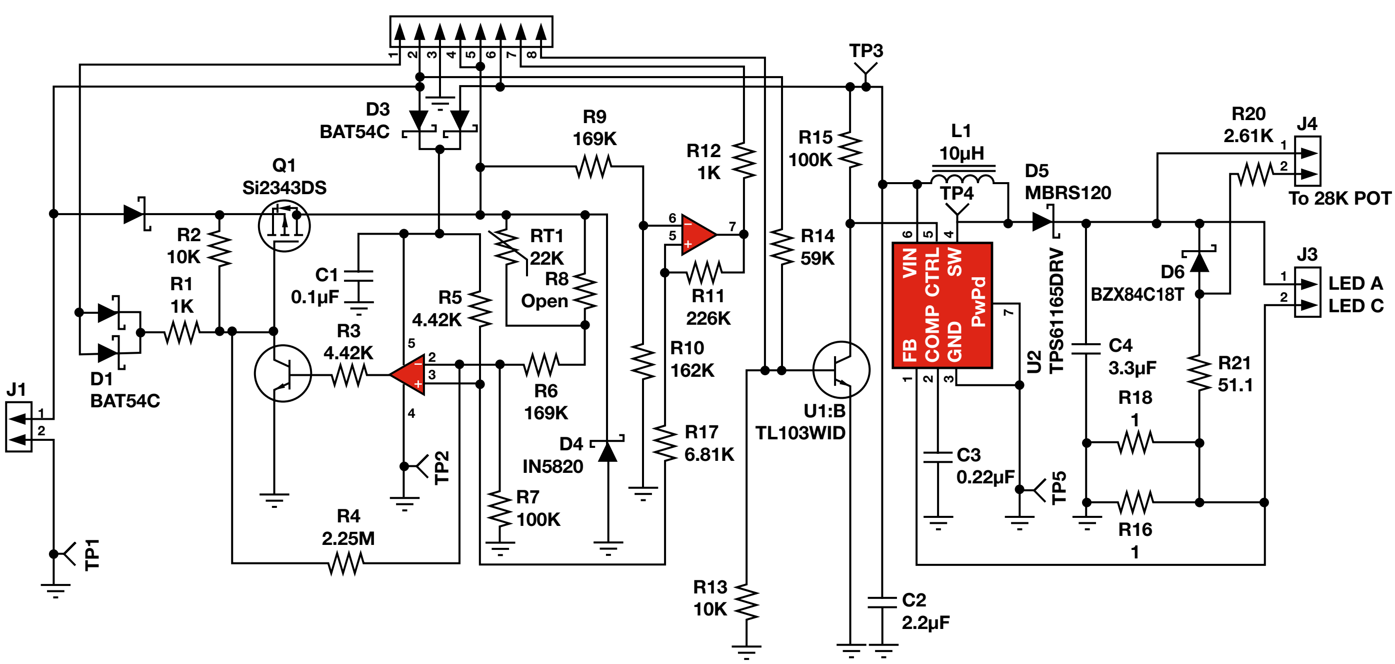
Reference designs:
www.ti.com/**powerreferencedesigns**

Datasheets, user's guides, samples:
www.ti.com/sc/device/**TPS61165**

Design Specifications

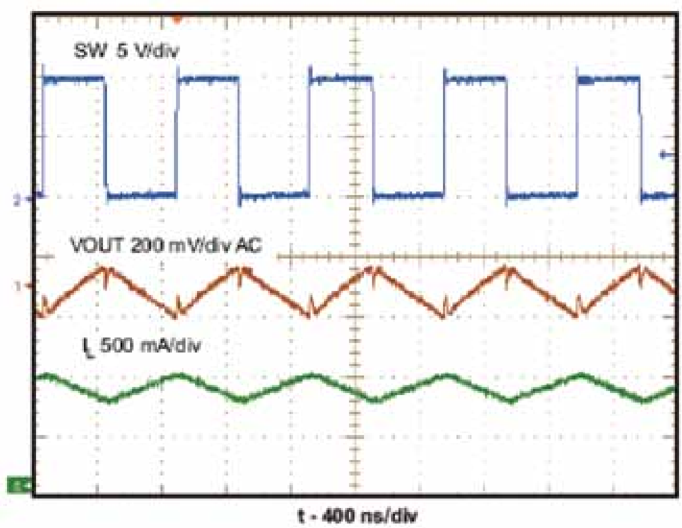
Parameter	Minimum	Typical	Maximum	Unit
Input Voltage	4.5	6	7.4	Volts
Output Voltage	10.45	10.5	10.65	Volts
Output Ripple	—	—	50	mV pp
Output Current	0	—	350	mA
Switching Frequency	—	1200	—	kHz

PMP3598 Schematic

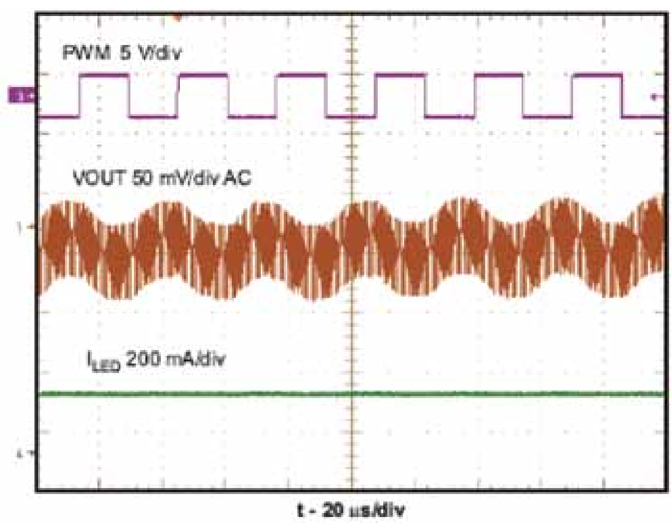


TPS61165 PMP3598

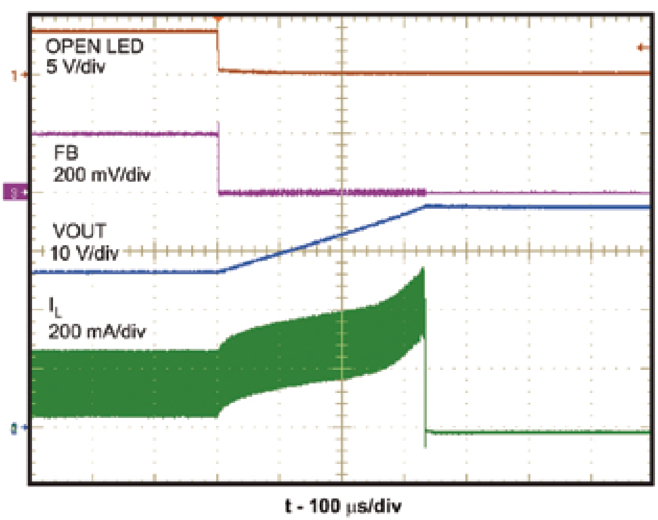
Switching Waveform



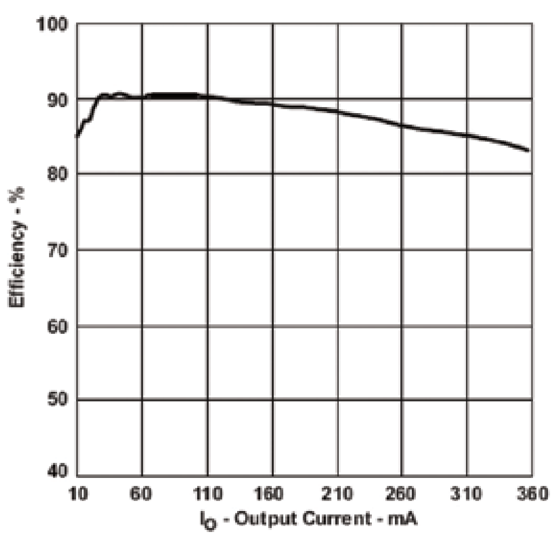
Output Ripple



Open LED Protection



Efficiency



TL4242 NEW!

Description

High-brightness LEDs are becoming more and more prevalent in all facets of life. Linear drivers are great for simple applications that do not require very high efficiency and for applications that must have little or no electromagnetic interference (EMI). Pulse-width modulation (PWM) is used for dimming in some of these applications but can also introduce EMI. This reference design uses a simple linear LED driver for high-brightness applications and demonstrates one of several methods of controlling dimming without the introduction of EMI.

The TL4242 is a linear constant-current single-channel LED driver capable of sourcing up to 500 mA. The TL4242 is capable of running from a supply of up to 42 V so that a large LED string can be driven through a single device. Figure 1 shows a simple example of the TL4242 used to drive four LEDs (typical VF = 3.5 V). In this design, the PWM pin is used only to enable and disable the TL4242. The current is set through a very simple relationship between the sense resistor (R_{REF}) and the voltage at the REF pin (V_{REF}):

$I_{OUT} = V_{REF}/R_{REF}$

The TL4242's typical VREF is 0.177 V. If R_{REF} is set to 2 Ω, then the corresponding I_{OUT} will be 88.5 mA.

In the application in Figure 1, the 18-V supply current is fed directly into the TL4242 for LED current. The TL4242 also monitors the LED string for an open condition and sets the status (ST) pin if an open is detected.

To enable dimming without PWM, R_{REF} must be changed and is easily manipulated with a simple analog switch. The TS3A4742 is chosen (see Figure 2) because of its low (typically 0.7-Ω) R_{ON}, high-current (100-mA) capability, dual-switch configuration and normally closed operation. Care must be taken to keep the channel current under 100 mA.

Figure 2 demonstrates the TL4242 used with the TS3A4742 to produce an LED dimming circuit capable of switching between 200, 250, 300 and 350 mA. Changing R_{REFP}, R_{REFS1} and R_{REFS2} provides a wide variety of dimming levels. R_{REFS1} and R_{REFS2} must be chosen with the R_{ON} of the switch in mind. Note that each leg has the same current when it is on, regardless of the other legs' current.

Figure 1. Simple TL4242 LED Drive Circuit

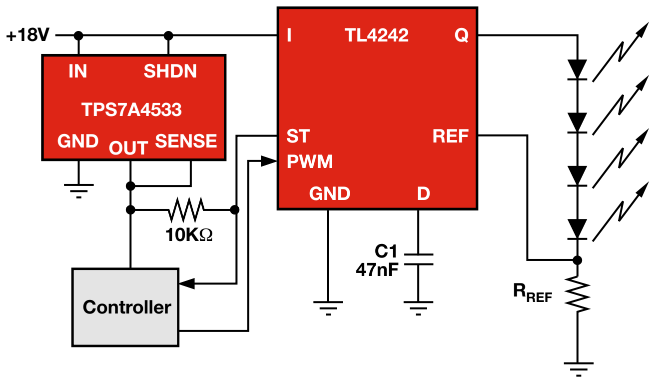
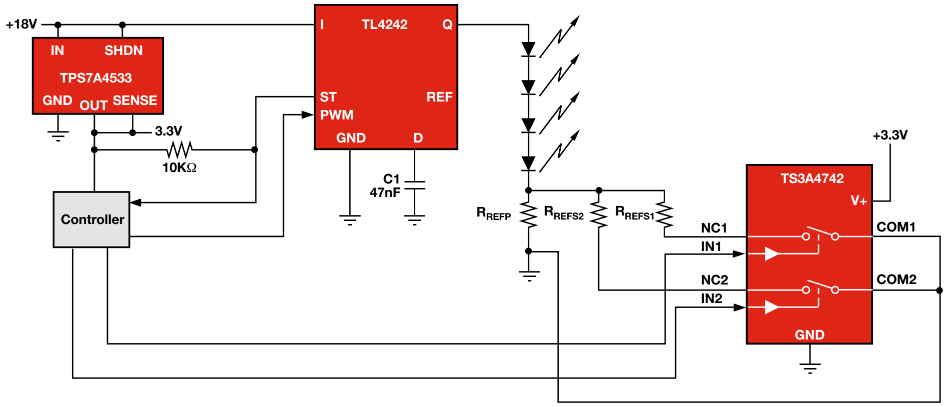


Figure 2. TS3A4742 Dual, Normally Closed Analog Switch Provides Four Brightness Levels



Primary Reference Resitor (R_{REFP})	Switched Reference Resistors (R_{REFS1})	(R_{REFS2})	Equivalent Resistance (R_{REF})	Nominal Output Current (I_{OUT})
0.885 Ω	1.77 Ω	3.54 Ω	0.506 Ω	350 mA
0.885 Ω	1.77 Ω	Open	0.590 Ω	300 mA
0.885 Ω	Open	3.54 Ω	0.708 Ω	250 mA
0.885 Ω	Open	Open	0.885 Ω	200 mA

Note: R_{REFS1} and R_{REFS2} include R_{ON} of the TS3A4742.

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

TL4242

Choosing a dual switch with a low RON allows the user to connect both channels in parallel, thereby reducing the effective R_{ON}. This parallel approach can reduce the TS3A4742's typical R_{ON} to 0.35 Ω. Figure 3 shows an example using this parallel approach to generate a dual-brightness design. This application uses a 0.65-Ω resistor (R_{REFS1}) in series with both switches, creating an effective R_{REF} of 1-Ω. This leg will sink 177 mA (88.5 mA through each switch) when on. Care must be taken to keep the current through the analog switch below the maximum allowed. Additionally, the power dissipation in the switch package must be considered. In the case of the TS3A4742, the maximum continuous current is 100 mA per channel. Figure 3 also removes the controller and replaces it with simple push-button switches. This design allows a single button (or other manual control) to enable the LEDs (simple push-button 1) and another to set the brightness level (simple push-button 2). This is a simple automotive tail-light solution for on/off and braking. The tail light is on when PWM is high (push-button 1 is not depressed). The brightness of the tail light is normal when push-button 2 is not depressed and brighter when it is depressed.

Another option is to hook up the switches in a serial manner (see Figure 4), thereby doubling the resistance to 1.4 Ω. This also permits dual brightness; but the current through the TS3A4742 is limited to 100 mA per channel, so the brightness will be lower than when the channels are in parallel.

