LED Lighting Solutions

TEXAS INSTRUMENTS

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LPP View of Application Evolution
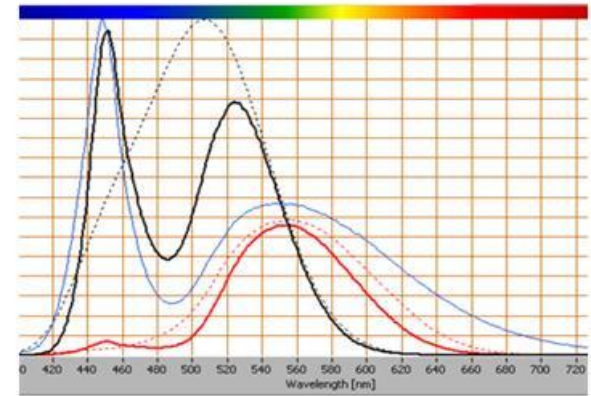
Phase 1
(Now)

- Retrofit
- Raw Efficacy
- Lowest Cost
- Lifetime / Reliability

Phase 2
(1 – 5 Years)

- Sensing & Detection
- Intelligence
- Communications
- Controls

Phase 3
(3 – 8 Years)

- Color / CCT Control
- Spectrum Shaping
- Ultra-Efficiency
- >50 Year Lifetime

TI Lighting Segment Focus

Lamp and Downlight

Wide Area

Automotive

Secondary Markets

- Architectural
- Emergency/Safety
- Entertainment
- Portable Consumer
- Projector and Copiers
- Industrial
- Retail and Display

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Energy-Efficient System Partner

How we partner with our customers

Technology	Application	Solution
Power Management Technology Leadership	**Deep Understanding of System Challenges**	**Collaborative Architecture and Design**

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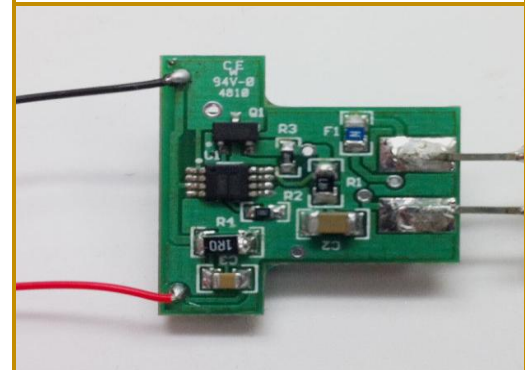
TI Solid State Lighting (SSL) Core Competencies

Applications

General Illumination
- Retrofit
- Commercial
- Professional

Back Lighting
- Portable
- Monitor
- Digital TV

Automotive
- Exterior Lighting

Expertise

AC/DC
- Analog
- Digital

DC/DC
- Analog
- Digital

Linear

Wireless & PLC

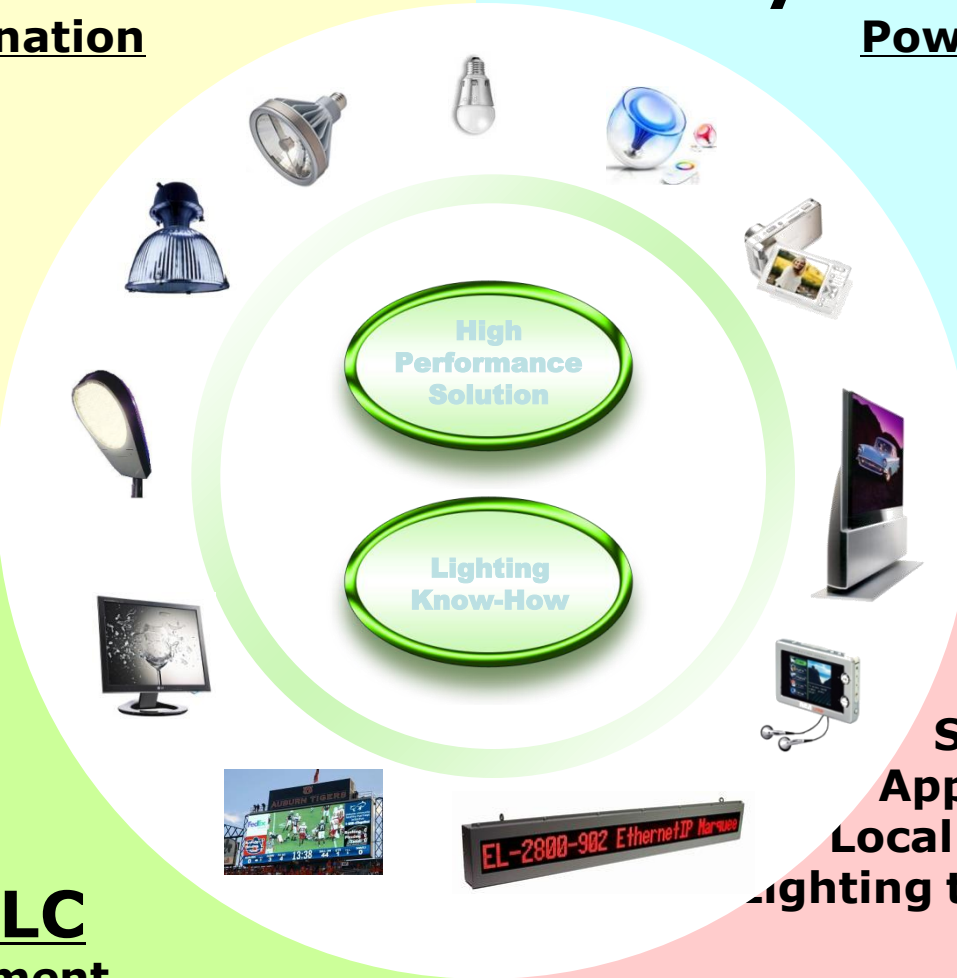### Light Measurement

Full System Solutions

Power Management
Multi-String
Single-String
Multi-Stage
Single-Stage

Monitoring

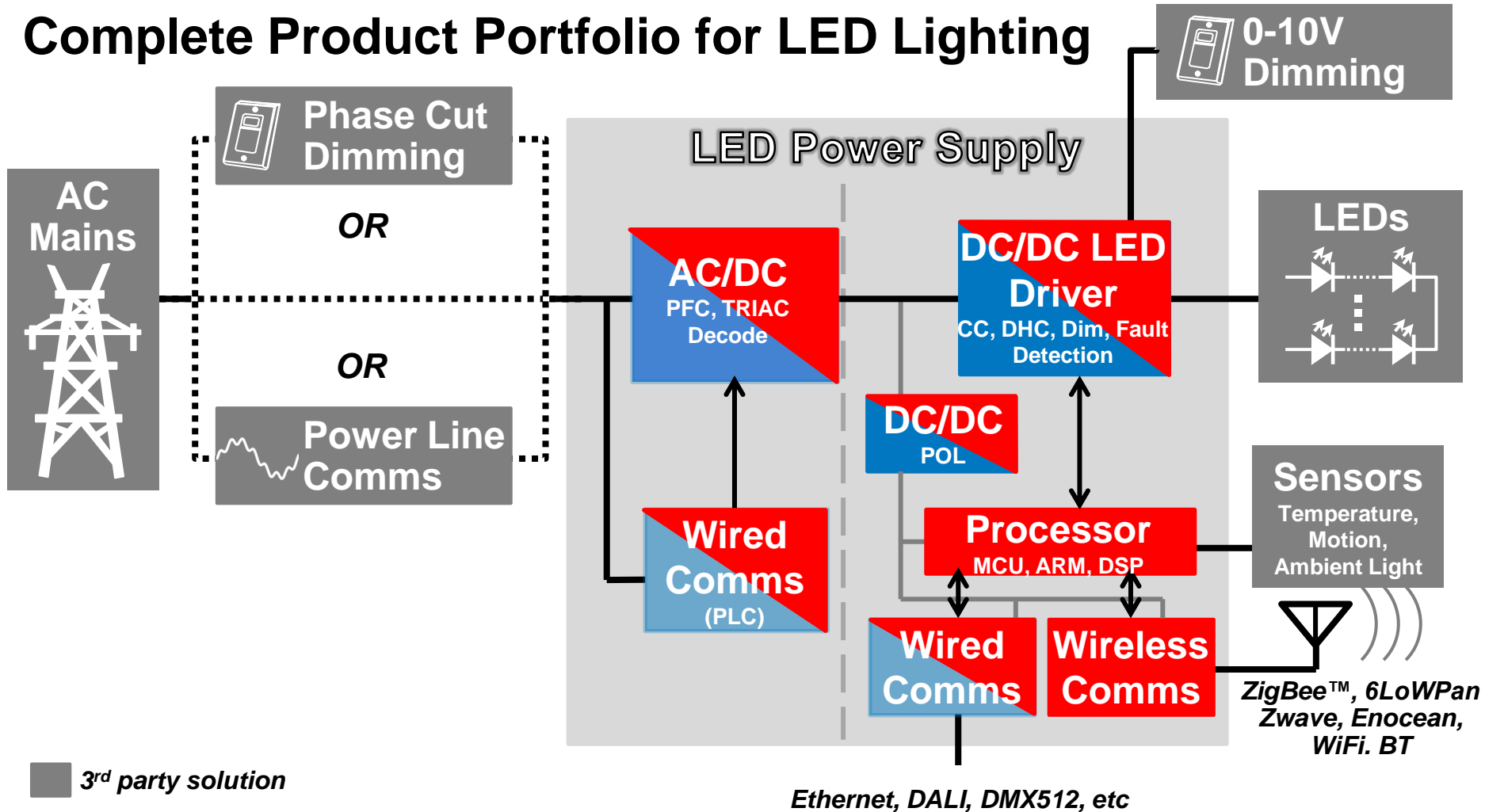### Communication

High Performance Solution

Lighting Know-How

Resources

EVMs
Cook Book
Ref. designs
Sample software
Application reports
Local design services
Lighting training support

Solid State Lighting Product Synergy

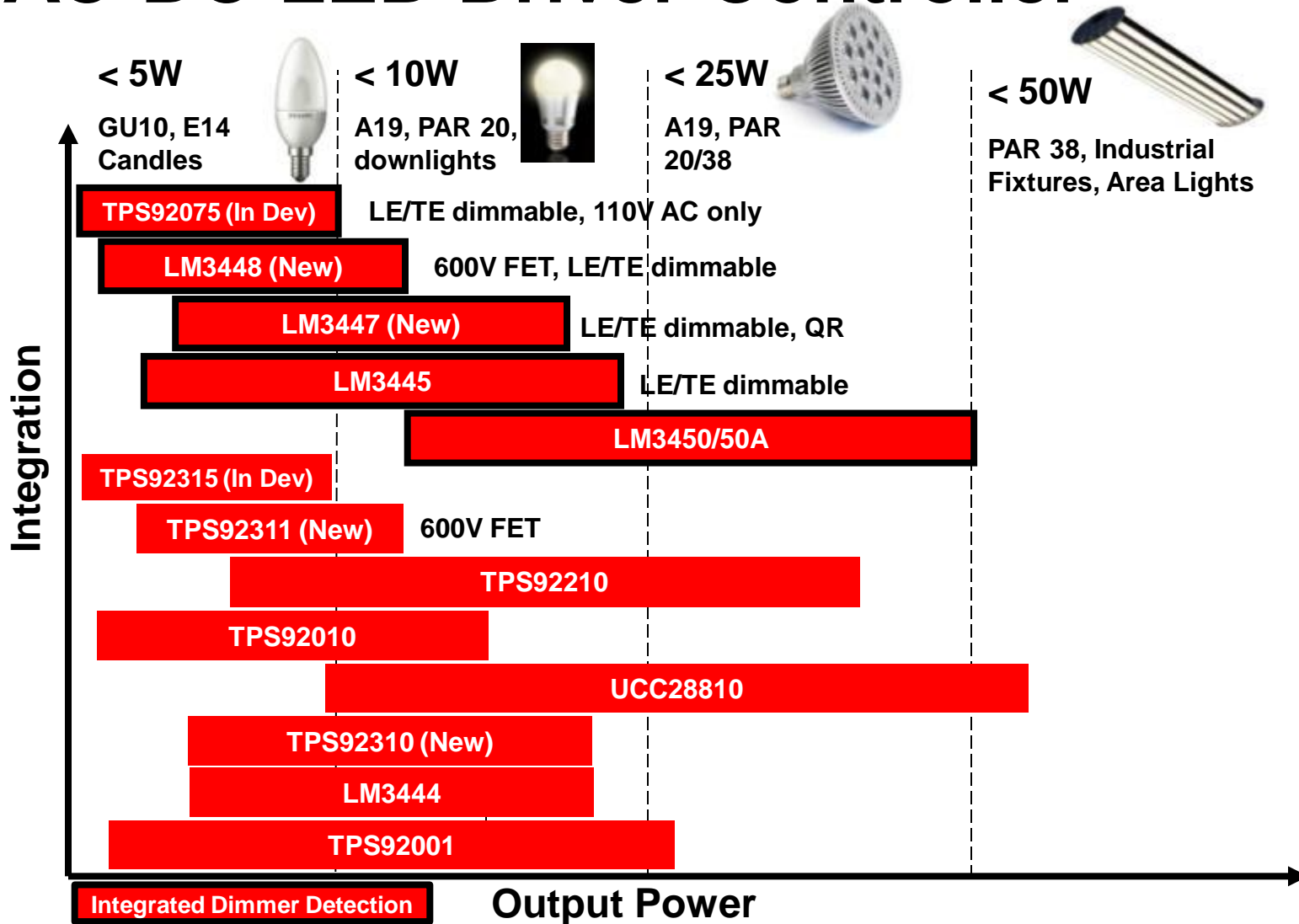**National Semiconductor and Texas Instruments**