Web Links

Datasheets, user's guides, samples:
www.ti.com/sc/device/**TL4242**

Figure 4. Switches in Series

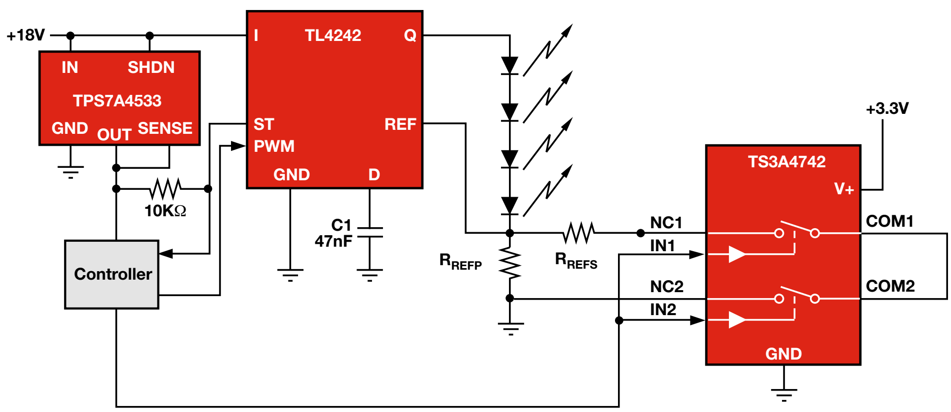
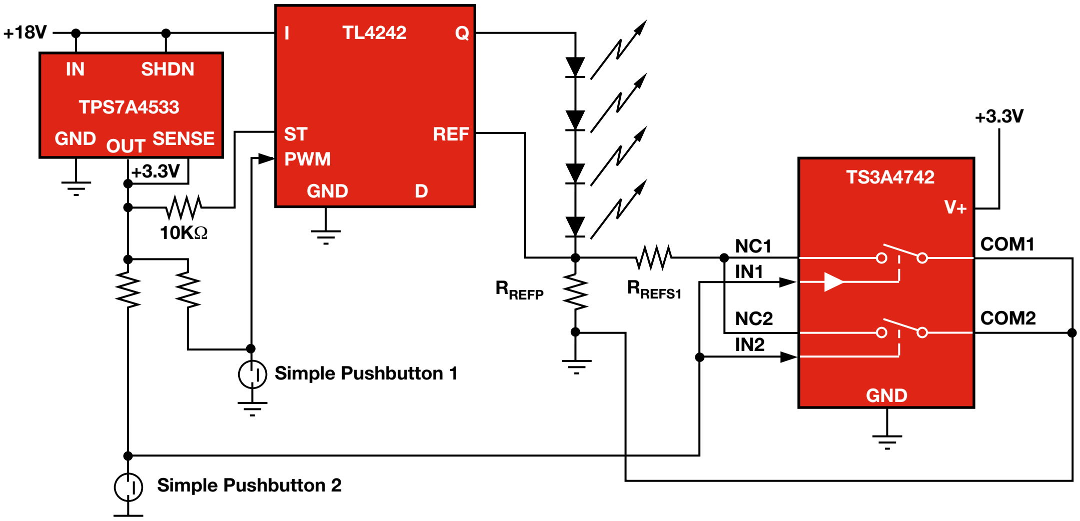


Figure 3. Analog-Switch Brightness Control



Primary Reference Resistor (R_{REFP})	Switched Reference Resistors (R_{REFS1} + $R_{REFSwitch}$)	Equivalent Resistance (R_{REF})	Nominal Output Current (I_{OUT})
1 Ω	1 Ω + 1.4 Ω = 2.4 Ω	1.09 Ω	162 mA
1 Ω	Switch Open	2 Ω	88.5 mA

TLC5917 NEW!

Description

The TLC5917 is an 8-channel, constant-current LED driver capable of up to 120 mA per channel. This is a great fit when an application requires a constant LED current that is independent of input voltage, temperature and differences in LED forward-voltage drops resulting from uncontrolled manufacturing processes. The outputs can also be tied in parallel when needed to drive high-brightness LEDs. Communication is accomplished through a basic serial port. Many applications do not have the capability for generating even simple serial commands. This reference design allows a user to overcome this issue with a simple 555 timer.

The TLC5917 drives eight independent constant-current sinks. Normally, a microprocessor drives the /OE (output enable), SDI (serial data input), CLK (clock) and LE (latch) pins with four separate GPIO pins, which allows the current sink to be independently turned on and off. If independent LED control is not needed, the TLC5917 can be turned on with a single clock signal or a 555 timer.

- /OE (output enable)—This pin enables and disables all outputs.
- SDI (serial data input)—The data clocked into this pin programs each output to be on or off.
- CLK (clock)—The rising edge of the clock shifts SDI data into internal shift registers.
- LE (latch)—The falling edge of LE latches data from the internal shift registers into the internal on/off latches.

Close examination of the TLC5917 timing diagram reveals that a single PWM signal can replace the CLK and LE inputs because the rising edge of CLK shifts data into the IC and the falling edge of LE latches the data. Figure 1 shows how to configure the TLC5917 to operate from a single clock signal.

/OE must be connected to ground to enable the IC. The SDI pin can be connected to VCC to shift 1's into the IC to turn all outputs on, and can be connected to ground to shift all 0's into the IC to turn all outputs off. The CLK and LE pins can be connected to any type of PWM signal. Turn-on and turn-off times with this circuit depend on the clock frequency. At power up, the TLC5917's internal on/off latches that turn each output on or off default to "0", so these latches must be set to "1" before the outputs turn on. Each rising and falling edge of the clock signal sequentially turns on each output, starting with OUT0. Therefore, it takes eight clock cycles to turn all LEDs on. Pulling SDI low turns all LEDs off after eight clock cycles. Figure 2 shows how the TLC5917 responds to turn-on and turn-off when it is configured as shown in Figure 1. Note that Figure 1 shows all the TLC5917 outputs connected in parallel to drive a single high-brightness LED. The TLC5917 outputs can either drive eight independent LEDs or be connected in parallel to drive higher-power LEDs. In Figure 1, R3 = 178Ω, which sets each output current at 105.3 mA. Connecting all outputs in parallel yields 105.3 mA x 8 = 842.4 mA of LED current.

This same approach can be used for any of the 8- and 16-channel TLC59xx families, including the TLC5916/25/26/27 and TLC59025.

Web Links

Datasheets, user's guides, samples:
www.ti.com/sc/device/TLC5917

Figure 1. TLC5917 Driven by 555 Timer

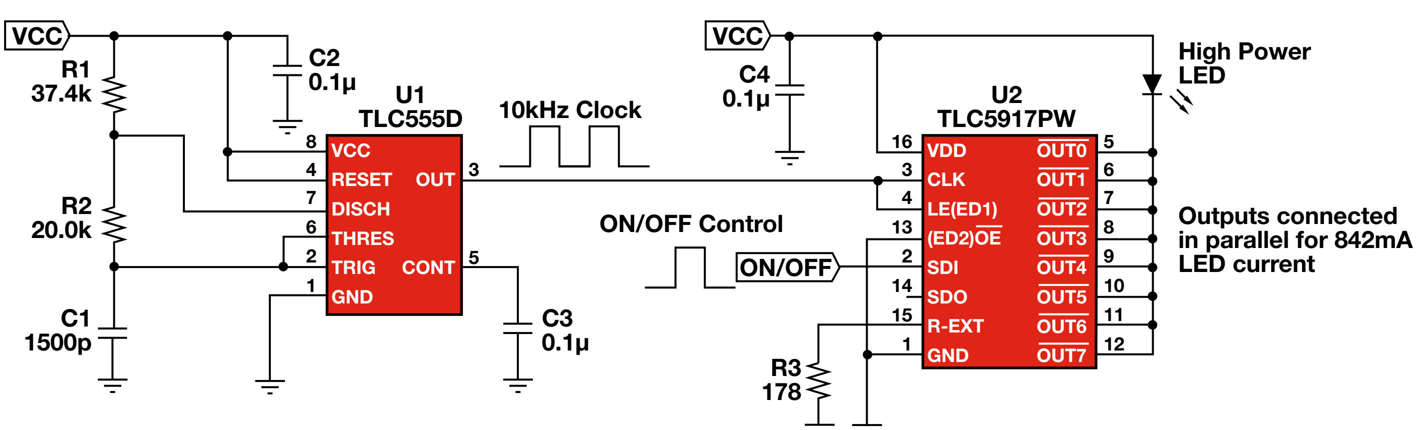
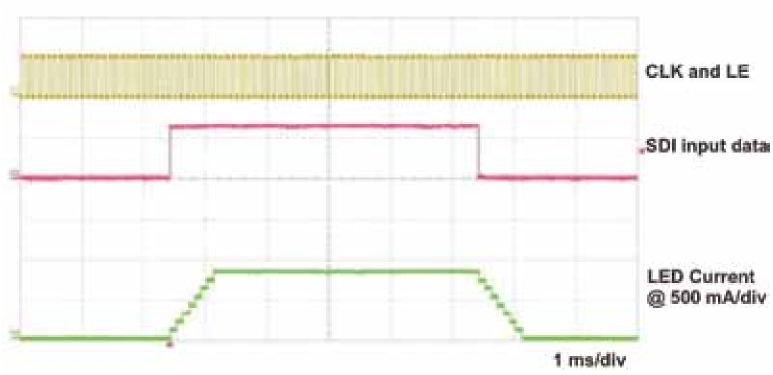


Figure 2. LED's Turn-On and Turn-Off Responses with 10-kHz Clock



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

TPS62260 TPS62260LED

Description

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™ ultralow-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-fet430uif.html**

Key Features

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

Web Links

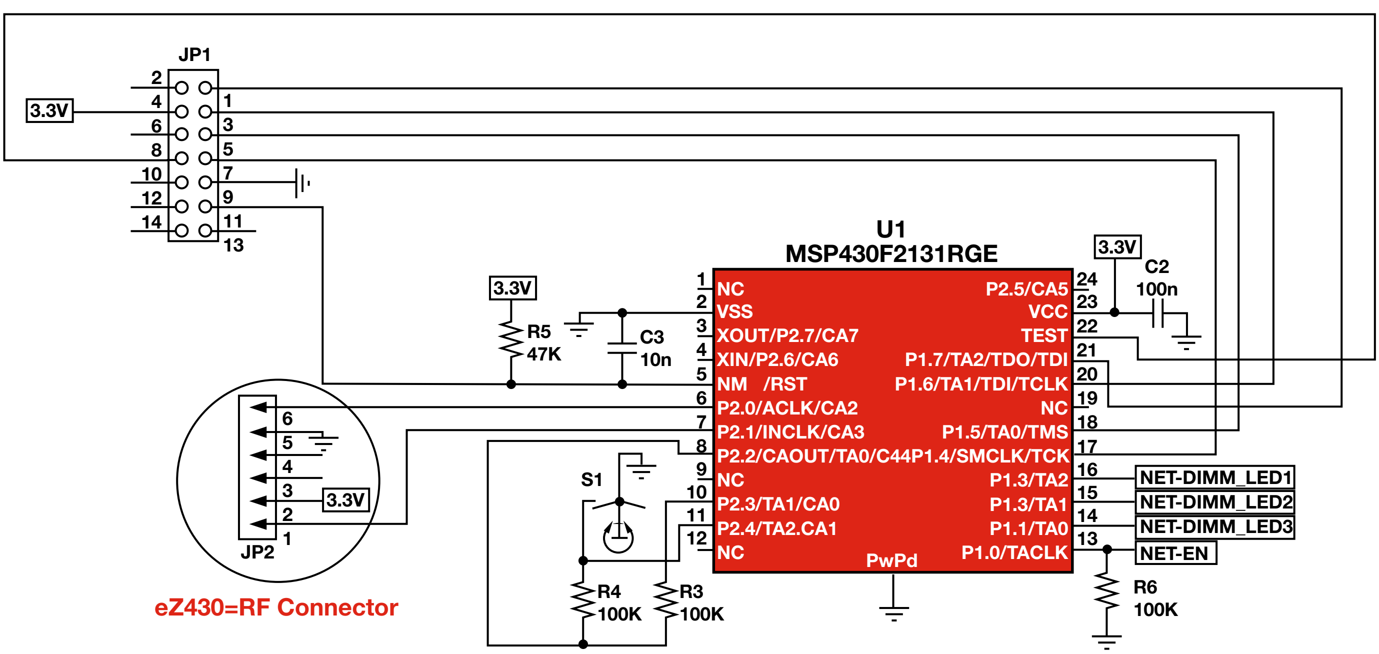
Datasheets, user's guides, samples:
www.ti.com/sc/device/**TPS62260**

EVM:
www.ti.com/**tps62260led-338**

Design Specifications

Parameter	Minimum	Typical	Maximum	Unit
Input voltage	4.5	5	5.5	V_{DC}
Output current	—	0.300	—	Amp

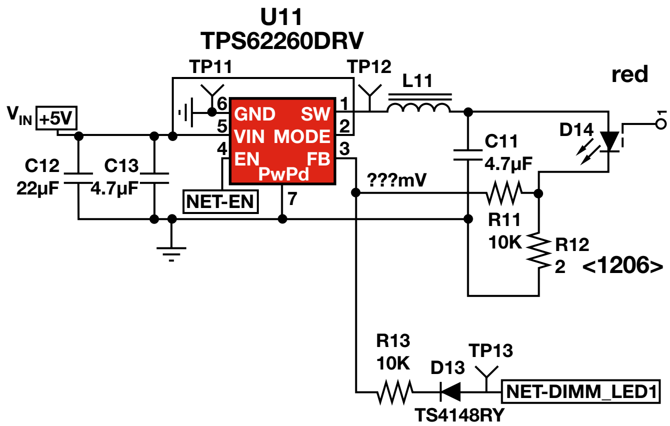
TPS62260LED-338 Schematic



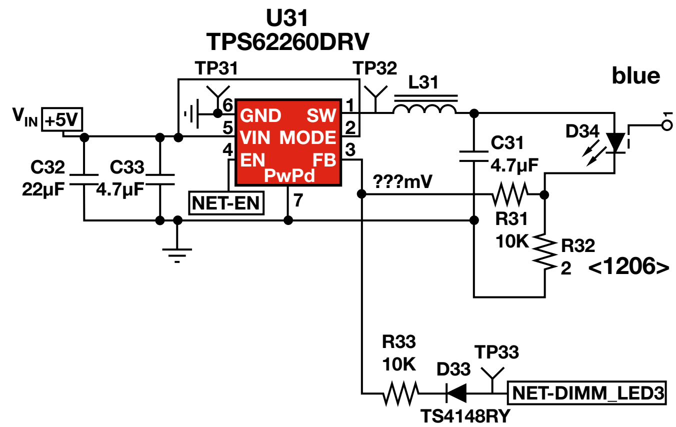
For more reference designs, see: www.ti.com/powerreferencedesigns

TPS62260 TPS62260LED

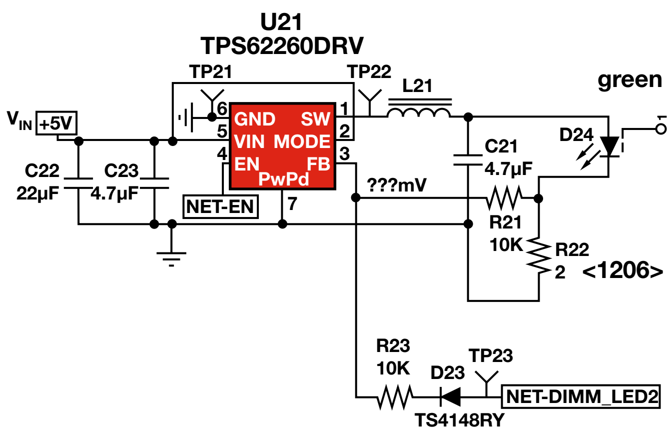
Red LED

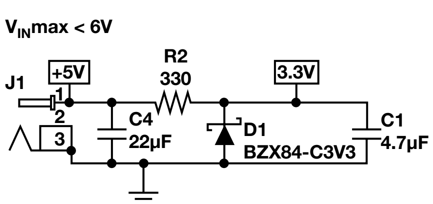


Blue LED



Green LED





TPS63000 PMP3038

Description

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

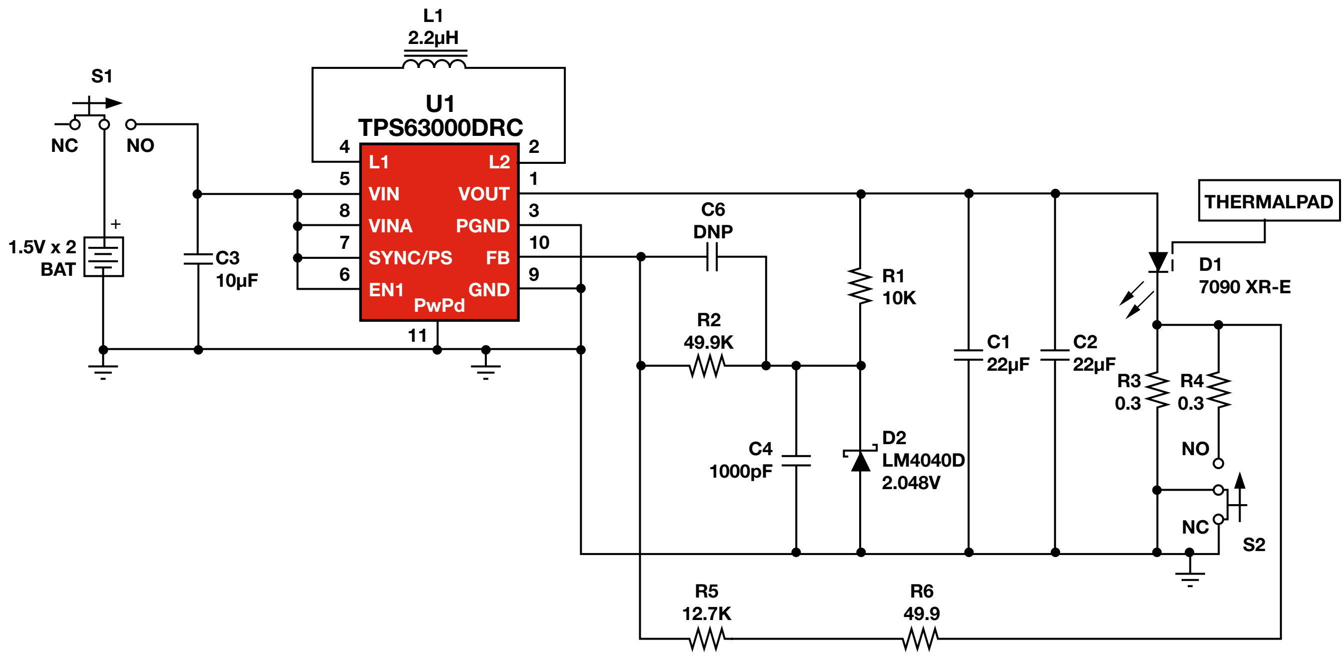
Web Links

Datasheets, user's guides, samples:
www.ti.com/sc/device/TPS63000

Design Specifications

Parameter	Minimum	Maximum	Unit
Input voltage	1.2	5	V_{DC}
Output voltage	—	5	Volts
Output current	300	600	mAmp
Switch frequency	—	1.5	MHz

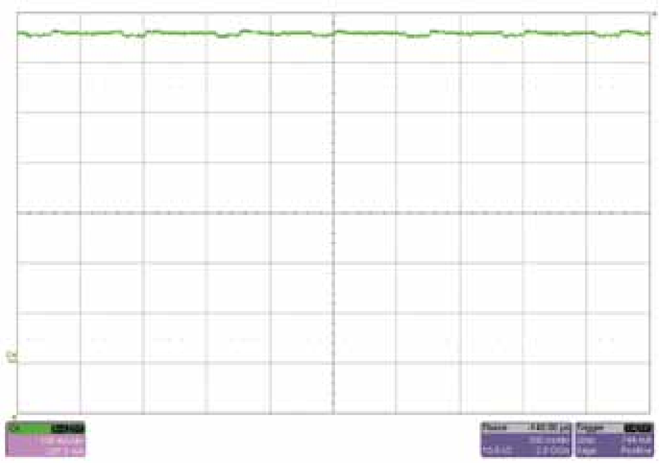
PMP3038 Schematic



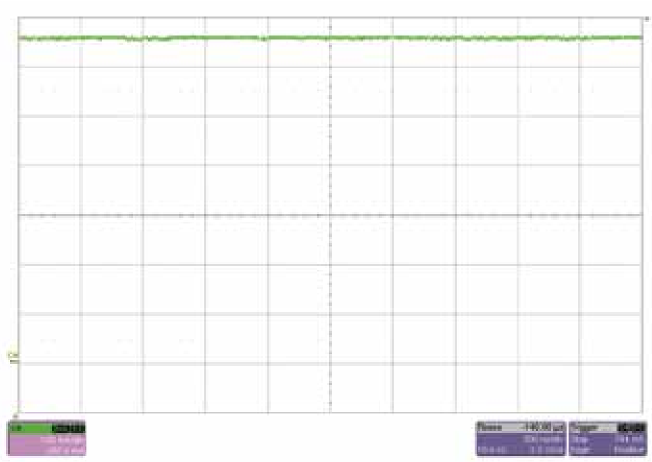
For more reference designs, see: www.ti.com/powerreferencedesigns

TPS63000 PMP3038

Output Current Graphs with DC Coupling

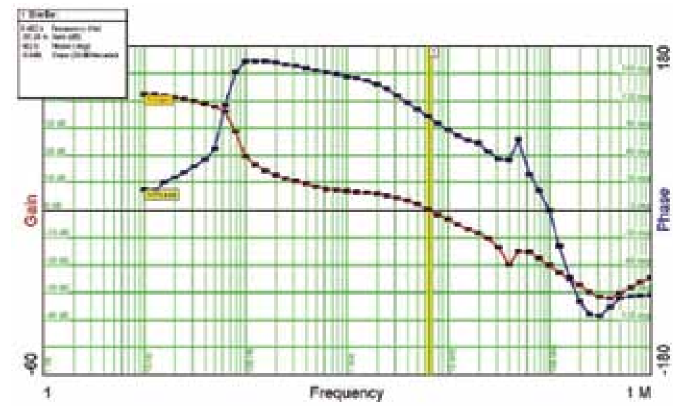


Output current with V_{IN} = 3 V.

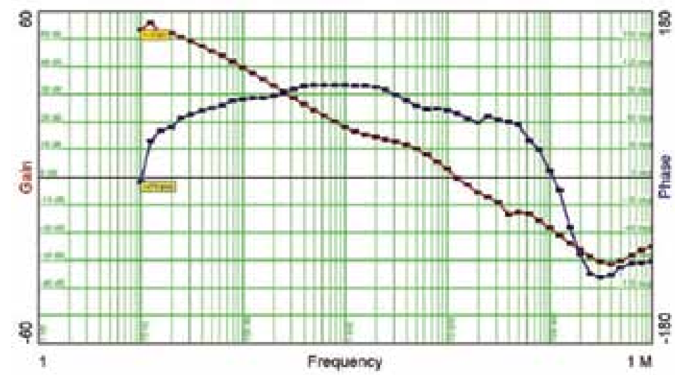


Output current with V_{IN} = 4 V.

Control Loop Response Graphs

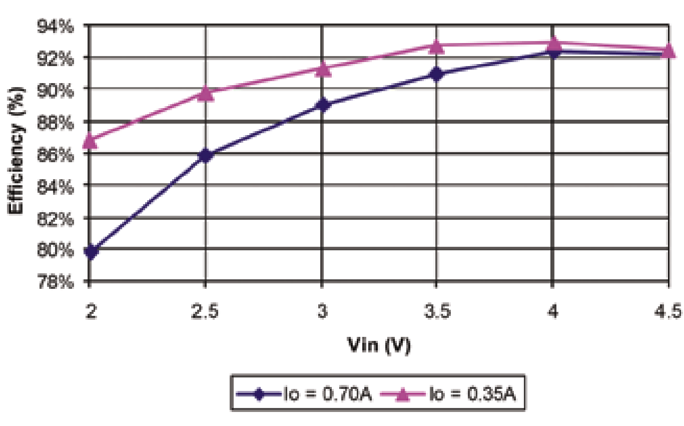


Control loop response with 0.63 A.



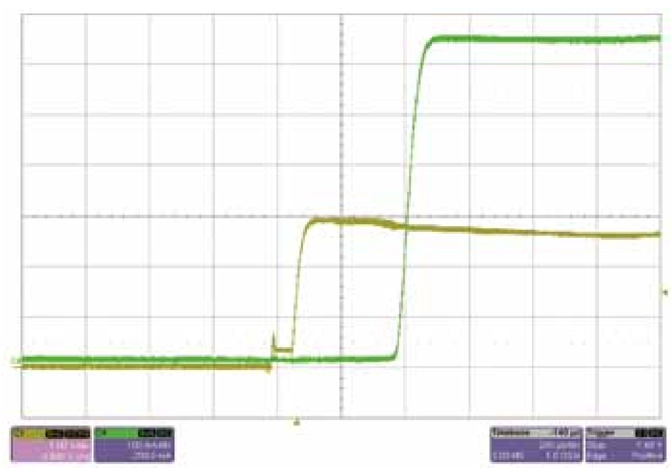
Control loop response with 0.32 A.

Efficiency Curve for I_O = 0.32 A and I_O = 0.62 A



Efficiency.

Turn On with 0.63 A



TPS61500

Description

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 multicell batteries or regulated 5-V to12-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

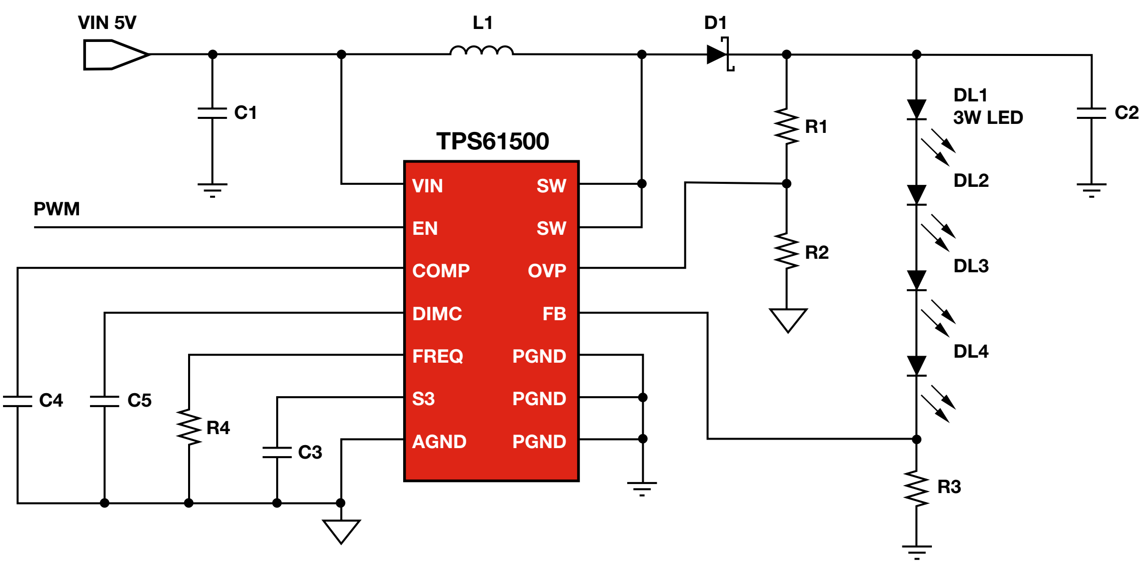
Datasheets, user's guides, samples:
www.ti.com/sc/device/**TPS61500**

LED Current vs. Input Supply and LED Number

Input Supply	5 V	12 V
LED number 4	1000 mA	2000 mA
LED number 6	600 mA	1200 mA
LED number 8	450 mA	1000 mA

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

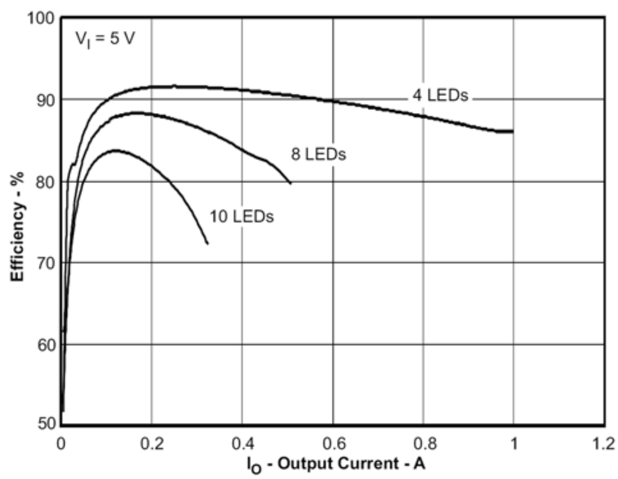
Typical Application Schematic



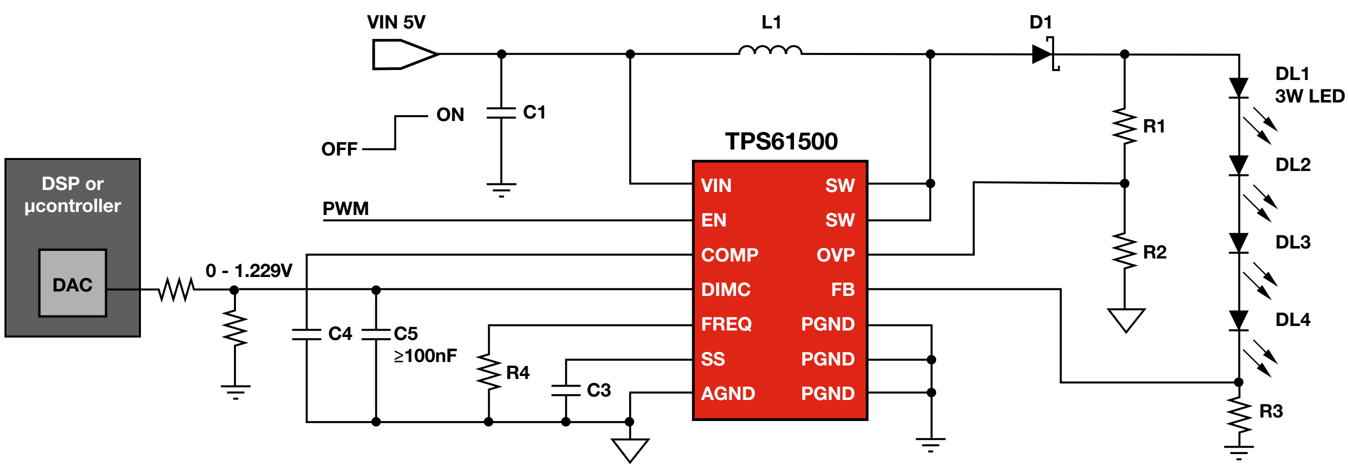
For more reference designs, see: www.ti.com/powerreferencedesigns

TPS61500

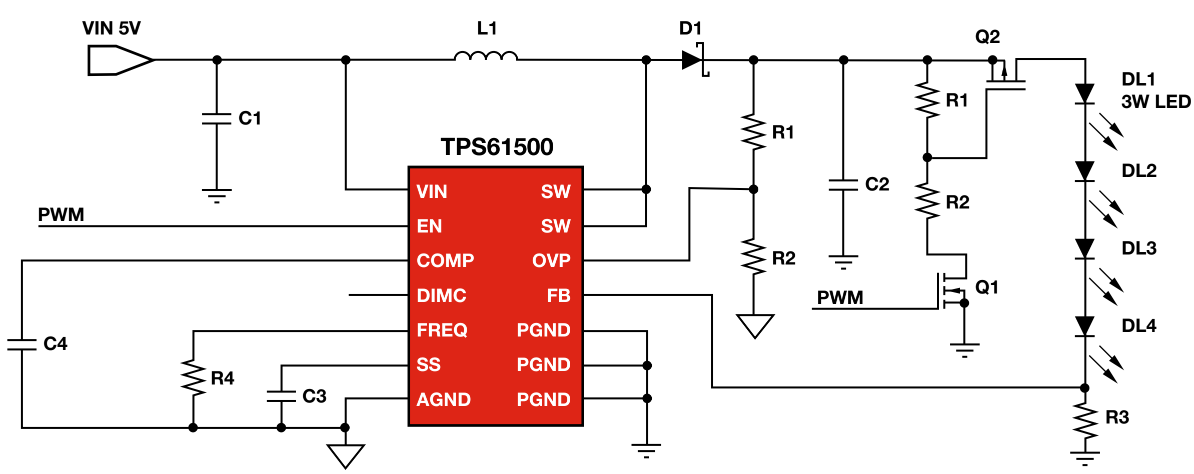
Efficiency vs. Output Current



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



TPS61180/1/2 NEW!