Complete Product Portfolio for LED Lighting

0-10V Dimming

Phase Cut Dimming

OR

OR

Power Line Comms

AC Mains

LED Power Supply

AC/DC
PFC, TRIAC Decode

DC/DC LED Driver
CC, DHC, Dim, Fault Detection

LEDs

DC/DC
POL

Wired Comms
(PLC)

Processor
MCU, ARM, DSP

Sensors
Temperature, Motion, Ambient Light

Wired Comms

Wireless Comms

ZigBee™, 6LoWPan Zwave, Enocean, WiFi. BT

Ethernet, DALI, DMX512, etc

3rd party solution

TI Information – Selective Disclosure

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AC-DC LED Driver Controller

< 5W

GU10, E14 Candles

< 10W

A19, PAR 20, downlights

< 25W

A19, PAR 20/38

< 50W

PAR 38, Industrial Fixtures, Area Lights

Integration (vertical axis)

TPS92075 (In Dev)	LE/TE dimmable, 110V AC only
LM3448 (New)	600V FET, LE/TE dimmable
LM3447 (New)	LE/TE dimmable, QR
LM3445	LE/TE dimmable
LM3450/50A	
TPS92315 (In Dev)	
TPS92311 (New)	600V FET
TPS92210	
TPS92010	
UCC28810	
TPS92310 (New)	
LM3444	
TPS92001	

Integrated Dimmer Detection

Output Power

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Product Summary (14 ICs)

Device	Description	Type	Applications	Output Power	PF
LM3448	Dimmable AC/DC LED Driver with Power Mosfet	AC/DC	•Retrofit Bulbs •Luminaire	3 – 8W	>0.9
TPS92075 **In development**	110V Dimmable AC/DC LED Driver Controller (small foot-print)	AC/DC	•Retrofit Bulbs •Luminaire	3 – 10W	>0.9
TPS92310 *(New)*	Single stage PFC LED Driver Controller	AC/DC	•Retrofit Bulbs •Luminaire	3 – 20W	>0.9
TPS92311 *(New)*	Single stage PFC LED Driver Converter with Power Mosfet	AC/DC	•Retrofit Bulbs •Luminaire	3 – 8W	>0.9
TPS92315 **In development**	Simple LED driver for low-power applications (small foot-print)	AC/DC	•Small-power retrofit bulbs •Luminaire	2 – 8W	
LM3447 *(New)*	Dimmable QR mode AC/DC LED Lighting Driver Controller	AC/DC	•Retrofit Bulbs •Luminaire	3-20W	>0.9
LM3444/ **LM3445**	AC/DC LED Driver	AC/DC	•Retrofit Bulbs •Luminaire	3-20W	>0.9
LM3450/50A	AC/DC LED Driver with Active PFC and Phase Dim Decoder	AC/DC	•Retrofit Bulbs •Luminaire •Street Lighting	10-50W	>0.9
TPS92210	Natural PFC LED Lighting Driver Controller	AC/DC	•Retrofit Bulbs •Luminaire	5-30W	> 0.9
UCC28810/1	LED Lighting Power Controller	AC/DC	•Retrofit Bulbs •Luminaire •Street Lighting	15-100W+	> 0.9

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HV AC LED LIGHT BULB REPLACEMENT

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TPS92310 / TPS92311

Single stage PFC AC/DC controller for LED application

TEXAS INSTRUMENTS

TPS92310

Single stage PFC AC/DC controller for LED application

Features

- Flexible Operating Modes:
  - Constant On-Time,
  - Peak Primary Current.
- Primary side current regulation
- Without control loop compensation
- Transformer Zero Energy Detection
- Advanced Over-Current Protection and Integrated Over-voltage Protection

Benefits

- Constant On-Time implements Single Stage Power Factor Correction (PFC)
- Without opto-coupler and secondly side regulation
- Design easily
- High Efficiency, Low EMI
- Protects Driver Against Fault Conditions

Applications

- Residential LED Lighting Drivers: A19 (E26/27, E14), PAR30/38, GU10
- Lighting Applications: Light Bulb Replacement, General Lighting and Solid state lighting

EVM

TEXAS INSTRUMENTS
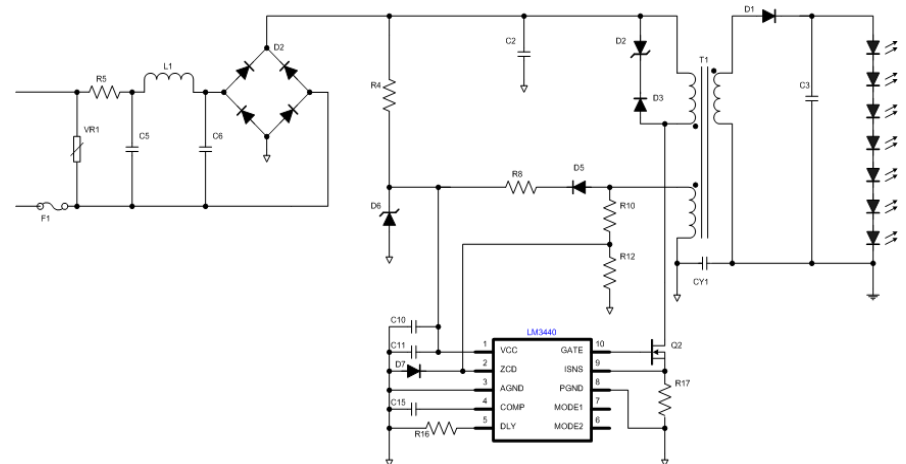
TPS92310EVM Specification

NEW

TPS92310	EVM-110VAC	EVM-220VAC	
Specification	**Value**	**Value**	**Unit**
Input voltage	85-132	180-264	VAC
LED config	5-7	5-7	series
Output current	350	350	mA
Output power	5-7	5-7	W
Topology	Flyback	Flyback	
Efficiency	85	85	%
Power Factor	>0.9	>0.9	
Current sensing	resistive	resistive	
Isolation	Yes	Yes	
Driver Dimemsion	55 x 23 x 18	55 x 23 x 18	mm

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TPS92310 Reference Solutions Plan

- **8W A-lamp driver (standard)**   **110/220Vac**   **20V@350mA**
- **13W A-lamp driver (standard)**   **110/220Vac**   **32V@400mA**
- **22W T-8 non-isolated**   **220Vac**   **70V@320mA**
- **18W T-8 isolated**   **100-240Vac**   **42V/0.42A**
- **28W Ballast Module**   **220Vac**   **Variable**
- **4.2W GU-10 driver**   **100-240Vac**   **9V @350mA**

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TPS92311

Single stage PFC AC/DC convertor for LED application

Features

- Flexible Operating Modes: Peak Primary Current, Constant On-Time

- Integrated 600V 3.6Ω MOSFET

- Transformer Zero Energy Detection

- Advanced Over-Current Protection and Integrated Over-voltage Protection

Benefits

- Constant On-Time implements Single Stage Power Factor Correction (PFC)

- Less component count

- High Efficiency, Low EMI

- Protects Driver Against Fault Conditions

Applications

- Residential LED Lighting Drivers: A19 (E26/27, E14), PAR30/38, GU10

- Lighting Applications: Light Bulb Replacement, Solid state Lighting, industrial and commercial lighting.

EVM

TEXAS INSTRUMENTS
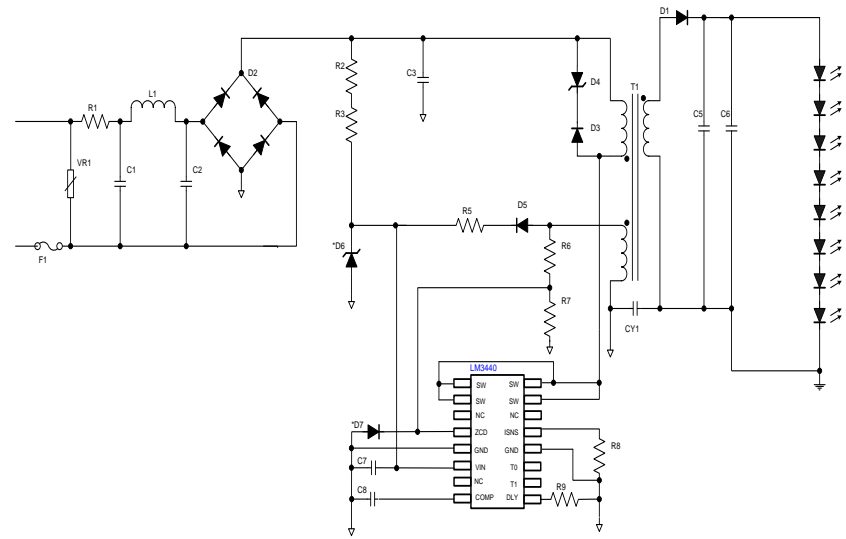
TPS92311EVM Specification

TPS92311	EVM-110VAC	EVM-220VAC	
Specification	Value	Value	Unit
Input voltage	85-132	180-264	VAC
LED config	5-7	5-7	series
Output current	350	350	mA
Output power	5-7	5-7	W
Topology	Flyback	Flyback, CRM	
Efficiency	85	85	%
Power Factor	>0.9	>0.9	
Current sensing	resistive	resistive	
Isolation	Yes	Yes	
Driver Dimemsion	55 x 23 x 18	55 x 23 x 18	mm

TI Information – Selective Disclosure

TEXAS INSTRUMENTS
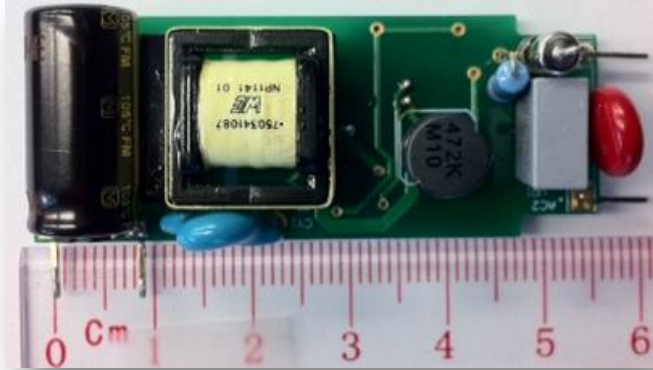
LM3445
TRIAC Dimmable Offline LED Driver

Features

- TRIAC Dimming Decoder for LED Dimming

- Master/Slave Operation

- Application Voltage Range (80-277Vac)

- Controls LED Currents of Greater than 1A
- Adjustable Switching Frequency
- Adaptive, Programmable Off-Time Control

- Thermal Shutdown, UVLO, Current Limit

Applications

- Dimmable Residential LED Lighting Drivers: A19 (E26/27, E14), PAR30/38, GU10
- Lighting Applications: Light Bulb Replacement, Wall Sconces, Wall Washers, Architectural and Display Lighting, Commercial Troffers and Downlights

- **LM3445-120VFLBK/NOPB (120V)**
- **LM3445-120VSMEV/NOPB (120V)**
- **LM3445-208277EV/NOPB (220-277V)**
- **LM3445-230VFLBK/NOPB (230V)**
- **LM3445-EDSNEV/NOPB(120V)**