Description

The TPS61180/1/2 ICs provide highly integrated solutions for media-size LCD backlighting. These devices have a built-in, high-efficiency boost regulator with an integrated 1.5-A/40-V power MOSFET. The six current-sink regulators provide high-precision current regulation and matching. In total, the device can support up to 60 white LEDs (WLEDs). In addition, the boost output automatically adjusts its voltage to the WLED forward voltage to improve efficiency.

The devices support pulse-width-modulation (PWM) brightness dimming. During dimming, the WLED current is turned on/off at the duty cycle, and frequency is determined by the PWM signal input on the DCTRL pin. One potential issue of PWM dimming is audible noise from the output ceramic capacitors. The TPS61180/1/2 family is designed to minimize this output AC ripple across wide dimming-duty-cycle and frequency ranges, therefore reducing the audible noise.

The TPS61180/1/2 ICs provide a driver output for an external PFET connected between the input and inductor. During short-circuit or overcurrent conditions, the ICs turn off the external PFET and disconnect the battery from the WLEDs. The PFET is also turned off during IC shutdown (true shutdown) to prevent any leakage current from the battery. The device also integrates overvoltage protection, soft starting and thermal shutdown.

The TPS61180 IC requires an external 3.3-V IC supply, while the TPS61181/2 ICs have a built-in linear regulator for the IC supply. All the devices are in a 3- x 3-mm QFN package.

Web Links

Datasheets, user's guides, samples:
www.ti.com/sc/device/**TPS61180**,
www.ti.com/sc/device/**TPS61181** or
www.ti.com/sc/device/**TPS61182**

Design Specifications

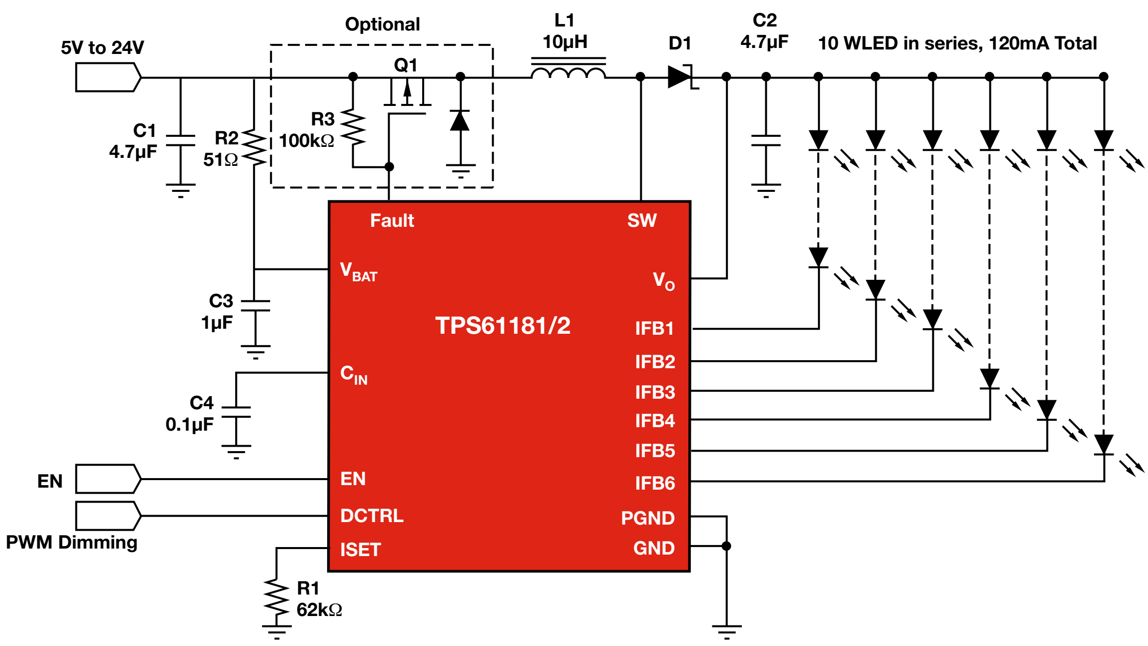
Parameter	Minimum	Typical	Maximum	Unit
Input voltage	4.7	—	24	Volts
Output voltage	15	—	38	Volts
Output ripple	—	—	200	mVPP
Output current	0	—	150	mA
Switching frequency	—	1000	—	kHz

Also Available Soon

Device	Switch	Channels	Current per Channel	LEDs per Channel
TPS61183	2.0 A	6	30 mA	Up to 10
TPS61185	2.0 A	8	25 mA	Up to 10
TPS61195	2.5 A	8	30 mA	Up to 12

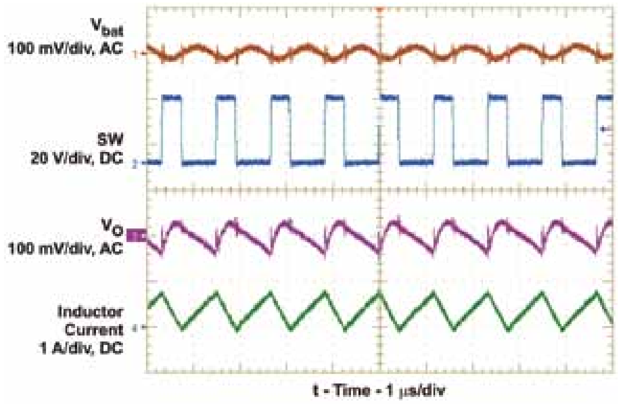
*Preview products are listed in **bold blue**.*

Typical Application Schematic

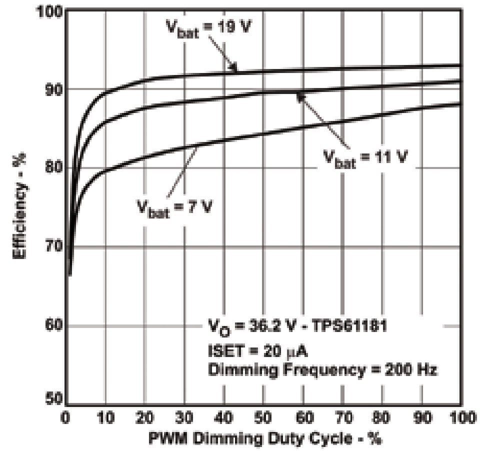


TPS61180/1/2

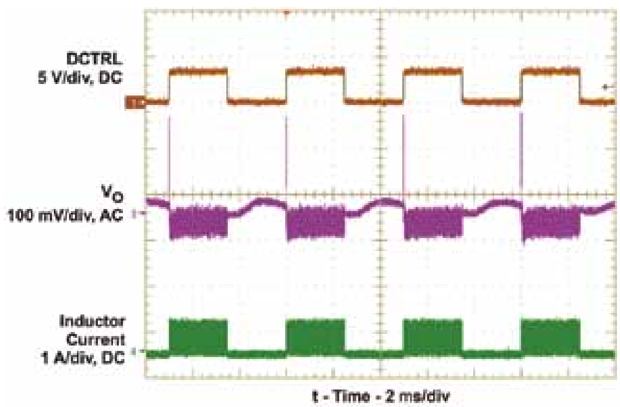
Switching Waveforms



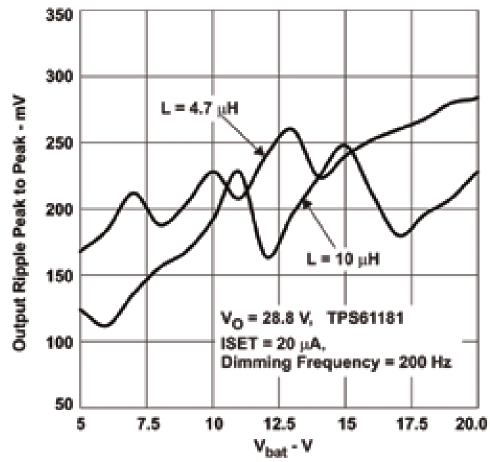
Efficiency vs. PWM Duty



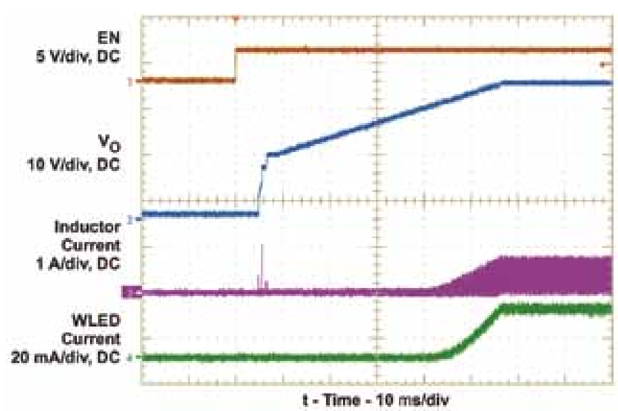
Output Ripple at PWM Dimming



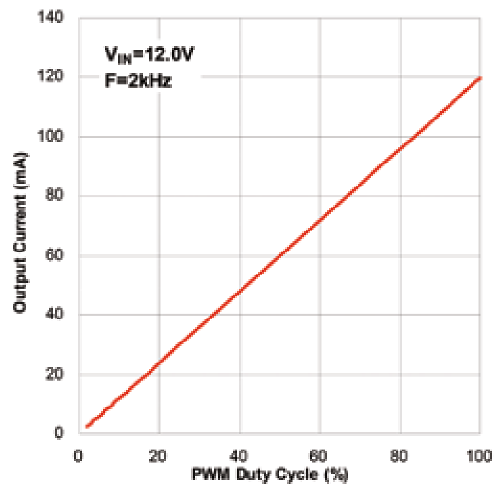
Output Ripple at PWM Dimming



Start-up Waveforms



Output Current vs. Dimming Duty Cycle



DRV9812 NEW!

Description

The DRV9812, which has a wide input voltage of up to 50 V, is a synchronous multichannel PWM power driver for LED applications. It can be configured as buck, boost or buck/boost, depending on the application requirements, and can drive 4 independent LED strings with up to 15 power LEDs in series per string. It can also provide DC, sine-wave, or any other kind of desired current to drive LEDs based on a PWM control algorithm from an external MCU controller.

Because of the integrated low-RDS(on) MOSFETs and intelligent gate-drive design, the efficiency of the DRV9812 can be as high as 96%. The device offers integrated, on-chip safeguards against a wide range of fault conditions such as short circuits and overcurrent and undervoltage conditions. It also offers integrated two-stage thermal protection. A programmable overcurrent detector provides an adjustable cycle-by-cycle current limit to meet different power requirements.

The DRV9812 has a unique, independent supply pin for each channel, enabling it to support multiple outputs with different power-supply-voltage requirements or with mixed converter topologies.

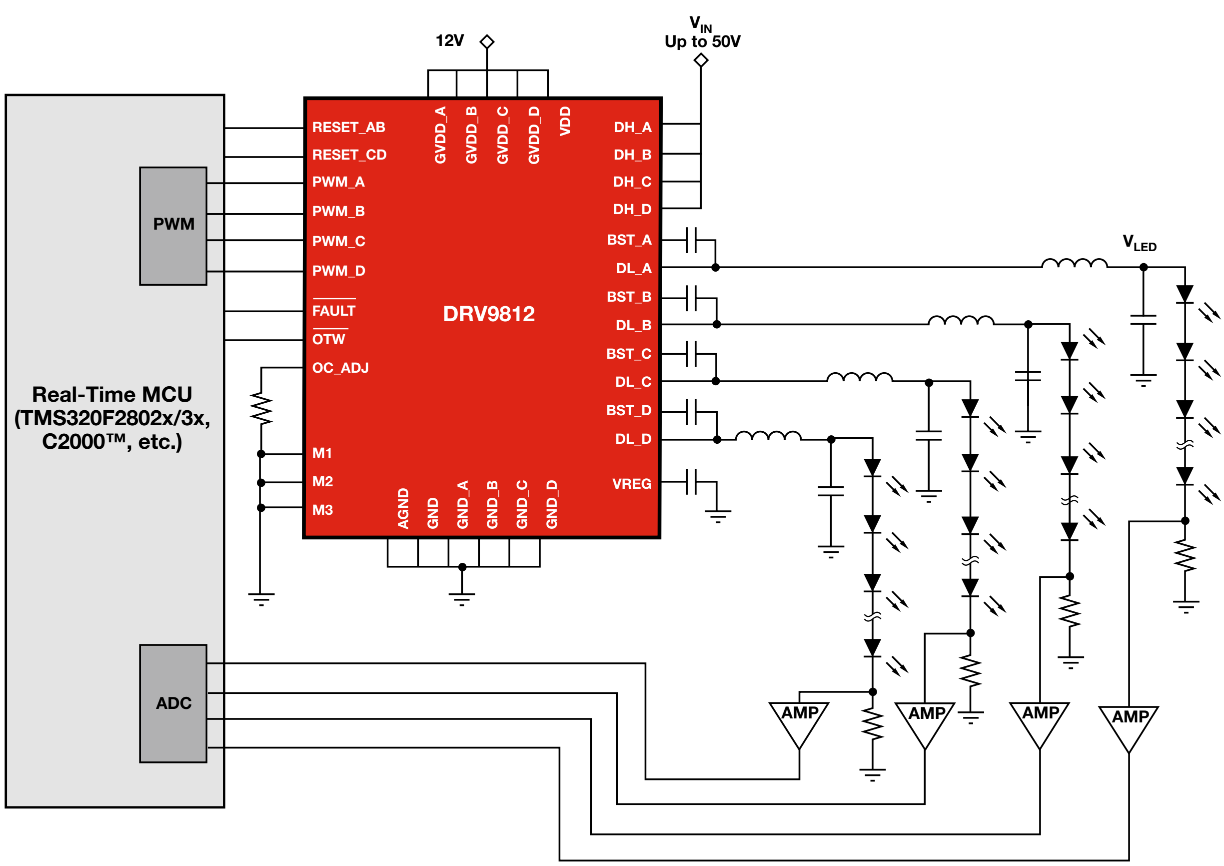
Web Links

Datasheets, user's guides, samples:
www.ti.com/sc/device/**DRV9812**

Design Specifications

Parameter	Minimum	Typical	Maximum
Input Voltage (V)	2	—	50
Output Voltage (V)	0	—	49.5
Gate Voltage (V)	11.4	12.3	13.2
Peak Output Current (A)	—	—	5
RMS Output Current (A)	—	—	2.5
Switching Frequency (kHz)	—	10 to 500	1000

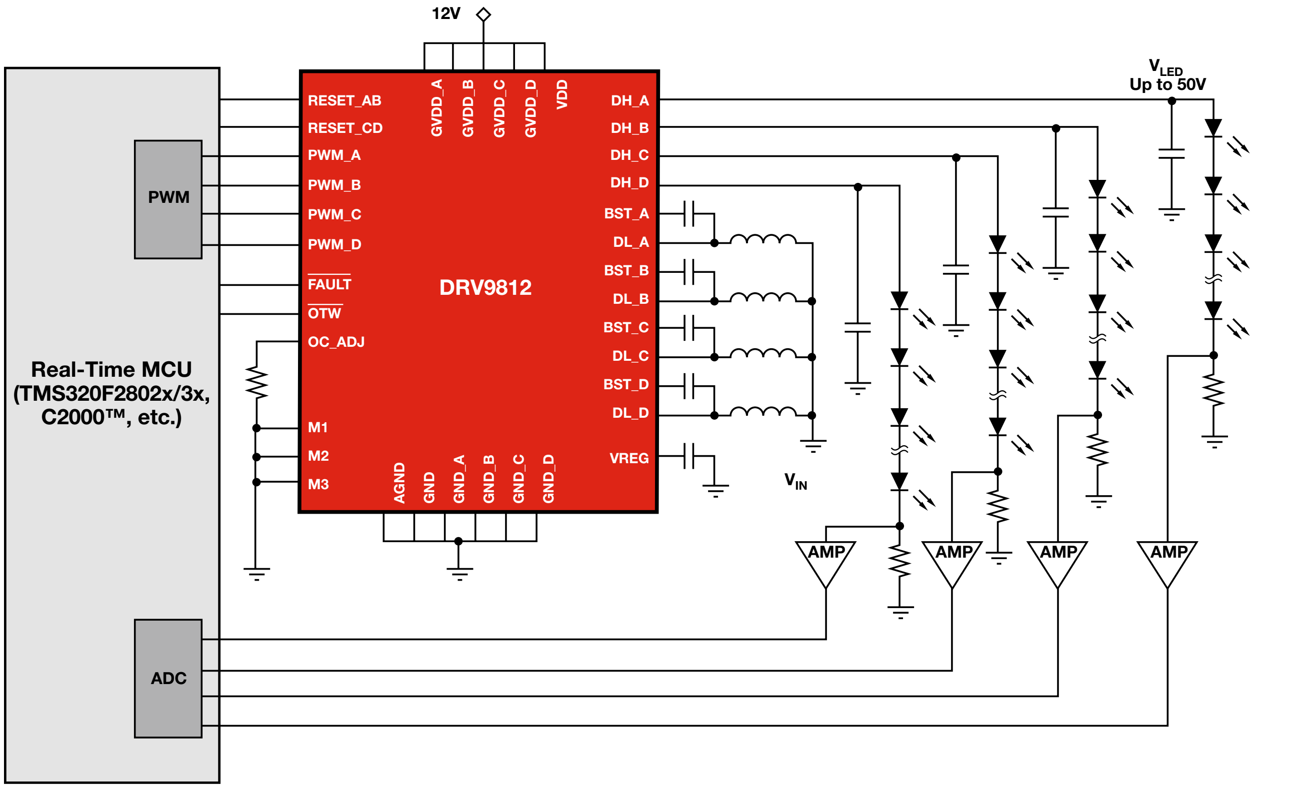
DRV9812 Typical Application Schematic in Buck Configuration



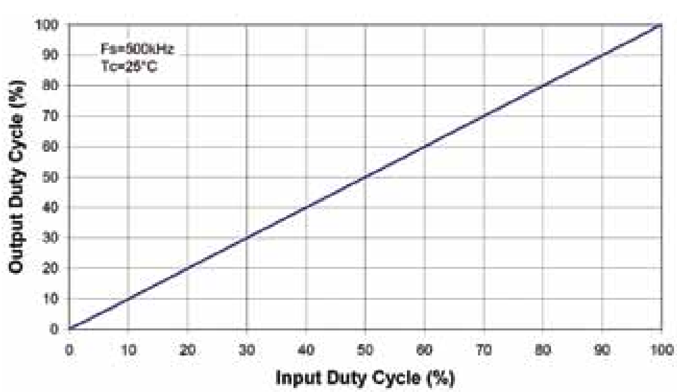
For more reference designs, see: www.ti.com/powerreferencedesigns

DRV9812

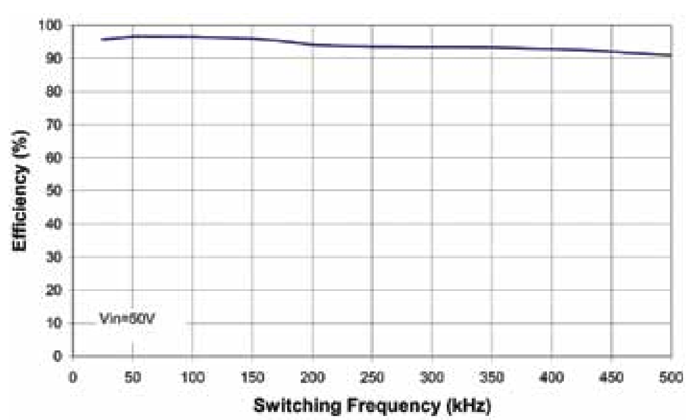
DRV9812 Typical Application Schematic in Boost Configuration



PWM Linearity Curve



Efficiency Curve



TPS61160/1

Description

With a 40-V integrated switch FET, the TPS61160/1 is a boost converter that drives up to 10 LEDs in series. The boost converter, which allows for the use of high-brightness LEDs in general lighting, runs at a fixed frequency of 1.2 MHz with a 0.7-A switch-current limit.

As shown in the schematic below of a typical application, the default white-LED (WLED) current is set with the external sense resistor, R_{SET}, and the feedback voltage is regulated to 200 mV. The LED current can be controlled via the one-wire digital interface (EasyScale™ protocol) through the CTRL pin. Alternatively, a PWM signal can be applied to the CTRL pin such that the duty cycle determines the feedback reference voltage. In either digital or PWM mode, the TPS61160/1 does not provide LED current in burst; therefore, it does not generate audible noise on the output capacitor. For protection during open-LED conditions, the TPS61160/1 has integrated circuitry to prevent the output from exceeding the absolute maximum ratings.

Key Features

- Efficient boost topology
- Integrated 40-V power switch
- Drives up to 10 LEDs
- PWM dimmable
- 200-mV V_{REF}
- No audible noise

Web Links

Datasheets, user's guides, samples:
www.ti.com/sc/device/**TPS61160**

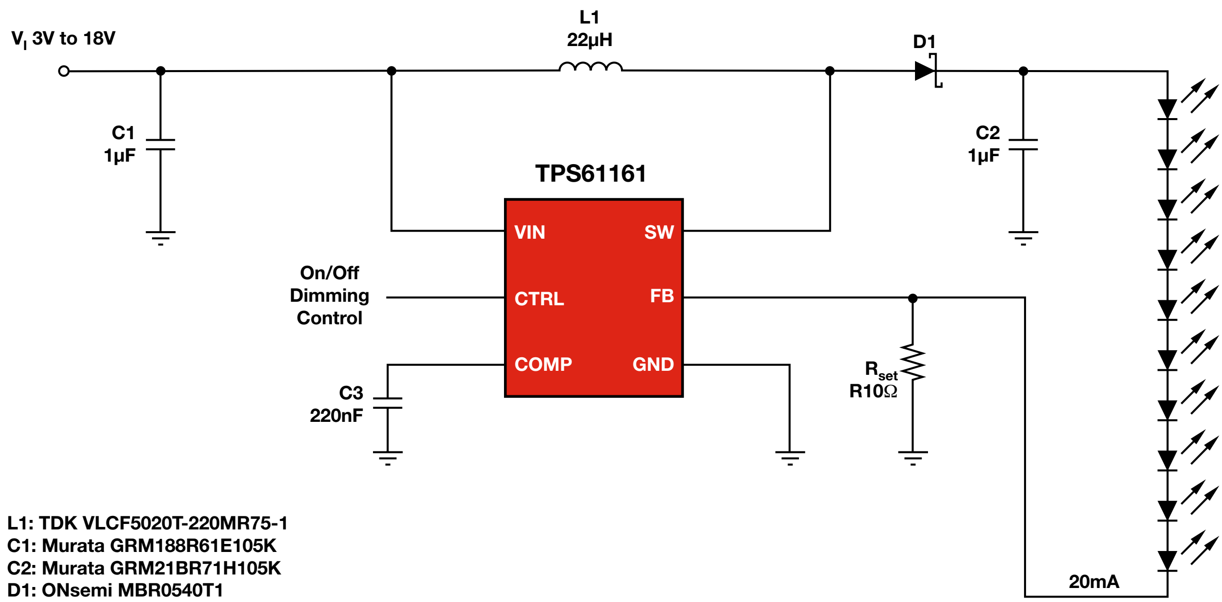
Ordering Information[1]

T_A	Open LED Protection (typical)	Package[2]	Package Marking
–40°C to 85°C	26 V	TPS61160DRV	BZQ
	38 V	TPS61161DRV	BZR

[1]*For most current package and ordering information: www.ti.com/sc/device/**TPS61160**.*

[2]*The DRV package is available in tape and reel. Add R suffix (TPR61160DRVR) to order quantities of 3,000 parts per reel or add T suffix (TPS61160DRVT) to order 250 parts per reel.*

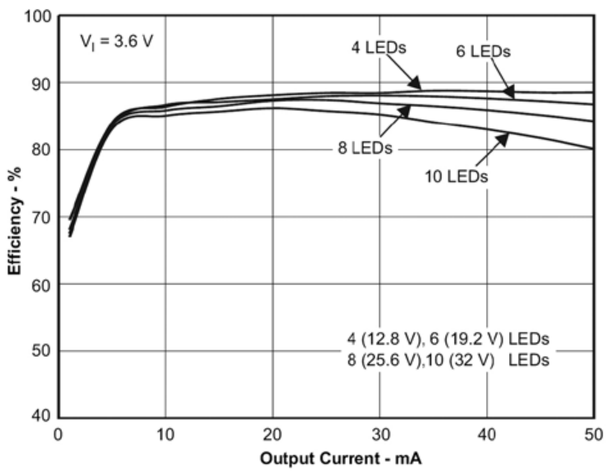
Typical Application Schematic



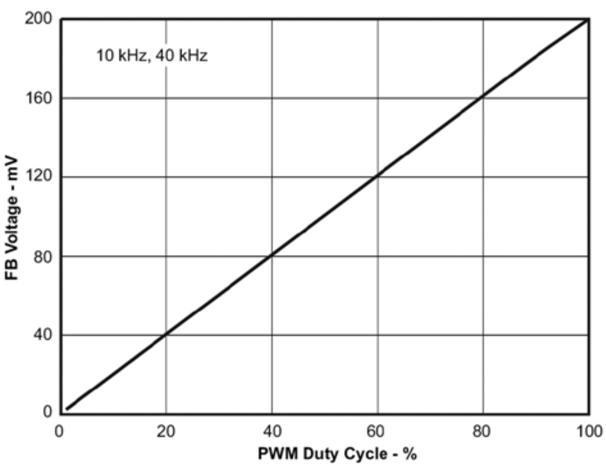
For more reference designs, see: www.ti.com/powerreferencedesigns

TPS61160/1

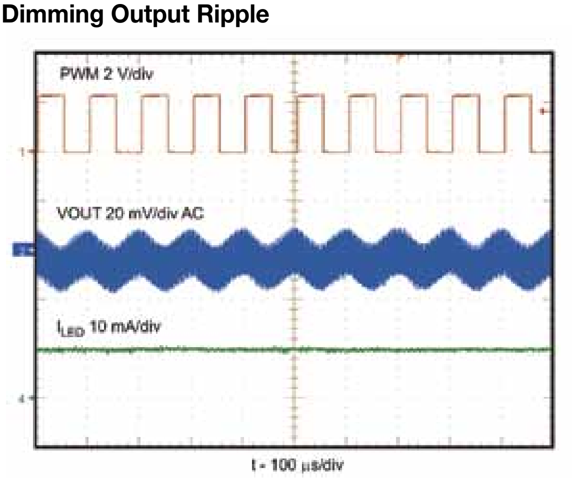
Efficiency vs. Output Current



PWM Dimming Linearity: FB Voltage vs. PWM Duty Cycle



PWM Dimming Output Ripple



TPS7510x

Description

The TPS7510x linear low-dropout (LDO) LED current source is optimized for low-power LED backlighting applications such as keypads and navigation pads. The device provides a constant current for up to four unmatched LEDs organized in two banks of two LEDs each in a common-cathode topology. Without an external resistor, the current source defaults to the factory-programmable, preset current level with ±0.5% accuracy (typical). An optional external resistor can be used to set initial brightness to user-programmable values with higher accuracy. Brightness can be varied from off to full brightness by inputting a PWM signal on each enable pin. Each bank has independent enable and brightness control, but the currents of all four channels are matched concurrently. The input-supply range is ideally suited for single-cell Li-Ion battery supplies, and the TPS7510x can provide up to 25 mA per LED. No internal switching signals are used, eliminating troublesome electromagnetic interference (EMI). The TPS7510x is offered in an ultra-small, 9-ball, 0.4-mm ball-pitch wafer chip-scale package (WCSP) and a 2.5 x 2.5-mm, 10-pin SON package, yielding a very compact total solution size ideal for mobile handsets and portable backlighting applications.

At first glance, using a linear LDO circuit to drive LEDs may seem impractical, given the linear regulator's reputation for low efficiency. However, the efficiency of LDOs is often misunderstood. LDO efficiency is entirely based on the input/output-voltage ratio; therefore, the efficiency of driving white LEDs (WLEDs) can be quite high. For example, driving a 3-V WLED from a 3.6-V Li-Ion-battery input translates into an LED efficiency of 83%.

Figure 1 shows a typical application for the TPS75105. Note that this device requires no external components to drive the WLEDs. The total solution is extremely small and very cost effective.

Figure 2 shows the TPS75105 efficiency data for several different WLED forward voltages over the Li-Ion battery's range. The LED efficiency for the TPS75105 is comparable to or better than that of other WLED-driver solutions.

Figure 3 demonstrates the LED efficiency of the TPS7510x over the Li-Ion battery's discharge curve. The average efficiency for the entire discharge range is over 80% for all three curves, and up to 90% when V_{LED} = 3.3 V.