EVM TOOLS

WEBENCH®

TI Information – Selective Disclosure

Benefits

- Integrated TRIAC Detection Reduces Component Count and Solution Size
- Single TRIAC Controls Multiple Strings with Consistent Dimming Performance
- Supports Residential and Commercial LED Lighting Applications
- Supports a Wide Variety of LED Configurations
- Stable Operation Over Varying Input Line Conditions
- Allows for Constant Output Ripple Current with no 120Hz Flicker
- Protects Against Faults and Abnormal Operating Conditions

LM3445 8W Isolated Evaluation Board Schematic

POWERWISE

TEXAS INSTRUMENTS

AVAILABLE
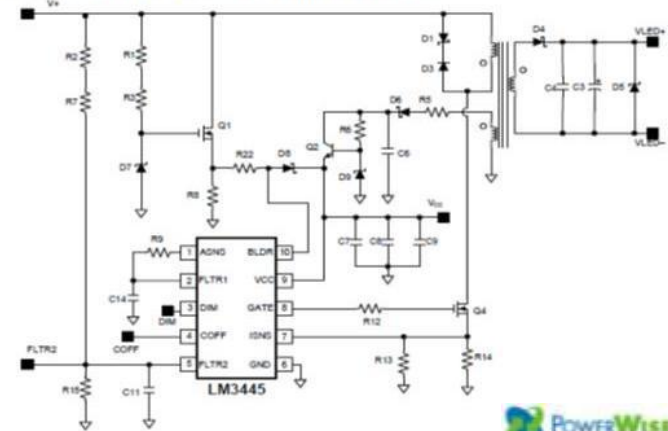
LM3448

TRIAC Dimmable Offline LED Driver

NEW

Features

- 85~265V Application Voltage Range
- Integrated, vertical 600V MOSFET with Superior Avalanche Energy Capability
- Input Phase Angle Dimming Decoder for LED Dimming
- Adaptive programmable OFF time
- Multiple Topologies Supported: Buck, Buck-Boost, Flyback

Benefits

- Supports Residential LED Lighting Voltages
- Reduced Component Count with High Solution Reliability/Robustness/Efficiency – Enables Space Constrained Bulb Designs Like GU10
- High Performance / Wide Range Dimming.
- 120Hz Flicker-Free Designs
- Provides Constant LED Ripple Current
- Flexible LED Driver Designs

Applications

- Dimmable LED Lighting Drivers: A19 (E26/27, E14), PAR30/38, GU10: 2W~8W
- Isolated or Non-Isolated Configurations

EVM TOOLS
WEBENCH®

- LM3448-EDSNEV
- LM3448-120VFLBK
- LM3448-230VFLBK

POWERWISE

TEXAS INSTRUMENTS
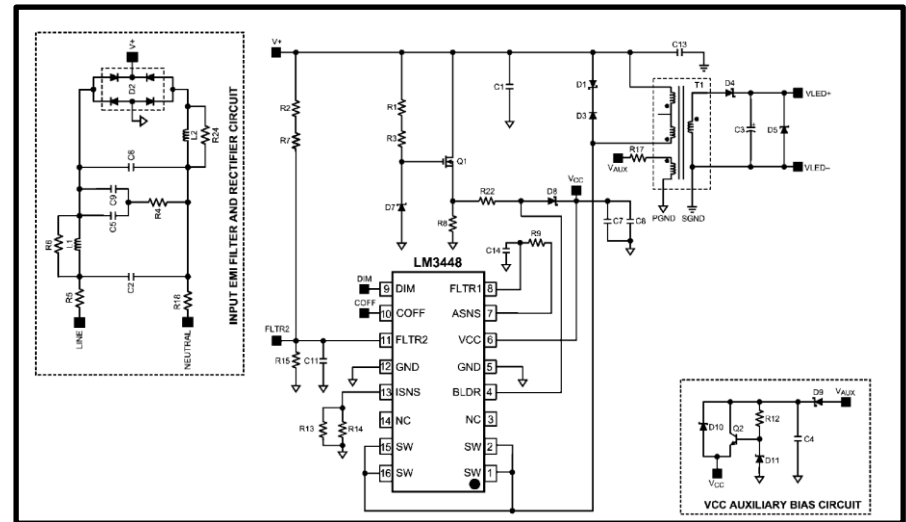
LM3447
Phase Dimmable, Primary Side Sensing, QR Flyback Controller

Features

- Fixed frequency PWM controller for isolated Flyback topology

- Integrated phase angle decoding circuit

- ***Constant power operation mode (based on input voltage feed-forward control)***

- Constant current operation mode (using an opto-isolator based feedback control)

- Output overvoltage protection based on VCC voltage

- Output short circuit protection based on current sense voltage

- Thermal shutdown

- TSSOP-14 package

- Quasi-Resonant mode operation

- Optional thermal foldback using VADJ

- Intelligent TRIAC hold circuitry enabling accurate zero crossing detection

TI Information – Selective Disclosure

Improvements

NEW
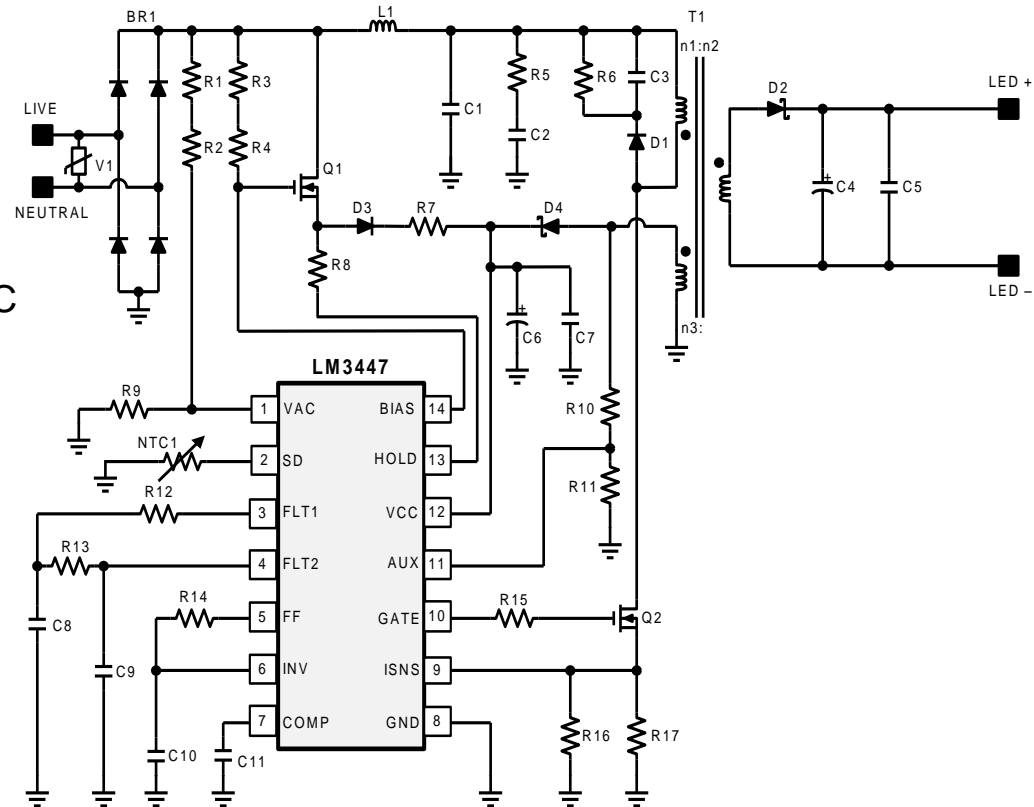
- Valley Switching
  - Better EMI
  - Better Efficiency

- Dimmer Detect, Holding Circuit ON when dimmer exists
  - Higher efficiency
  - Less heat at holding circuit

- Line feed forward
  - Narrow output current change with AC line variation

- Thermal protection
  - Safer lamp operation

- Constant current control possible with opto coupler

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Constant Power Regulation Maximize Lumen Output

Y-axis: Normalized Flux (%)
X-axis: LED Board Temperature (°C)

Legend: Constant Power — Constant Current
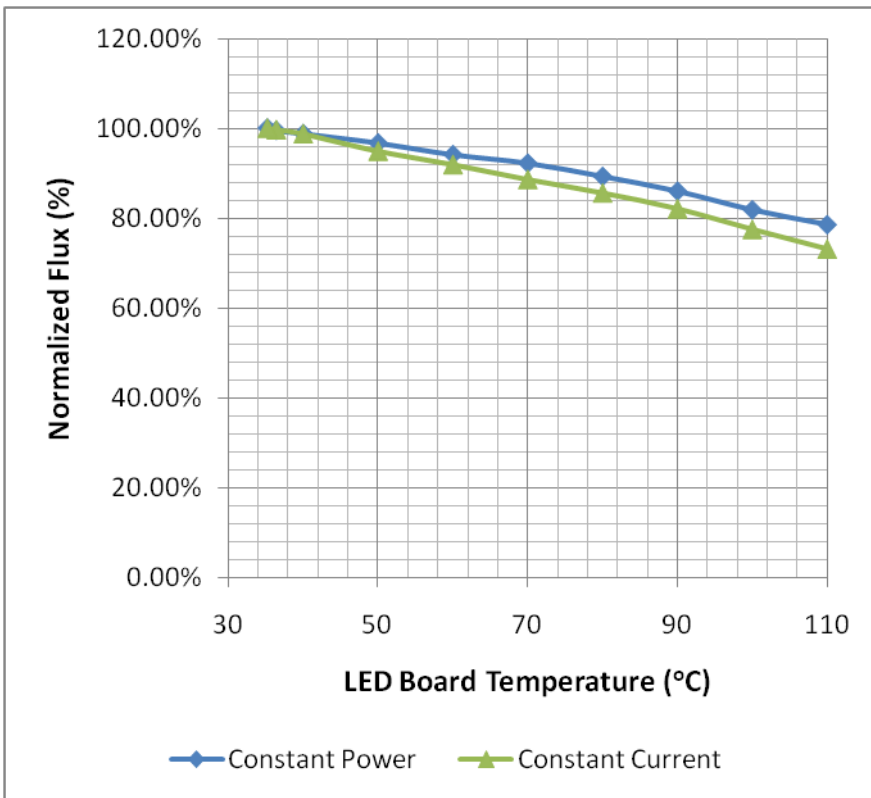
Up to 5 % improvement in light output over operating temperature when using constant power over constant current

- Output power is regulated, LED current is <u>NOT</u> regulated

- LED current varies based on forward voltage drop of LEDs

- Can compensate for forward voltage variations over
  - Junction temperature
  - LED operating lifetime

- Improvement in luminous efficacy and lamp lumen maintenance

- Allows for LED heatsink size optimization

- Best for LED lamps with
  - Number of series LED strings
  - Large series parallel LED array

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Holding Current
– Only Turn On When Dimmer Detected

- **No Dimmer Detected**
  - HOLD FET OFF
  - Gate of Q1 set to 13.5V (int. Zener)
  - Drain of Q1 become BIAS - VGS
  - No current flows through R8 (holding resistor)