Key Features

- Drives four constant current outputs
- PWM dimmable
- 0.5% current accuracy
- 25 mA per LED
- Ultra-small size ball pitch packaging 83% efficient solution

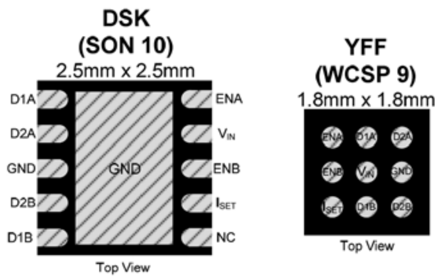
Web Links

Datasheets, user's guides, samples:
www.ti.com/sc/device/**TPS75105**

Device Specifications

Device	V_{IN}	LEDs	ΔI_{DX} MAX	VDO	ΔI_{DX}	Packages
TPS7510x	2.5 V to 5.5 V	2 mm x 2 mm	25 mA	28 mV	±2%	WCSP, DSK

TPS7510x Package Options



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

TPS7510x

Figure 1 - Typical Application

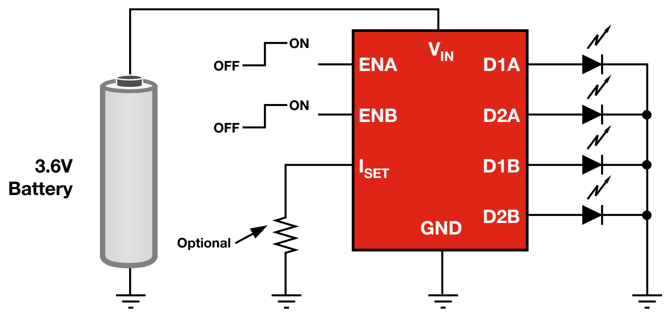


Figure 2 - Efficiency Data

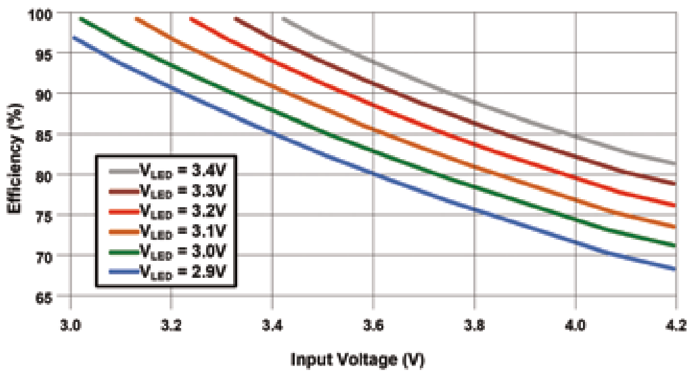
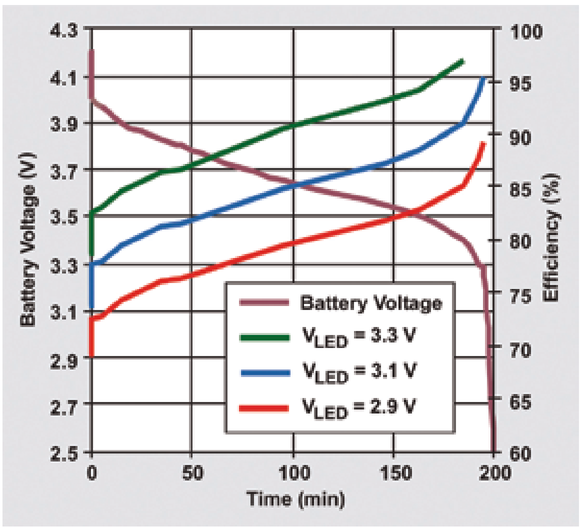


Figure 3 - LED Efficiency



TPS61165

Description

With a 40-V integrated switch FET, the TPS61165 is a boost converter that drives up to ten LEDs in series. The boost converter, which allows for the use of high-brightness LEDs in general lighting, runs at a fixed frequency of 1.2 MHz with a 1.2-A switch-current limit.

As shown in the schematic below of a typical application, the default white-LED (WLED) current is set with the external sense resistor, R_{SET}, and the feedback voltage is regulated to 200 mV. The LED current can be controlled via the one-wire digital interface (EasyScale™ protocol) through the CTRL pin. Alternatively, a PWM signal can be applied to the CTRL pin such that the duty cycle determines the feedback reference voltage. In either digital or PWM mode, the TPS61160/1 does not provide LED current in burst; therefore, it does not generate audible noise on the output capacitor. For protection during open-LED conditions, the TPS61165 has integrated circuitry to prevent the output from exceeding the absolute maximum ratings.

The TPS61165 is available in a space-saving, 2 x 2-mm QFN package with a thermal pad.

Key Features

- Boost converter for high efficiency
- 40-V integrated power switch
- Drives up to 10 LEDs
- Low Vref for high efficiency
- One wire digital interface
- PWM dimming
- No audible noise

Web Links

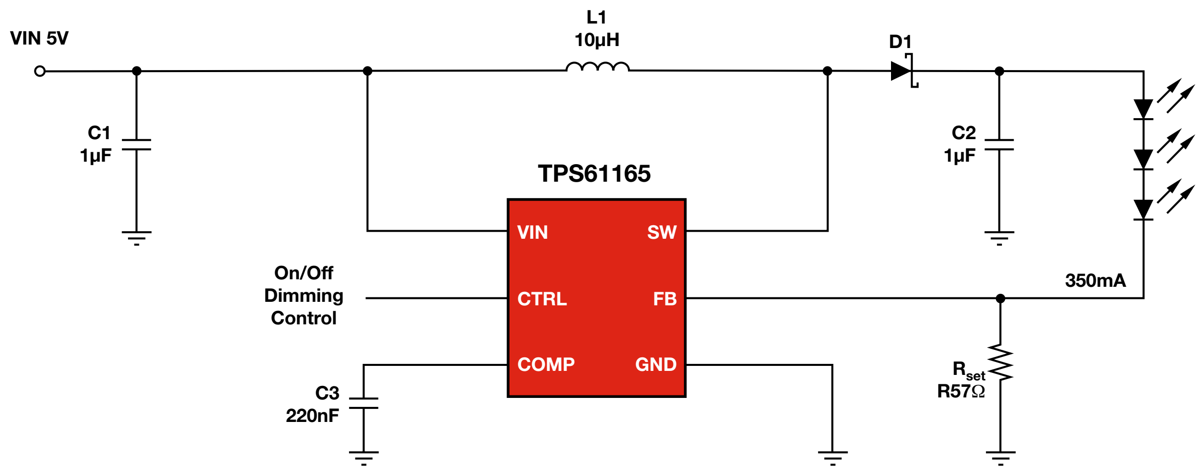
Datasheets, user's guides, samples:
www.ti.com/sc/device/**TPS61165**

LED Current vs. Input Supply and LED Number

Input Supply	3 V	5 V	12 V
LED number 3	200 mA	350 mA	820 mA
LED number 6	100 mA	175 mA	410 mA
LED number 8	70 mA	120 mA	300 mA

Note: Assumption that LED forward voltage is 3.5 V, and TPS61165's conversion efficiency is 80%.

Typical Application Schematic

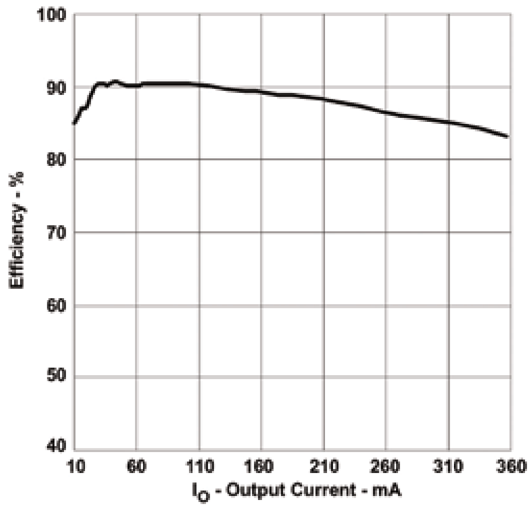


L1: TOKO #A915_Y-100M
C1: Murata GRM188R61A475K
C2: Murata GRM188R61E105K
D1: OSRAM LW-W 5SM

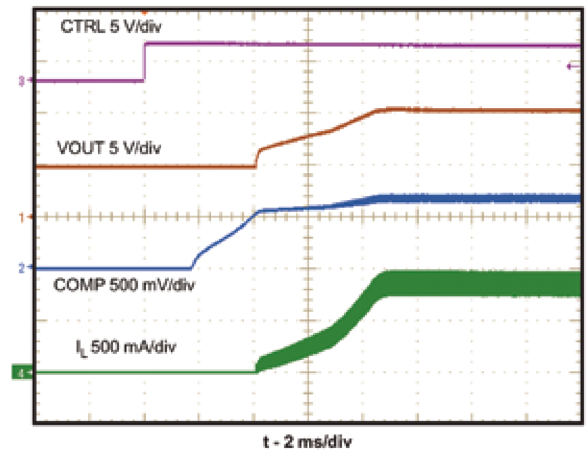
For more reference designs, see: www.ti.com/powerreferencedesigns

TPS61165

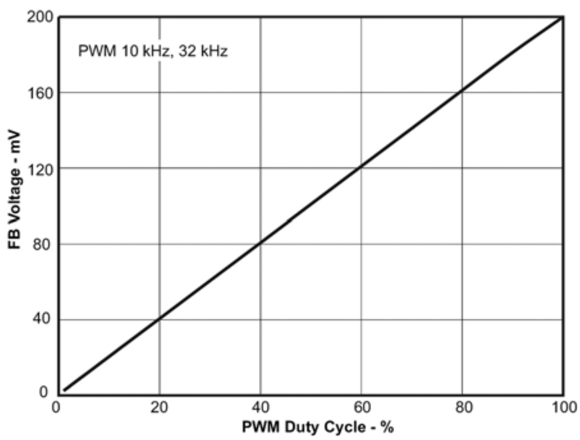
Efficiency vs. Output Current



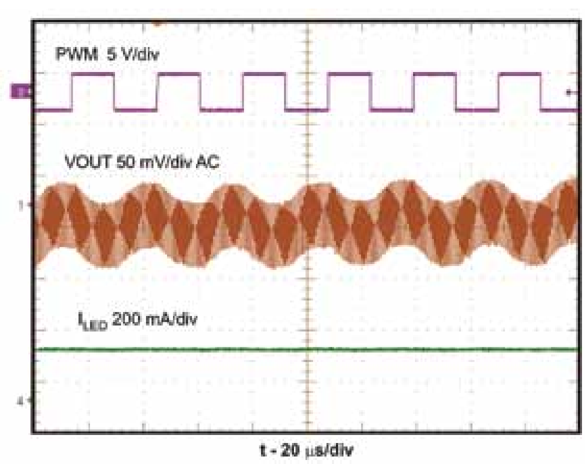
Startup



PWM Dimming Linearity: FB Voltage vs. PWM Duty Cycle



PWM Dimming Output Ripple



TPS61195

Description

The TPS61195 provides highly integrated solutions for large-LCD backlights. This device has a built-in, high-efficiency boost regulator with an integrated 2.5-A, 50-V power MOSFET. The eight current-sink regulators provide high-precision current regulation and matching. In total, the device can support up to 96 white LEDs (WLEDs). In addition, the boost output automatically adjusts its voltage to the WLED forward voltage to improve efficiency.

The TPS61195 supports multiple brightness-dimming methods. During direct PWM dimming, the WLED current is turned on/off at the duty cycle, and the frequency is determined by an integrated PWM signal. In PWM-dimming mode, the frequency of this signal is resistor-programmable, while the duty cycle is controlled from an external PWM signal input from a PWM pin. In analog mixed dimming modes, the input PWM duty-cycle information is translated into an analog signal to control the WLED current signal linearly over a brightness area of 12.5 to 100%. The device also allows PWM dimming to be added when the analog signal keeps the WLED current down to 12.5%. Below 12.5%, the analog signal will be translated into PWM duty-cycle information to control the on/off of the WLED current and to average the WLED current down to 1%.

The TPS61195 integrates overcurrent protection, short-circuit protection, soft start and overtemperature shutdown. The device also provides programmable output overvoltage protection, and the threshold is adjusted by an external resistor/divider combination.

The TPS61195 has a built-in linear regulator for the IC supply and is available in a 4 x 4-mm QFN package.

Key Features

- Boost regulator with integrated 3-A 50-V power switch
- Eight current-sink regulators for precision intensity control
- High efficiency through automatic V_{OUT} to LED Vforward
- PWM dimming
- Multiple protection features:
  - Overcurrent
  - Short circuit
  - Over temperature

Web Links

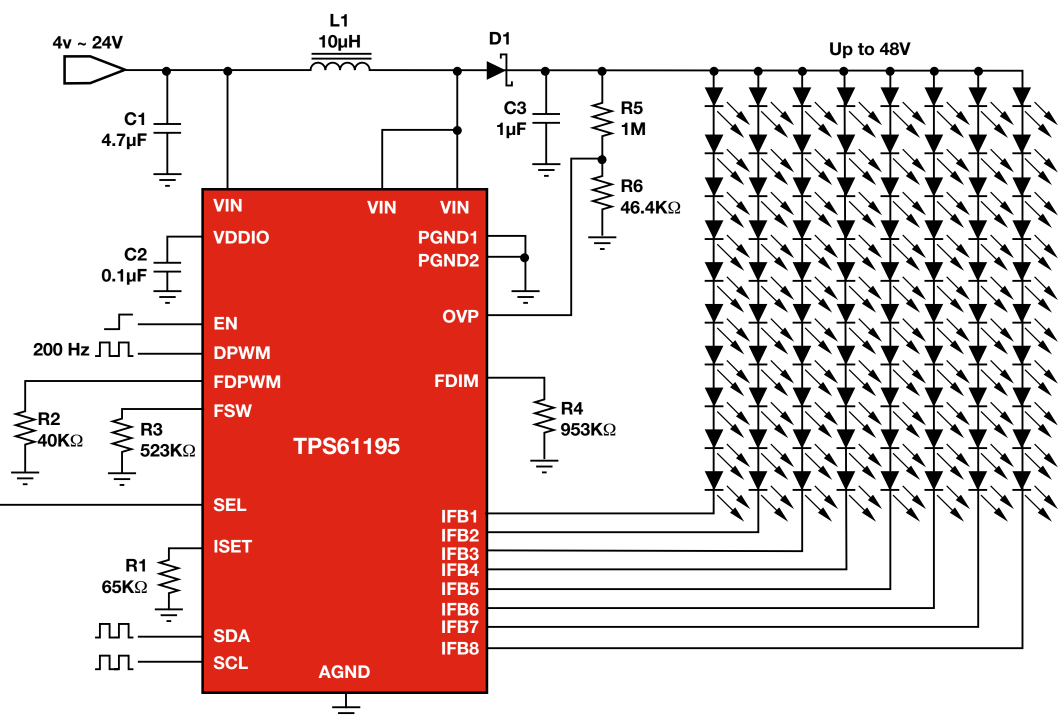
Reference designs:
www.ti.com/**powerreferencedesigns**

Datasheets, user's guides, samples:
www.ti.com/sc/device/**TPS61195**

LED Current vs. Input Supply and LED Number

Parameter	Minimum	Maximum	Unit
Input voltage	4.0	24	Volts
Output voltage	16	48	Volts
Number of channel	—	8	—
Output current	0	0.32	Amp
Switching frequency	600 KHz	1 MHz	—

TPS61195 Schematic

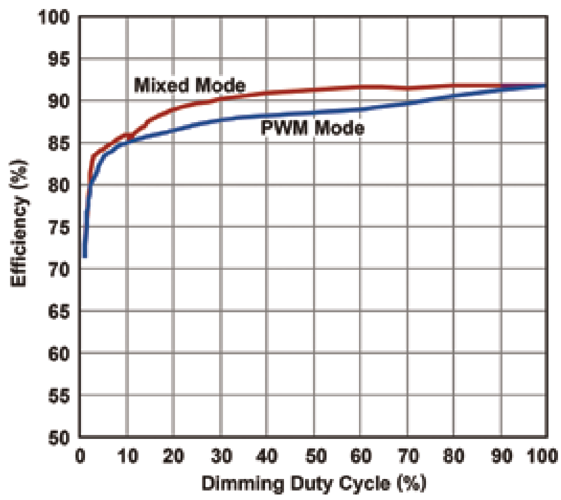


SEL	Dimming Mode	Interface
VDDIO	PWM	SMBus
Open	D-PWM	PWM
GND	PWM	PWM
R*	Mix Mode	PWM