- **Dimmer Detected**
  - HOLD FET ON
  - Gate of Q1 set to 13.5V (int. Zener)
  - Drain of Q1 become BIAS – VGS
  - Current flows through R8
  - R8 sets the amount of TRIAC holding current

$$I_{HOLD} = \frac{V_{GATE} - V_{GS}}{R_8}$$

TEXAS INSTRUMENTS
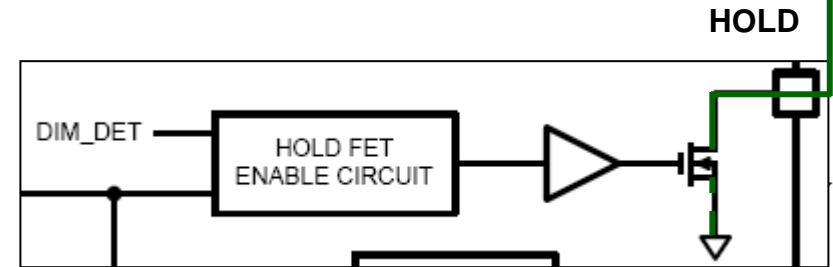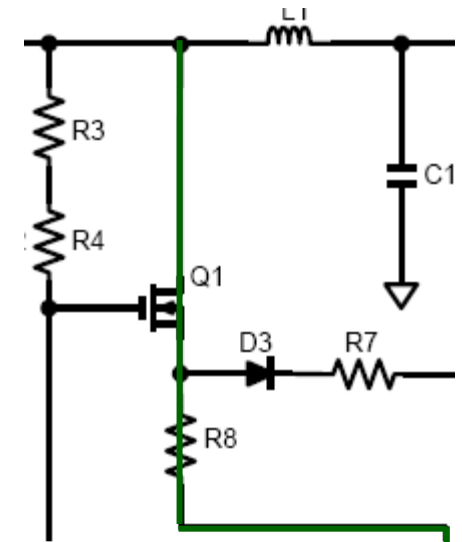
Intelligent Holding Current Control
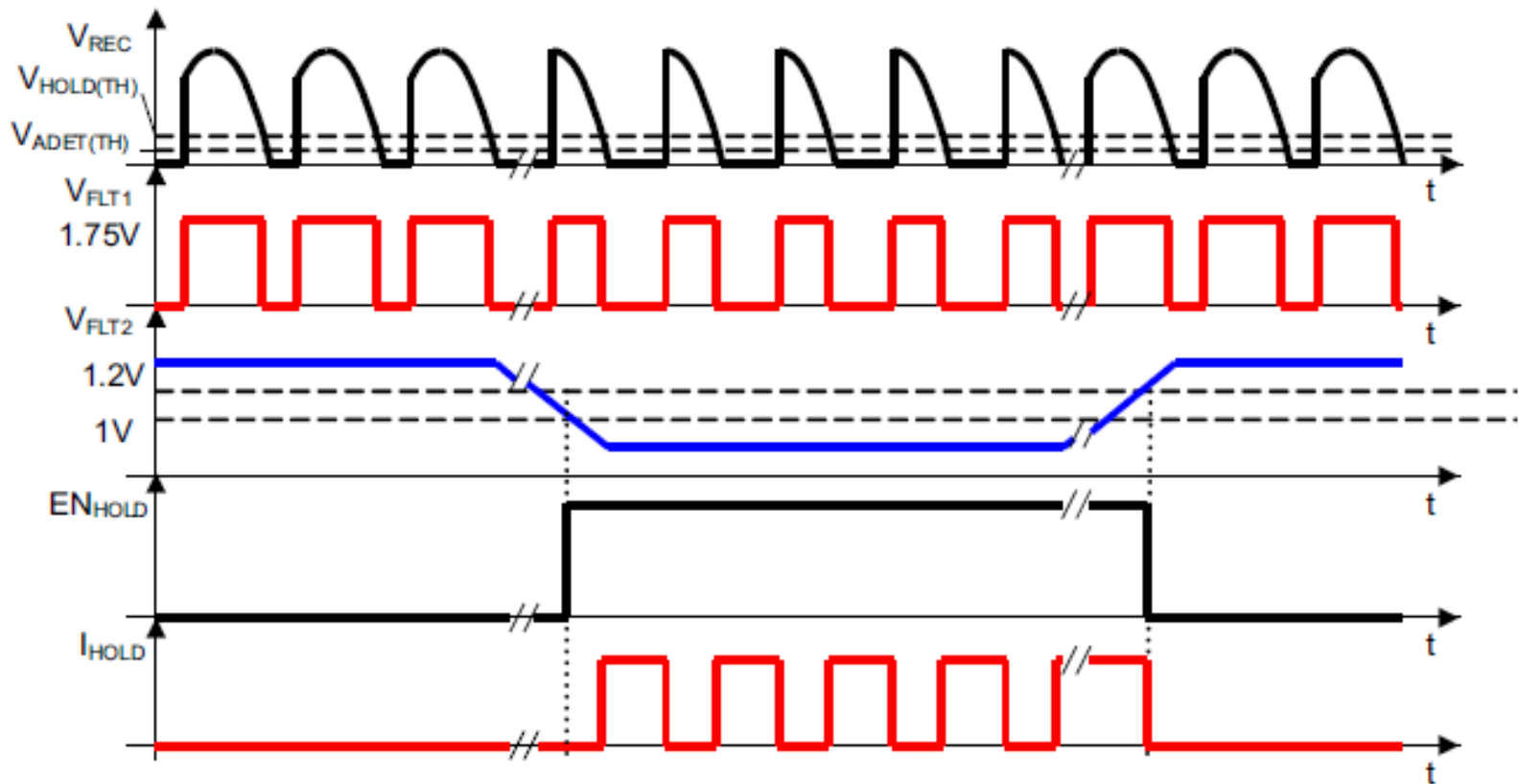
Figure 28. Angle Detection Circuit and Hold Current Circuit Operation

FLT2 Input Signal (Filtered 120Hz PWM)

- Resulting signal from FLT1 is filtered and the result is a DC voltage that is proportional to the dimmer phase-cut angle

- This DC voltage is applied to FLT2 and decoded by the ANGLE DECODING CIRCUIT
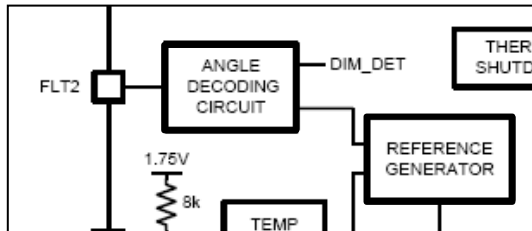
- This circuit provides a DIM_DET signal for the HOLD current internal FET and provides a signal to the REFERENCE GENERATOR that in turn generates an internal reference voltage V_{REF}

- V_{REF} is a voltage that linearly varies from 1V to 0V depending on the phase-cut angle
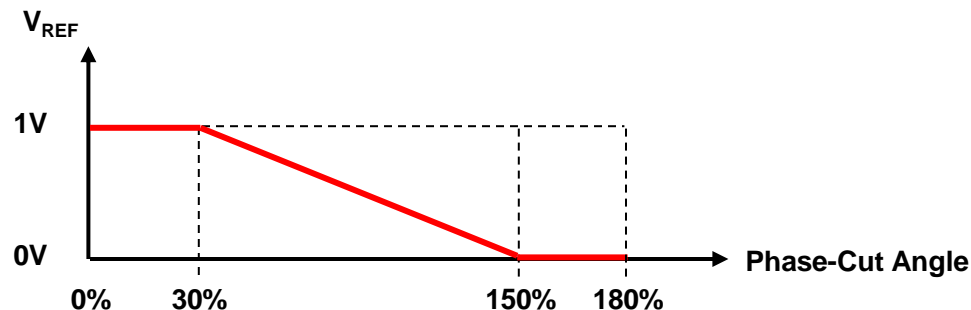
LM3447 – Typical Application Circuit Constant Power Regulation
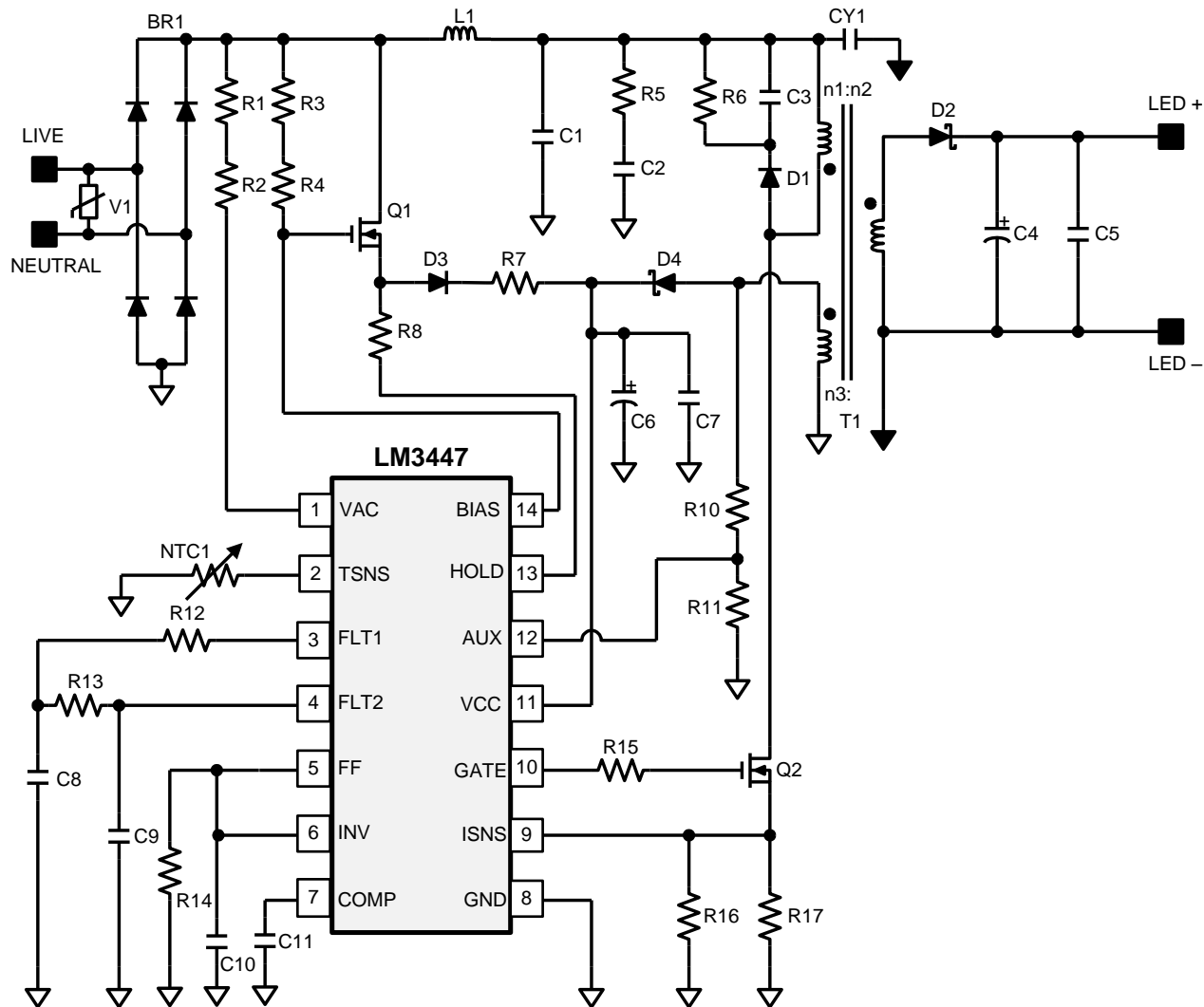
Target Performance Specifications

- Improve efficiency
  - Target > 85 %

- Improve line regulation
  - Target < ± 8 %

- Improve EMI signature
  - Reduce size of LC filter

- Improve TRIAC dimming range
  - Dimming ratio of 50:1

- Reduce BOM
  - Less than 30 components

TEXAS INSTRUMENTS
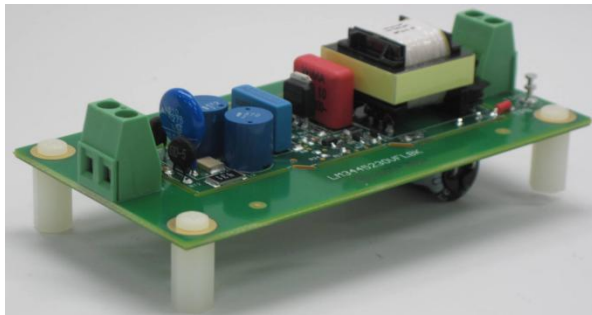
LV AC LED LIGHT BULB REPLACEMENT

TEXAS INSTRUMENTS

MR16 / AR111 LED IC Driver Solutions
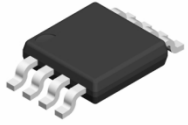
- **LM3401** - **Hysteretic PFET Controller for High Power LED Drive**
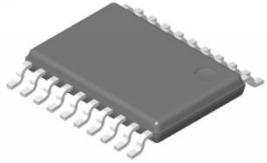
- **LM3409** - **PFET Buck Controller for High Power LED Driver**
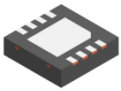
- **LM3414** - **1A 60W Constant Current Buck LED Driver**
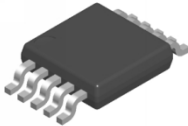
- **LM3444** - **AC-DC Offline LED Driver**
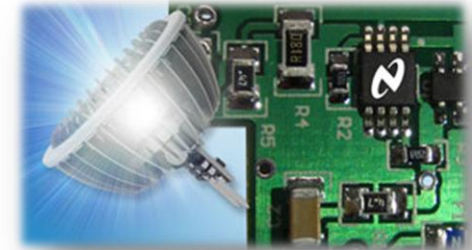
LM3401 (Buck, Non-dimmable)
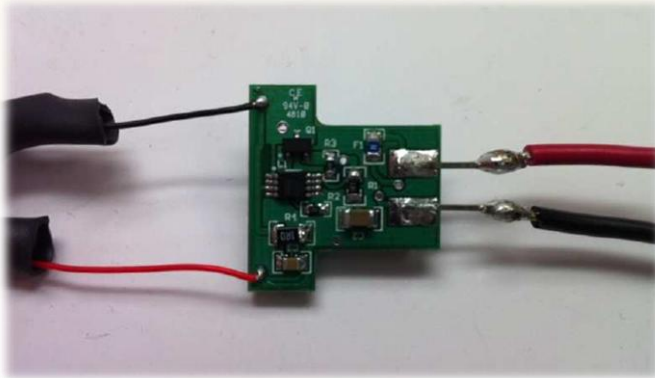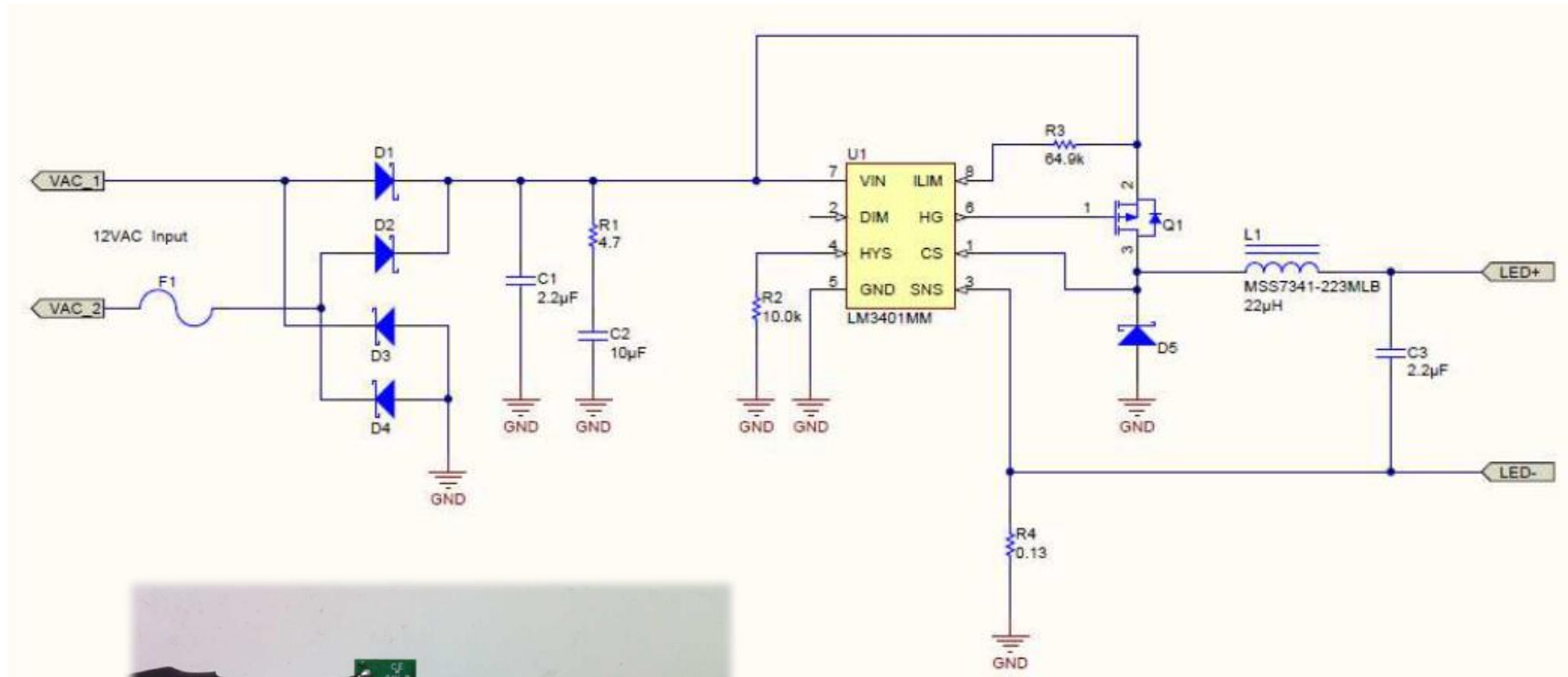
LM3414 (Buck, Non-dimmable)
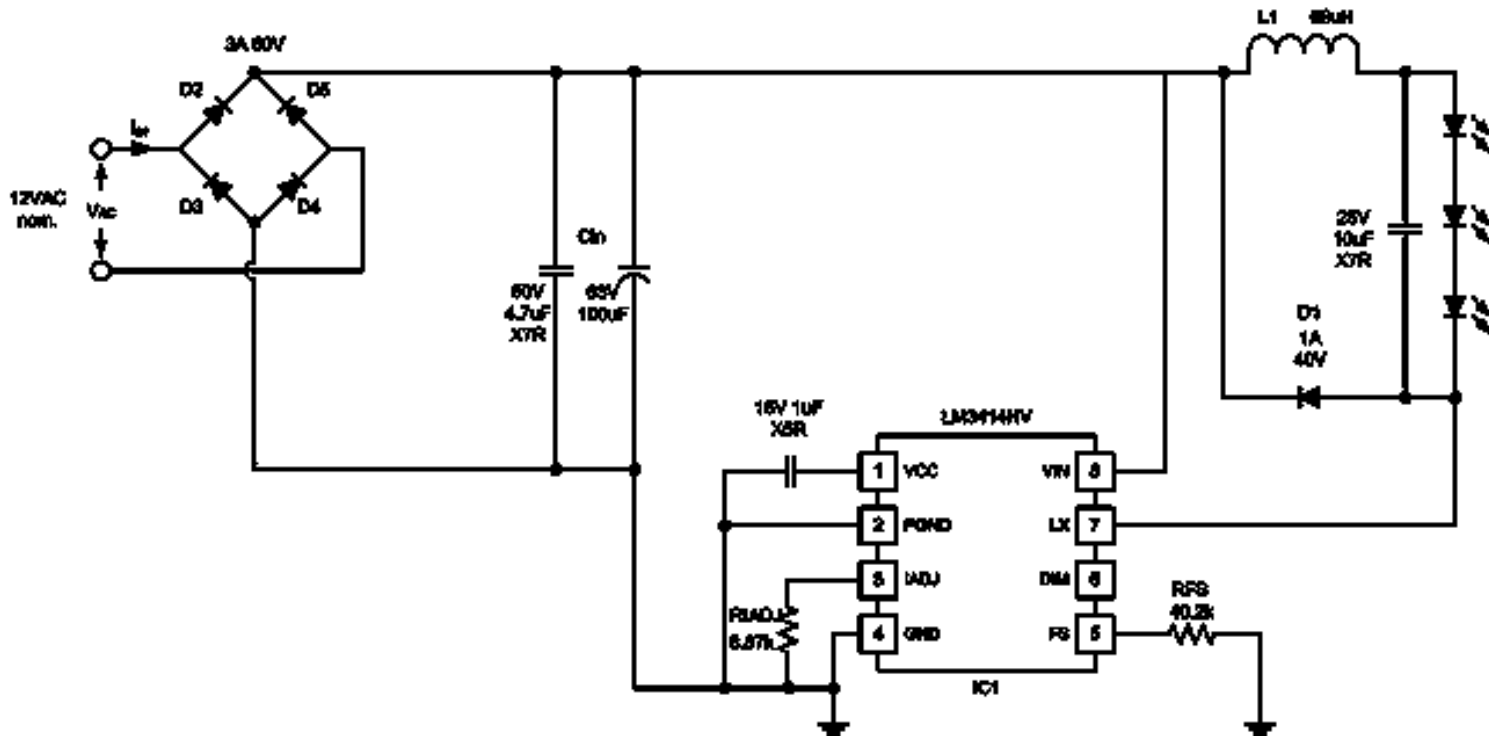
LM3444 (Boost, Dimmable)
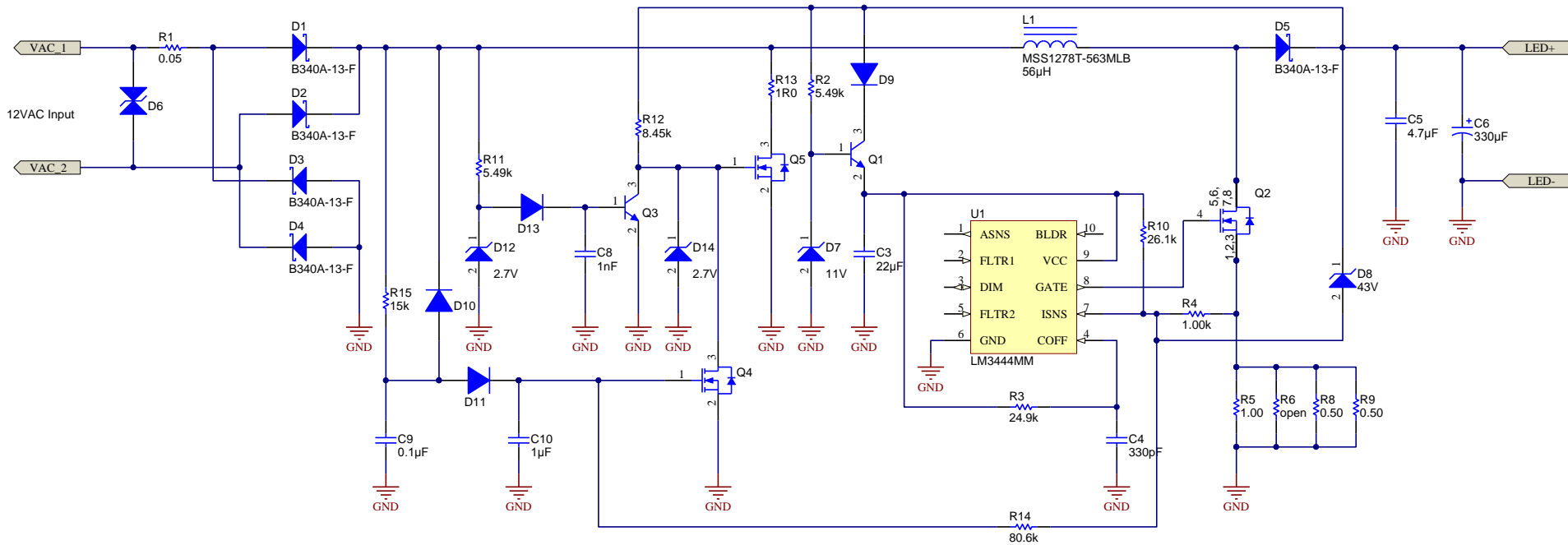
LM3409 (Buck-boost)
(dimmable, designed for multiple MR16 systems)
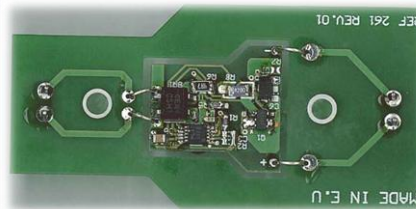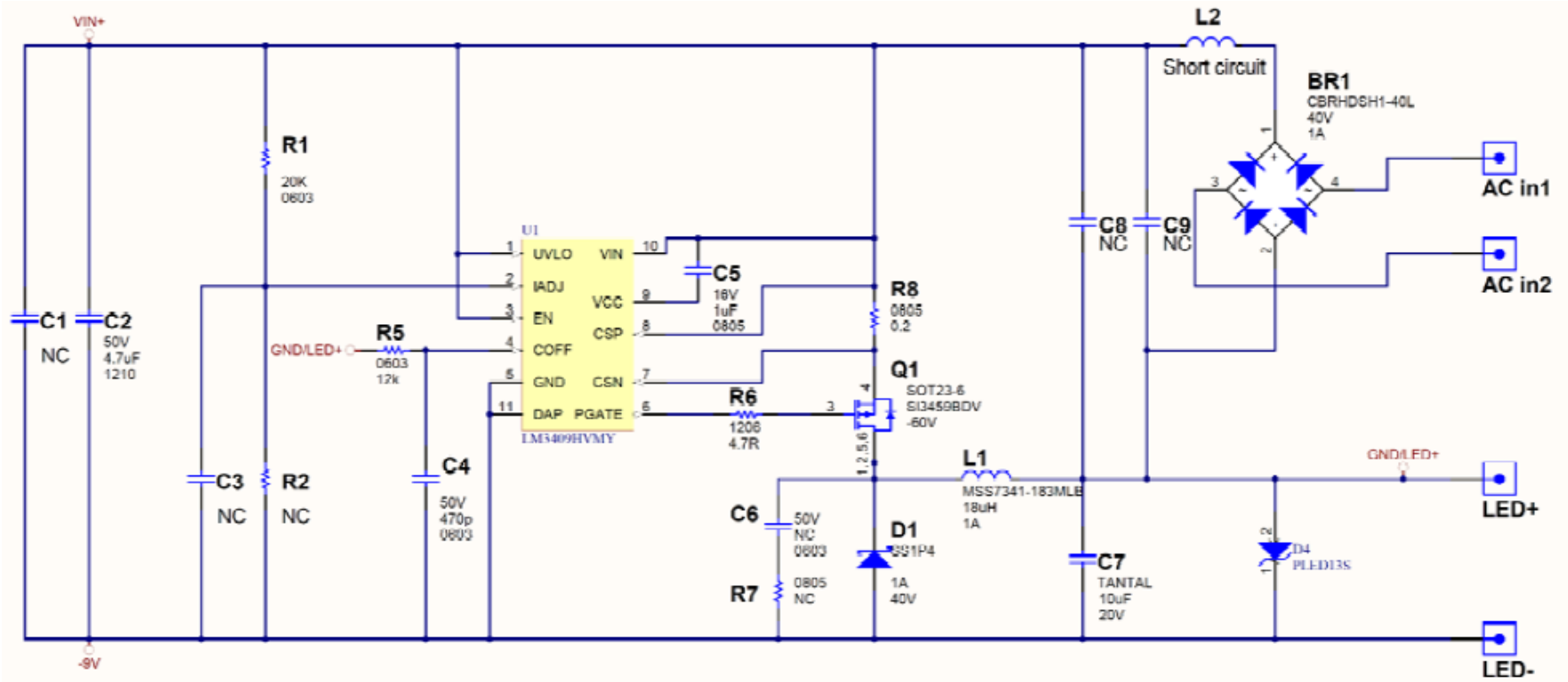
LED DRIVER MICRO-MODULE