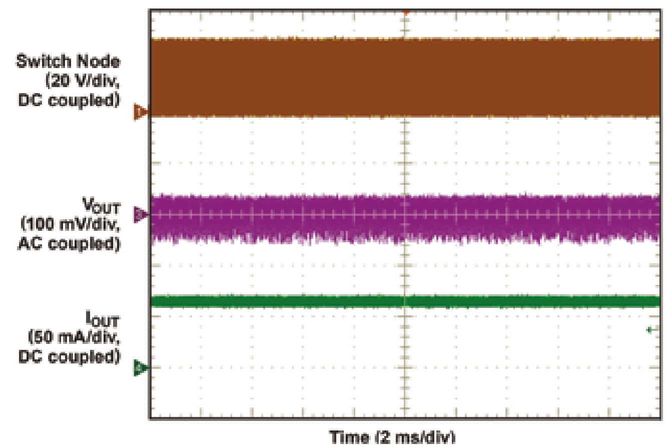
** 510Kohms resistance to ground.*

TPS61195

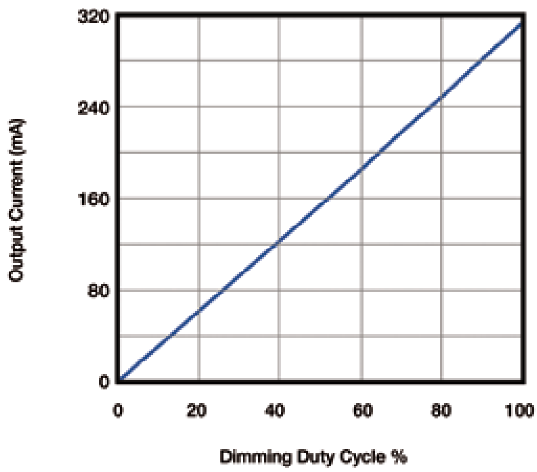
Dimming Efficiency V_{IN} = 10.8 V; 9s8p



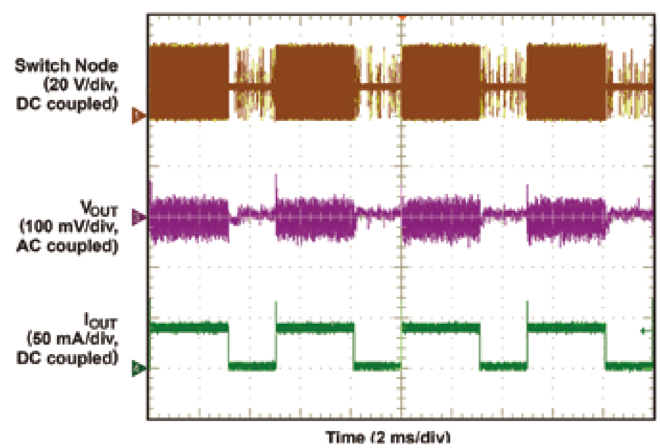
Mixed Mode Dimming Waveform: 20% Brightness—Pure Analog



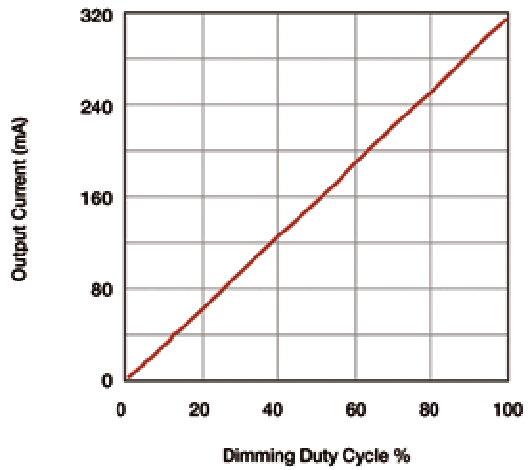
PWM Dimming Current Linearity V_{IN} = 10.8 V



Mixed Mode Dimming Waveform: 8% Brightness Mode



Mix Mode Dimming Current Linearity V_{IN} = 10.8 V



TLC5951 NEW!

Description

The TLC5951 is a 24-channel, constant-current sink driver. Each channel has an individually adjustable, 4096-step, pulse-width-modulation (PWM) grayscale (GS) brightness control (BC) and 128-step constant-current dot correction (DC). The DC adjusts brightness deviation between channels and other LED drivers. The output channels are grouped into three groups of eight channels. Each channel group has a 256-step global BC function and an individual GS clock input.

GS, DC and BC data are accessible via a serial-interface port. DC and BC can be programmed via a dedicated serial-interface port. The TLC5951 has three error-detection circuits: LED open detection (LOD), LED short detection (LSD) and a thermal-error flag (TEF). LOD detects a broken or disconnected LED, LSD detects a shorted LED, and TEF indicates an overtemperature condition.

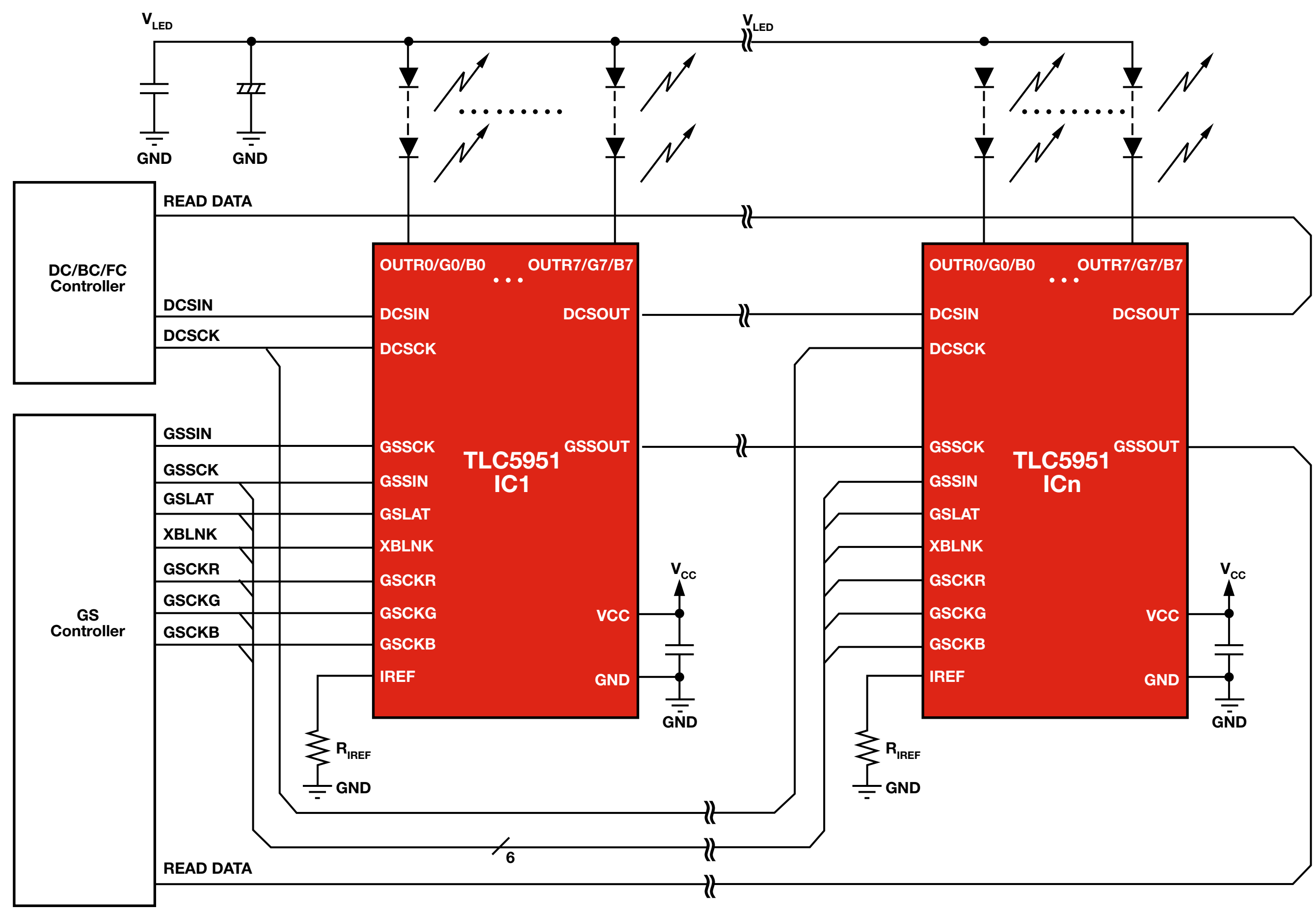
Web Links

Datasheets, user's guides, samples:
www.ti.com/sc/device/TLC5951

Design Specifications

Parameter	Test Conditions	Minimum	Typical	Maximum	Unit
Input voltage	—	3.0	—	5.5	Volts
Output Voltage	OUTR/G/B 0 to 7	3.0	—	17	Volts
Dot correction/global brightness control	—	—	7/8	—	Bits
Output current	—	35	40	45	mA
Grayscale clock frequency	—	—	—	33	MHz

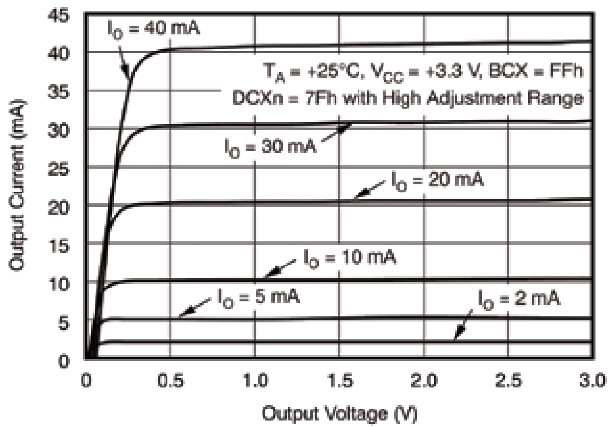
Typical Application Schematic (used when DCSIN/DCSCK Ports are used)



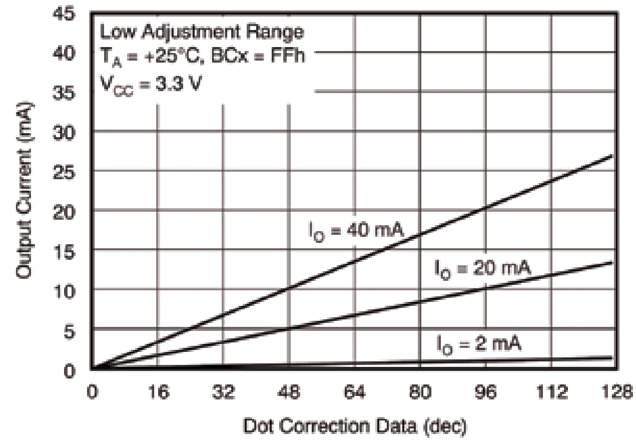
For more reference designs, see: www.ti.com/powerreferencedesigns

TLC5951

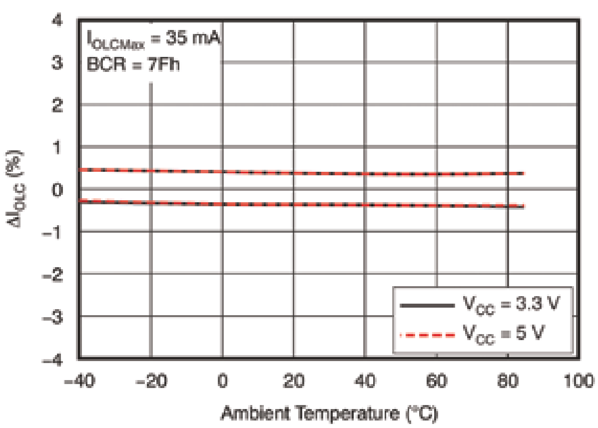
Output Current vs. Output Voltage



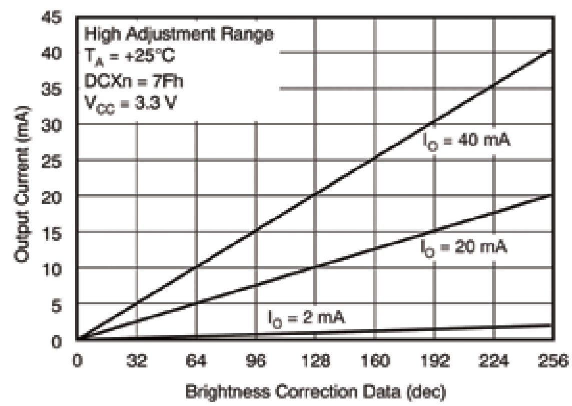
Dot-Correction (DC) Linearity (IOLCMax with Lower Range)



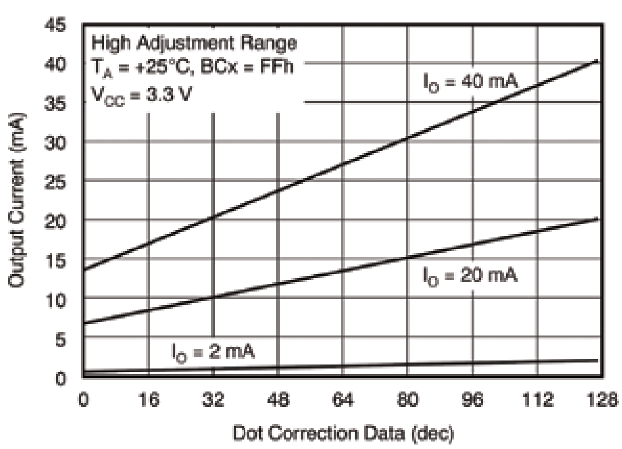
Constant-Current Error vs. Ambient Temperature (Channel-to-Channel, Red Group)



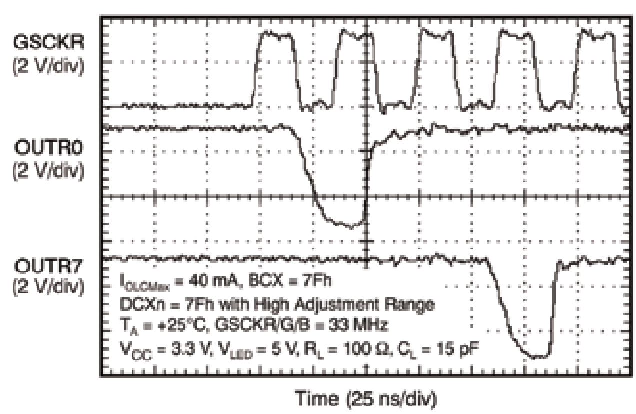
Global-Brightness-Control (BC) Linearity (IOLCMax with Upper Range)



Dot-Correction (DC) Linearity (IOLCMax with Upper Range)



Constant-Current Output-Voltage Waveforms (Red Group)



TLC5952 with Global Brightness Control

NEW!

Description

The TLC5952 is a 24-channel, constant-current sink driver. Each channel can be turned on/off with internal register data. The output channels are grouped into three groups of eight channels each. Each channel group has a 128-step global-brightness-control (BC) function.

Both on/off data and BC are writable via a serial interface. The maximum current value of all 24 channels is set by a single external resistor. The TLC5952 has three error-detection circuits: LED open detection (LOD), LED short detection (LSD) and a thermal-error flag (TEF). The error detection is read via a serial interface. LOD detects a broken or disconnected LED, LSD detects a shorted LED, and TEF indicates an overtemperature condition.