TPS92550/1: 450mA Constant Current Buck LED Driver Micro-Module

Features

- Wide input voltage range :
  - 4.5V – 36V (TPS92550)
  - 4.5V – 60V (TPS92551)

- Constant switching frequency :
  - 400kHz (TPS92550)
  - 800kH z(TPS92551)

- LED current adjustable from 300mA to 450mA

- PWM Dimmable with High Contrast Ratio

- 1 Module drives up to 16 LEDs (TPS92551)

- Integrated all power components

- High current accuracy
  - +/- 3.6% for TPS92550
  - +/- 3.5% for TPS92551

- Thermal shutdown

- TO-PMOD 7 pin package

- -40°C to +125°C junction temperature range

- Can be connected in parallel for higher current operation
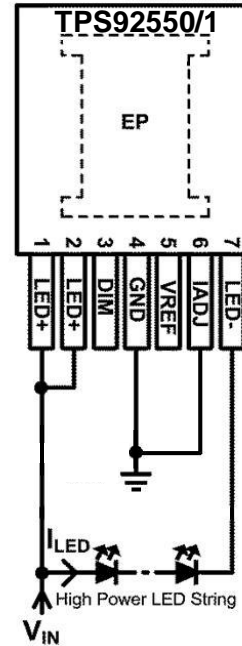
Easy to Use 7 Pin Package
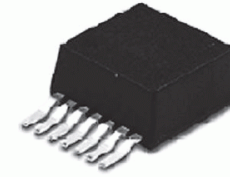
Top View
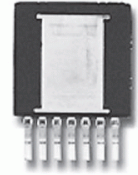
Bottom View

30172701

TO-PMOD 7 Pin Package
10.16 x 13.77 x 4.57 mm (0.4 x 0.39 x 0.18 in)
$\theta_{JA} = 20°C/W$, $\theta_{JC} = 1.9°C/W$
RoHS Compliant

Benefits

- **Fully integrated solution, no design needed**
- **High efficiency, up to 95%**
- **Low EMI**

Applications

- **Desk Lamps**
- **Decorative Lamps**
- **Street Lamps**
- **Architectural lighting**

TEXAS INSTRUMENTS

TPS92550 / TPS92551 Application Circuit and Evaluation Board

TPS92550 / TPS92551 Application Circuit

*optional
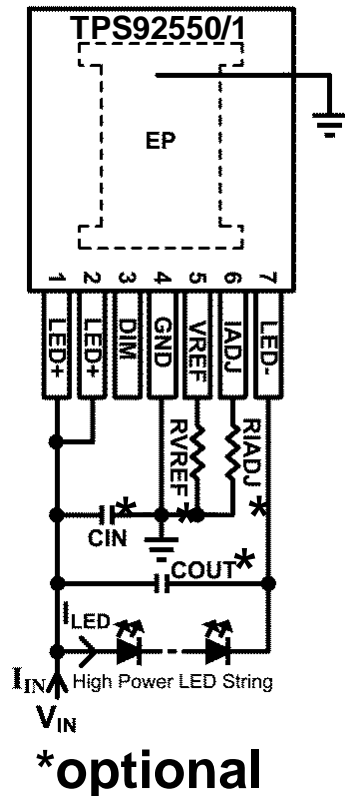
TPS92550 / TPS92551 Evaluation Board

LED current setting

IADJ PIN	VREF PIN	ILED
499 Ω	OPEN	300 mA
GROUND	OPEN	350 mA
GROUND	10.5k Ω	450 mA

TPS92550/1 LED Driver Micro Module

General Lighting Applications

14W & 23W capable Constant Current Drivers

Capable of driving up to 16 LEDs at 450mA

TI Information – Selective Disclosure

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LED STREET LAMP SOLUTIONS

TEXAS INSTRUMENTS

UCC25710
LLC Half-Bridge Controller for LED lighting

Features

- **Single Stage approach for Multiple LED string Driver with global dimming**
- **LLC Resonant Half Bridge Topology**
- **Better than 1%LED string current matching**
- **PWM LED dimming control**
- **Programmable Dimming LLC ON/OFF Ramp Feature**

Benefits

- **50% Cost Reduction Compared to Individual Boost Regulator Approach**
- **93% Plus Efficiency for Best In Class LED Backlighting Performance**
- **Provides Uniform Backlighting Providing Exceptional Picture Quality**
- **Provides Simple interface to System Micro for Intelligent Control**
- **Eliminates audible noise from PWM dimming frequency**

Applications

- **LCD TV Backlighting**
- **Edge Lit LCD TV**
- **LED lighting**
- **Street lighting**
- **LLC Power Supplies**

EVM Available

TEXAS INSTRUMENTS
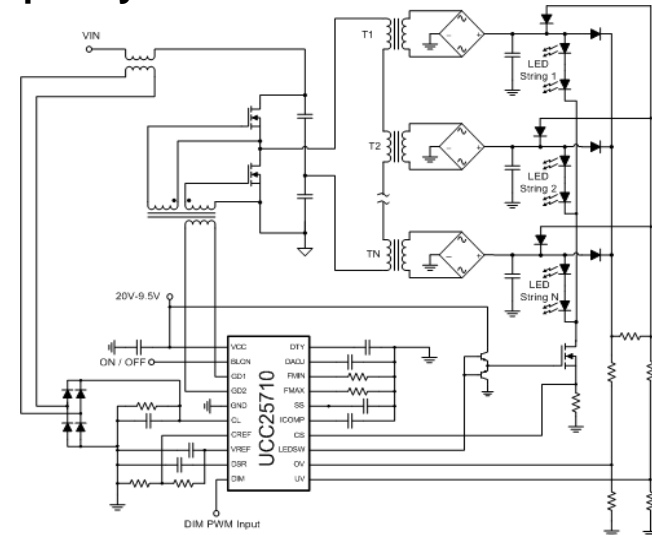
PMP4302A: Multi-string LLC AC/DC Driver for general LED lighting

Reference Design	TI Parts	V_{in}	Output	Topology	Eff.	Dimming
PMP4302A: **AC input Multi-string LLC converter for general LED lighting**	UCC28810 *(TM PFC)* UCC25710 *(Multi-string LLC)* UCC28610 *(Aux Flyback)*	90V~264V	54V@500mA with 4 string	TM PFC+Multi-string LLC converter	92%	PWM dimming with CC2530 daughter board

Features

- Lowest cost than AC/DC + DC/DC
- Highest efficiency to 92%
- PWM dimming compatible
- Integrate LED open/short protection and over current protection

Applications

- General LED lighting and LED backlight TV

Outdoor and Infrastructure >100W

400Vdc

EMI Input Bridge

PFC Control

UCC28810

Ga   Gb

CS
UV
OV

Gate Driver

PWM Control

UCC25710

TI Information – Selective Disclosure

TEXAS INSTRUMENTS
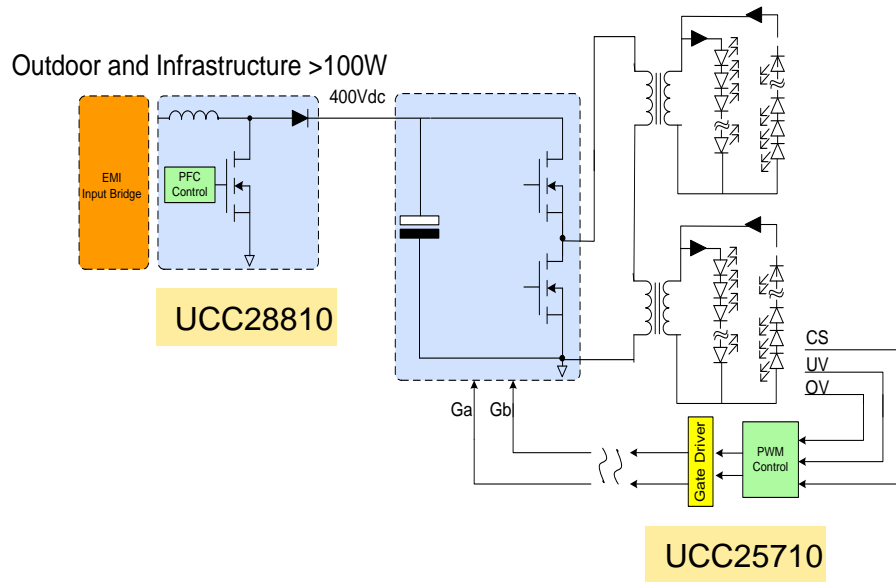
PMP4317: Single-string LLC AC/DC Driver for general LED lighting

Reference Design	TI Parts	V$_{in}$	Output	Topology	Eff.	Dimming
PMP4317: **AC input single-string LLC converter for general LED lighting**	UCC28810 *(TM PFC)* UCC25710 *(Multi-string LLC)* UCC28610 *(Aux Flyback)*	90V~264V	200V@700mA	TM PFC+single string LLC converter	94.5%	PWM dimming with CC2530 daughter board Or 0~10V analog dimming

200V/700mA

UCC28810   UCC25710

60LEDs

PWM dimming

Features

- Lowest cost
- Highest efficiency to 94%
- PWM and analog dimming compatible
- Integrate LED open/short protection and over current protection

Applications

- General LED lighting and LED backlight TV
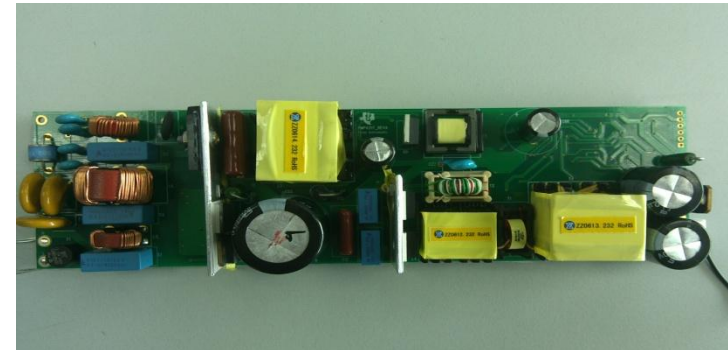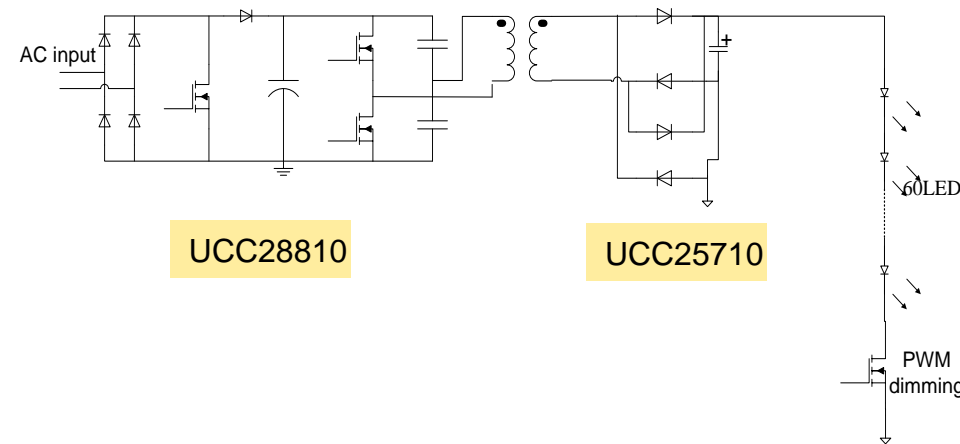
TI Information – Selective Disclosure

LM3464/LM3464A

4-Channel High-Voltage, Constant Current LED Driver with Dynamic Headroom Voltage Monitoring

Features

- Wide Input Voltage Range
  - 12 to 60V (LM3464)
  - 12 to 95V (LM3464A)
- Dynamic Headroom Control

- Analog and PWM Dimming

- LED Open, LED Short Detection
- Thermal Detection with Foldback

Benefits

- Two voltage grades optimized for different application needs

- Provides Feedback to AC/DC Converter to Ensure Maximum Efficiency
- Optimize for LED Color Shift and Brightness Control
- Fault Flag Notifies MCU of Abnormal Condition
- Maintains LEDs ON, but at Reduced Brightness Until LED Over-Temperature Condition Clears.

Applications

- LED Street Lighting, High-Bay Lighting
- Multi-String LED Luminaires

EVM TOOLS
- LM3464-120V24W/NOPB
- LM3464EVAL/NOPB

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TEXAS INSTRUMENTS
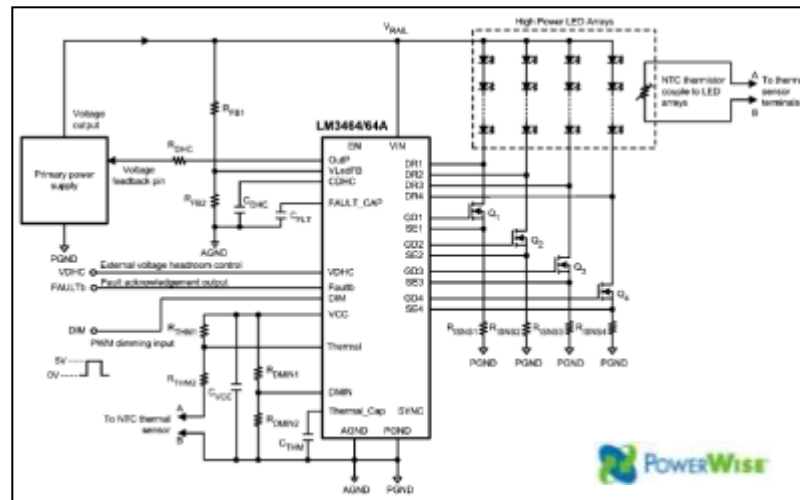
LM3466
Smart Linear LED Driver for Multi-Channel LED Systems

coming soon!

Features

- Wide Input Voltage Range: 6 to 70V
  - 70V, 1.5A MOSFET with 2A Limit
- Works with Constant Current Power Supplies
- Automatic Equalization
- LED Open, LED Short Detection
- Thermal Shutdown

Benefits

- Support Up to 20 LEDs in Series
- Regulates LED String Current Based on User Settings
- Balances Current of Every Active String, Even if String Voltages Are Not Equal
- Fault Flag Notifies MCU of Abnormal Condition
- Protects LM3466 Against High-Temperature Conditions

Applications

- LED Street Lighting, High-Bay Lighting
- Multi-String LED Luminaires

EVM TOOLS
WEBENCH®

•LM3466MREVAL

TEXAS INSTRUMENTS
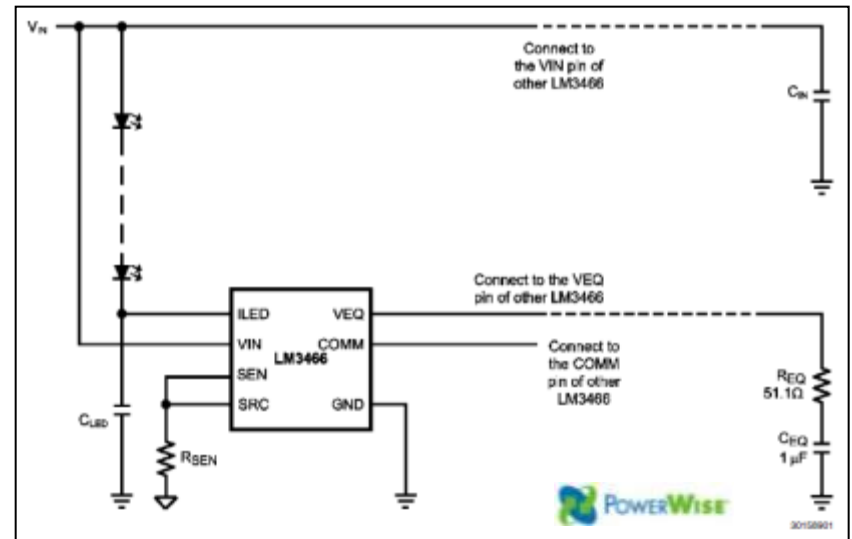
LM3466: Dynamic Current Equalizer

- LM3466 is a linear LED driver which acts like an intelligent ballast resistor.

- Each IC communicates with other IC's to equalize the current in each channel i.e., divides the current equally

- Application: high power fixture with multiple output channels and constant current power supply
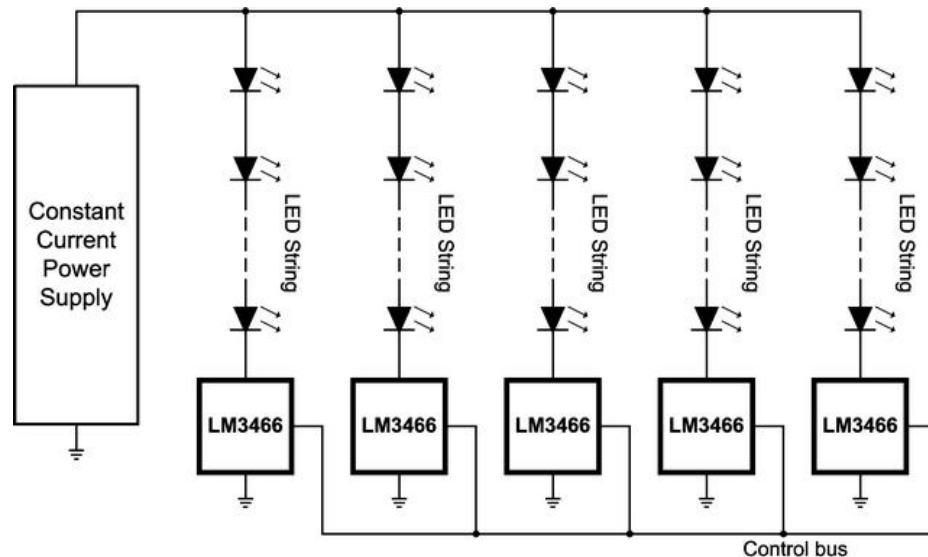
LM3466 Features

- Linear circuitry
  - No extra EMI

- Simple to use and design
  - Off-the-shelf constant current power supply + LM3466

- Wide input voltage range from 6V to 70V
  - Can extend >70V

- Flexible
  - The number of channel is not limited
  - To add 1 LED channel, just add 1 LM3466, 1 resistor, and 1 capacitors without further calculation required