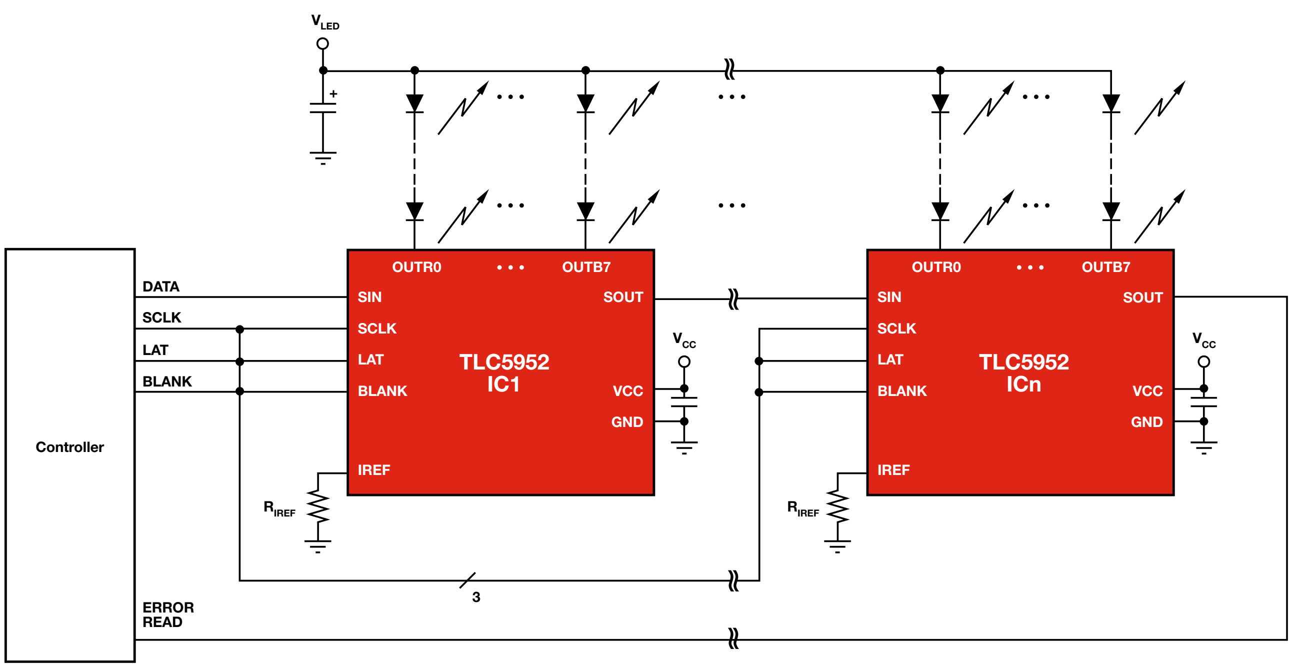
Web Links

Datasheets, user's guides, samples:
www.ti.com/sc/device/TLC5952

Design Specifications

Parameter	Test Conditions	Minimum	Typical	Maximum	Unit
Input voltage	—	3.0	—	5.5	Volts
Output Volatage	OUTR/G/B 0 to 7	3.0	—	17	Volts
Global brightness control	—	—	7	—	Bits
Output current	—	29	32	35	mA
Data shift clock frequency	—	—	—	35	MHz

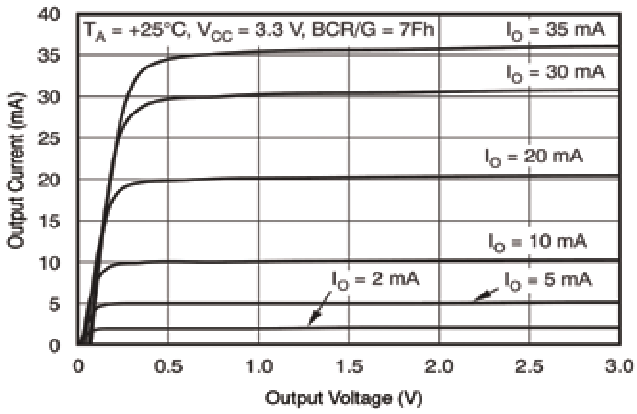
Typical Application Schematic



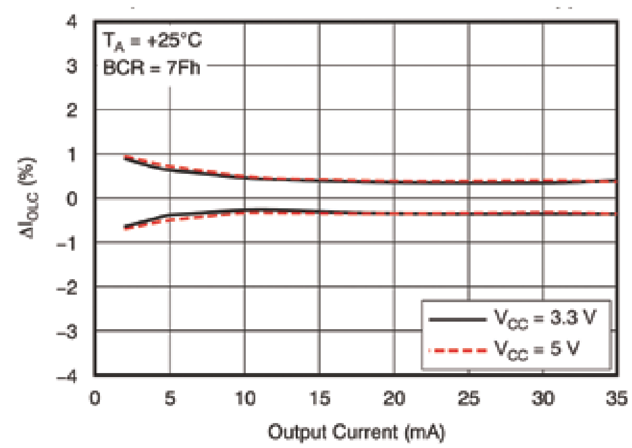
For more reference designs, see: www.ti.com/powerreferencedesigns

TLC5952 with Global Brightness Control

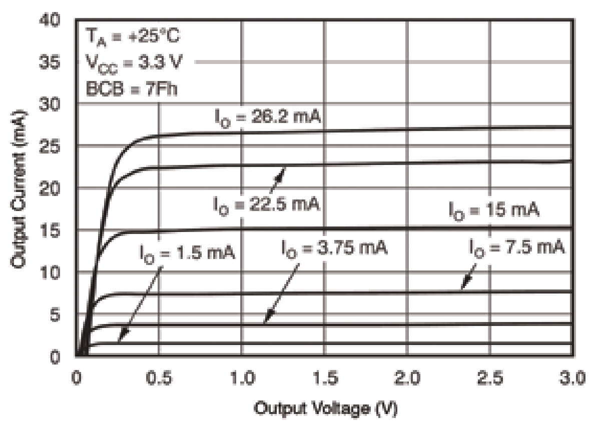
Output Current vs. Output Voltage (Red and Green Groups)



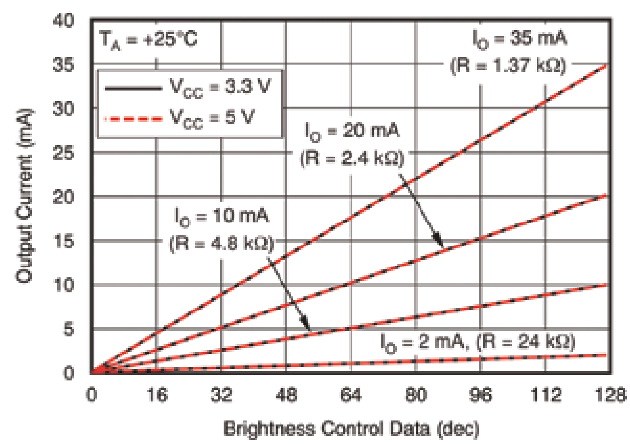
Constant-Current Error vs. Output Current (Channel-to-Channel, Red Group)



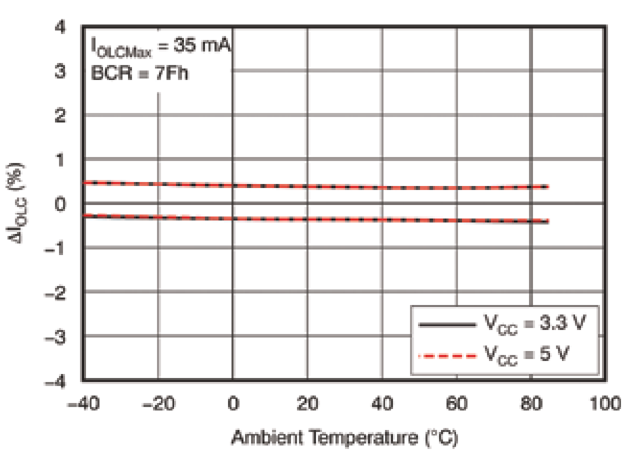
Output Current vs. Output Voltage (Blue Group)



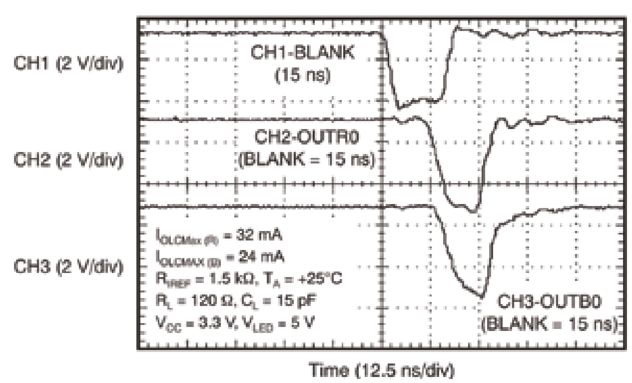
Global Brightness-Control (BC) Linearity (Red and Green Groups)



Constant-Current Error vs. Ambient Temperature (Channel-to-Channel, Red Group)



Constant-Current Output-Voltage Waveforms (red group)



TLC59116 NEW!

Description

The TLC59116 is a 16-channel, constant-current LED driver capable of sinking up to 100 mA per channel. External current (IOUT) is programmed by an external resistor (R_{EXT}). The device has a serial I^2C interface and multiple functions, some of which allow individual pin blinking and global brightness control. Internal brightness and blinking are accomplished by using the TLC59116's internal oscillator to create digital dimming, commonly referred to as pulse-width-modulation (PWM) dimming. The TLC59116 also has an internal register that can be set to change the brightness "gain" from 99.2% (the default) to 8.3%. This reference design allows any of these options to be used but also has an added load switch for manipulating the REXT to change brightness. This method can also be used to produce blinking between different brightness levels, which cannot be achieved with the TLC59116 alone.

LED brightness can be programmed to change depending on the time of day or the level of ambient light. LED dimming can be accomplished through analog or digital methods. In analog dimming, the current through the LED is reduced. In digital (PWM) dimming, the LED is turned on and off at a high frequency. The human eye integrates the on and off brightness in such a way that the LED appears to dim. Changing the frequency and duty cycle of the PWM signal will impact the brightness. For example, an LED application that requires 40 mA to be at full brightness will be at 50% brightness if the analog dimming is set for a drive current of 20 mA or if the PWM operates at a 50% duty cycle. Figure 1 shows the difference between analog and PWM dimming.

For the TLC59116 LED driver, IOUT is set by the relationship between the external resistor and the R_{EXT} pin's reference voltage (V_{REXT}), as shown in equation 1.

(1) $I_{OUT} = V_{REXT}/R_{EXT} \times 15$

Equation 2 solves for R_{EXT}.

(2) $R_{EXT} = V_{REXT}/I_{OUT} \times 15$

The default V_{EXT} value is 1.25 V. The actual value is dependent on the brightness "gain" set by the user via the TLC59116's internal register. As a result, any manipulation of the current based on R_{EXT} is still dependent on the gain.

Changing R_{EXT} changes the resulting current. For example, if I_{OUT} was set to 80 mA, R_{EXT} would be

(3) R_{EXT} = 1.25 V/80 mA x 15 = 234.

Similarly, a 40-mA current would result in an R_{EXT} of 468 Ω.

Figure 2 shows a basic configuration for an LED application that requires 40 mA per channel. The 5-V supply is stepped down to 3.3 V by a simple LDO to drive the MSP430™ controller and the TLC59116 LED driver. The 5-V supply powers the LEDs directly.

Brightness control is enabled by adding a resistor in parallel with REXT. Adding another 468-Ω resistor allows I_{OUT} to be doubled from 40 mA to 80 mA. Using an available GPIO line from the MSP430 to the load switch allows the designer to add or remove the extra resistor as desired. Figure 3 shows a simple implementation using a TPS22901 load switch.

The TPS22901 load switch fits this dimming-control application because the RON is below 100 mΩ (negligible in series with 468 Ω) and V_{REXT} is 1.25 V, which is higher than the 0.9 V required for operation.

The TPS22901's default is "on" and its resistor is used to compute IOUT, resulting in 80 mA. When the TPS22901 is off (the switch is open), the resulting current changes to 40 mA. The host MSP430 controller can easily control the frequency of the dim/full-brightness timing. The TPS22900 (dual load switch) can provide up to four brightness levels.

Web Links

Datasheets, user's guides, samples:
www.ti.com/sc/device/**TLC59116**

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

Figure 1. Analog vs. PWM Dimming

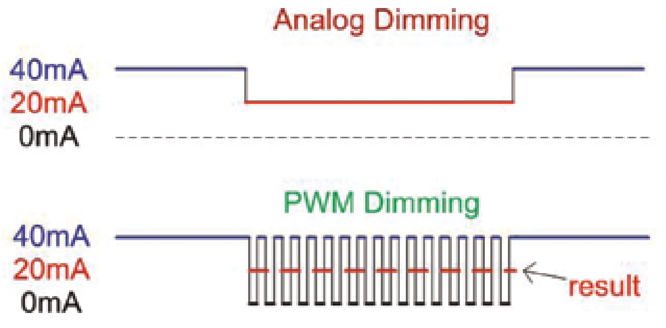


Figure 2. Programmable LED Driver

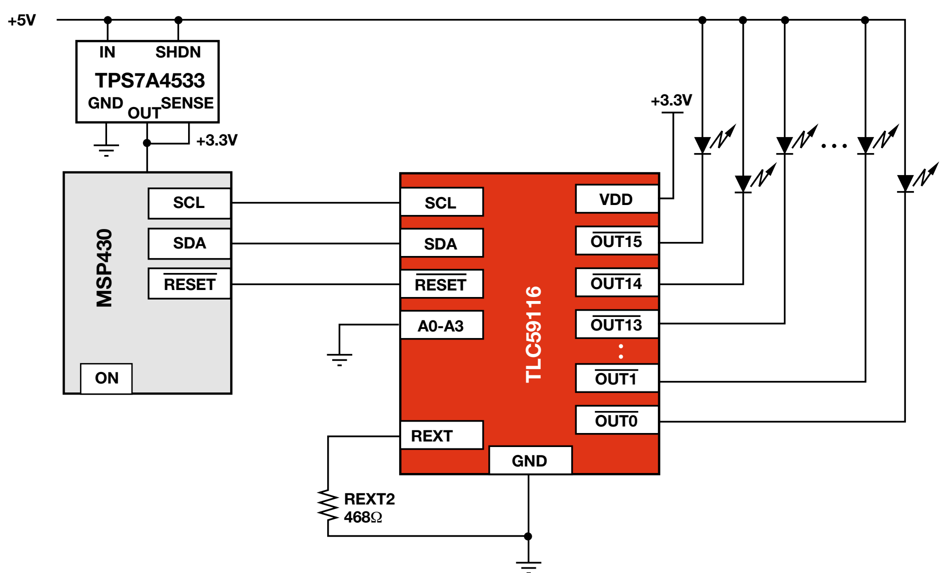
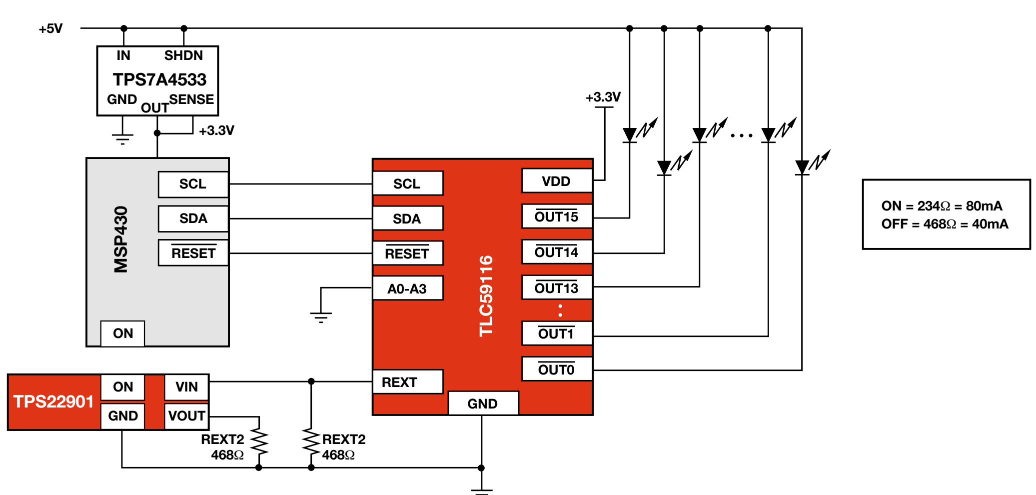


Figure 3. Analog Dimming/Blinking with a Load Switch



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