LM3466 BUILDING BLOCK
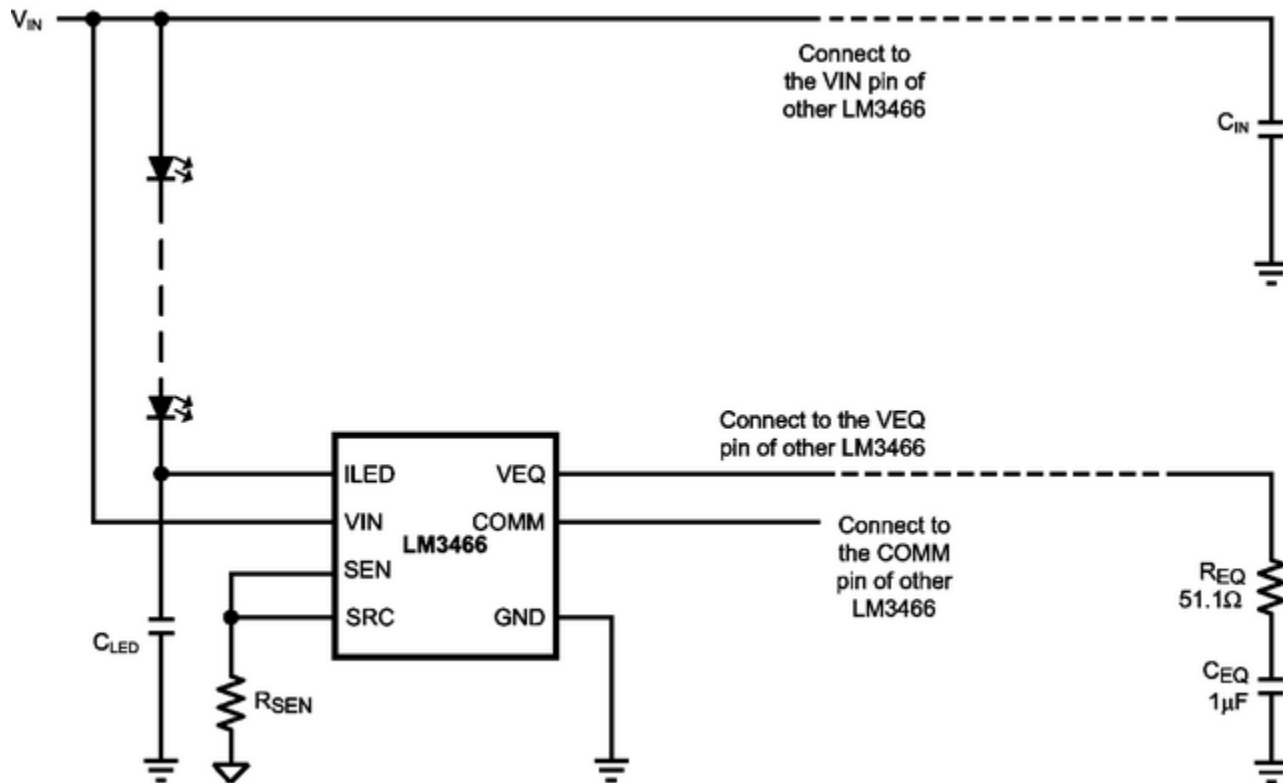
TYPICAL APPLICATION
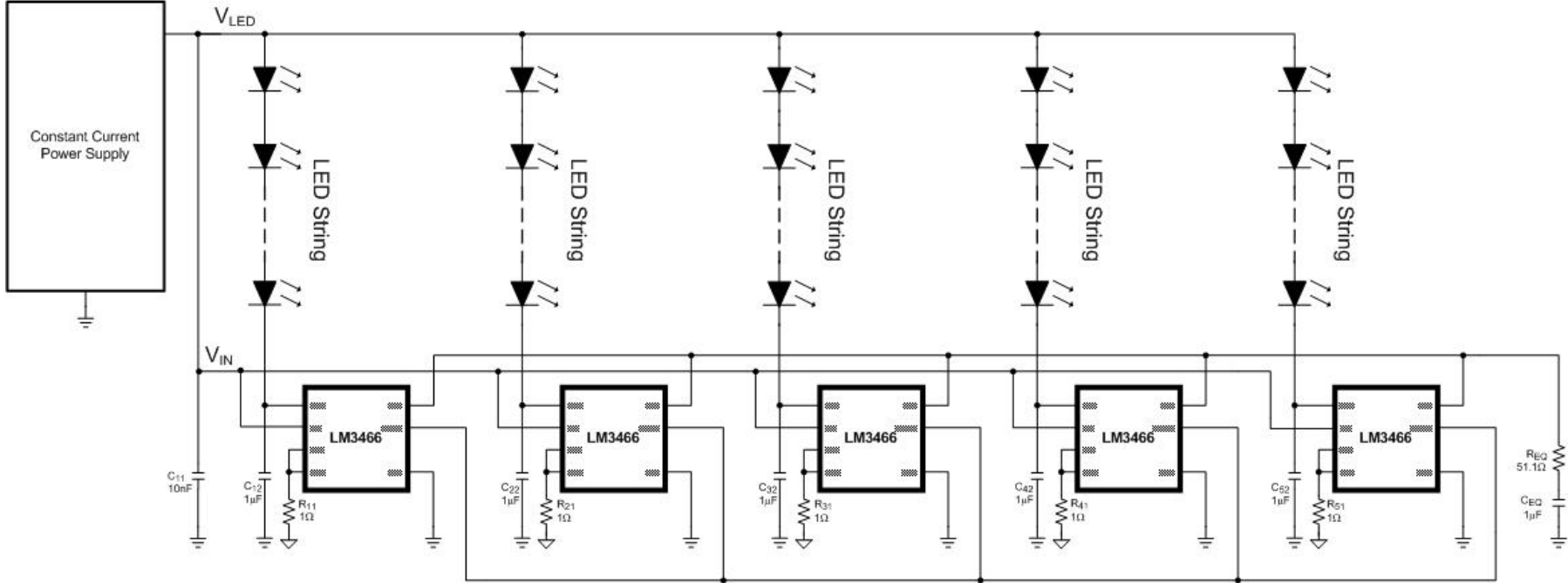
UCC28810 & LM3466: Complete AC/DC Multi-String System
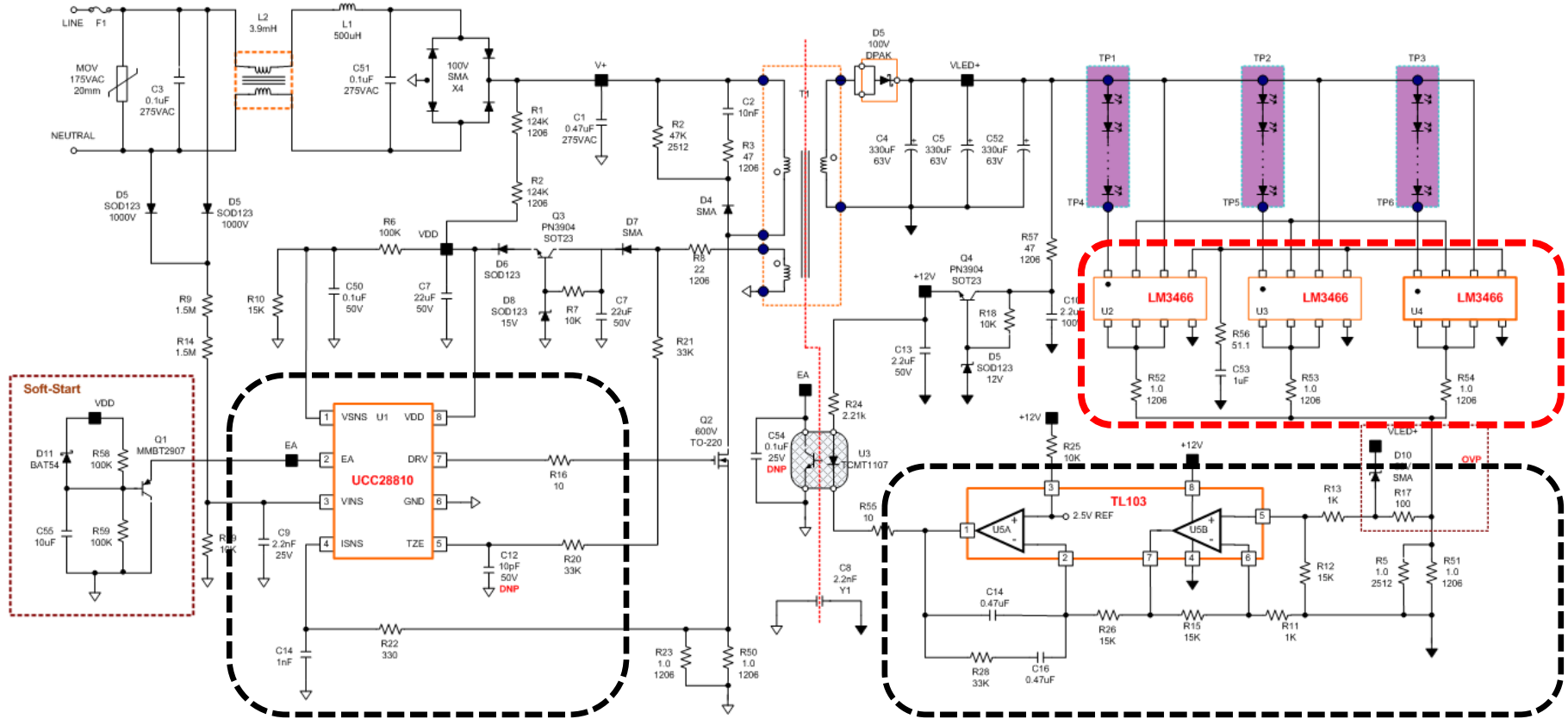
- **Comments** – Low 120/100Hz ripple into LEDs. Short/Open LED easily managed. No increase in EMI signature . Slight increase in cost over direct drive solution. Well regulated current through multiple strings of LEDs.

LM3402/LM3402HV
0.5A Constant Current Buck Reg. for Driving HB LEDs

Features

- VIN range from
  - 6V to 42V (LM3402)
  - 6V to 75V (LM3402HV)
- Hysteretic Operation with Controlled On-Time
- Integrated 0.5A N-Channel MOSFET
- PWM Dimming Input

- Over-Temperature, LED Open/Short Protection

Applications

- LED General Illumination
- Industrial Lighting
- Automotive Lighting

Benefits

- Two voltage grades optimized for different application needs

- No Control Loop Compensation Required
- Easily Drives 1W HB LEDs
- Allows for External Source Such as a MCU to Control LED Brightness
- Protects Against Abnormal and Fault Conditions

- LM3402EVAL/NOPB

EVM TOOLS
WEBENCH®

TI Information – Selective Disclosure
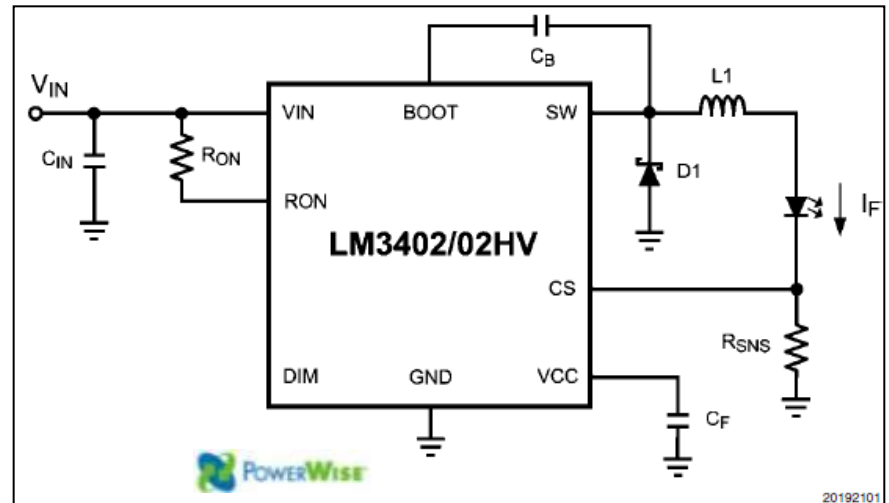
LM3404/LM3404HV
1A Constant Current Buck Reg. for Driving HB LEDs

Features

- VIN range from
  - 6V to 42V (LM3404)
  - 6V to 75V (LM3404HV)
- Hysteretic Operation with Controlled On-Time
- Integrated 1A N-Channel MOSFET
- PWM Dimming Input
- Over-Temperature, LED Open/Short Protection

Applications

- LED General Illumination
- Industrial Lighting
- Automotive Lighting

Benefits

- Two voltage grades optimized for different application needs
- No Control Loop Compensation Required
- Easily Drives 3W HB LEDs
- Allows for External Source Such as a MCU to Control LED Brightness
- Protects Against Abnormal and Fault Conditions

EVM TOOLS
- LM3404EVAL/NOPB
- LM3404FSTDIMEV/NOPB
- LM3404MREVAL

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TI Information – Selective Disclosure

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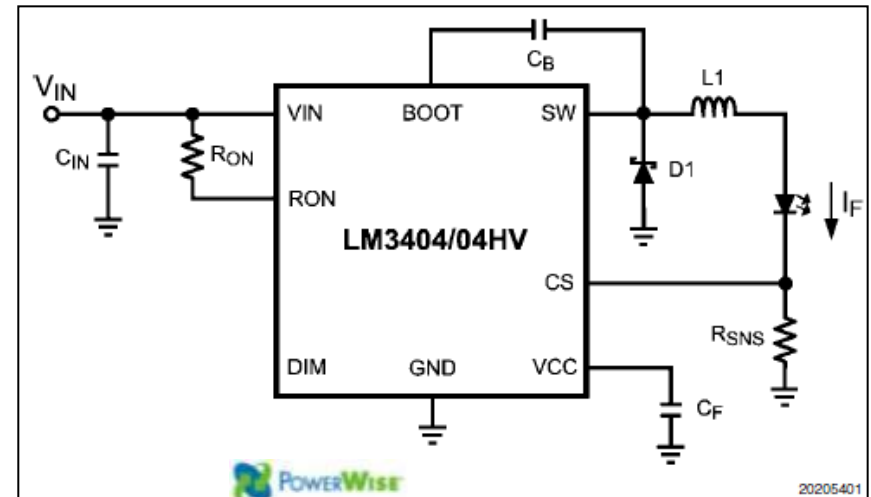
LM3414/LM3414HV
1A Floating Buck for Driving HB LEDs (No Sensing Resistor)

Features

- Input Operating Range
    - 4.5 to 42V (LM3414)
    - 4.5 to 65V (LM3414HV)
- Adjustable LED current: 350-1000mA
- Adjustable Switching Frequency: 250kHz to 1MHz
- Analog and PWM Dimming
- Internally Compensated
- UVLO, Thermal Shutdown and Open-Circuit Protection

Applications

- High Light Output Designs (Troffers, Architectural Lighting)
- MR-16 Replacement
- Automotive Lighting

EVM TOOLS
- **LM3414HVMREVAL/NOPB**
- **LM3414HVSDEVAL/NOPB**

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Benefits

- Two Voltage Grades Optimized for Different Application Needs
- Supports 1-3W HB LEDs
- Allows for Optimization of Efficiency Versus Inductor Size, Reduced EMI
- Up to 1/10 Switching Frequency (PWM)
- Simplifies Design and Reduces Component Count
- Protects Against Abnormal and Fault Conditions

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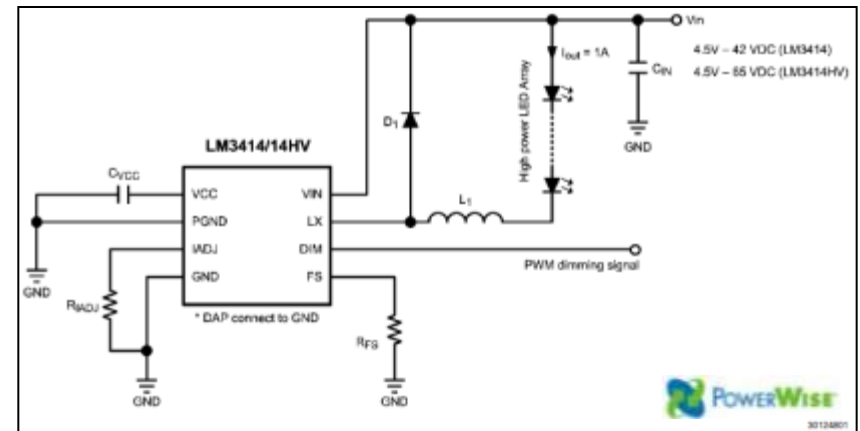
WEBENCH LED Architect

Simulation Models

- **Excel based**

- **SPICE based**

Thank you

TEXAS
INSTRUMENTS