TI Technology Days 2010

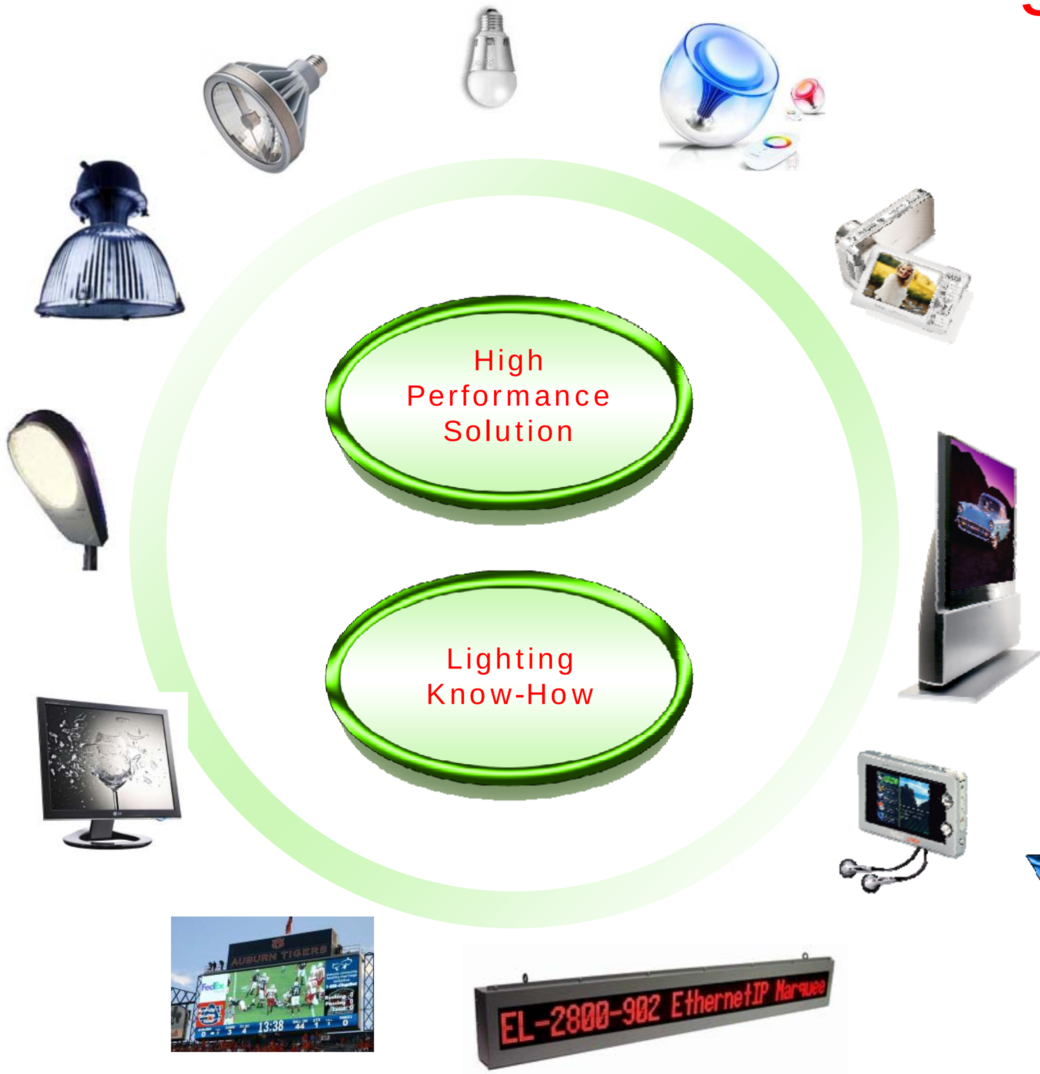
LED‘s sind überall . . .

Treiberschaltungen von AC und DC

Roland Prager, AFA Austria

AC/DC solutions
DC/DC solutions
Adding intelligence to LED systems

...and Solid State Lighting System Knowledge

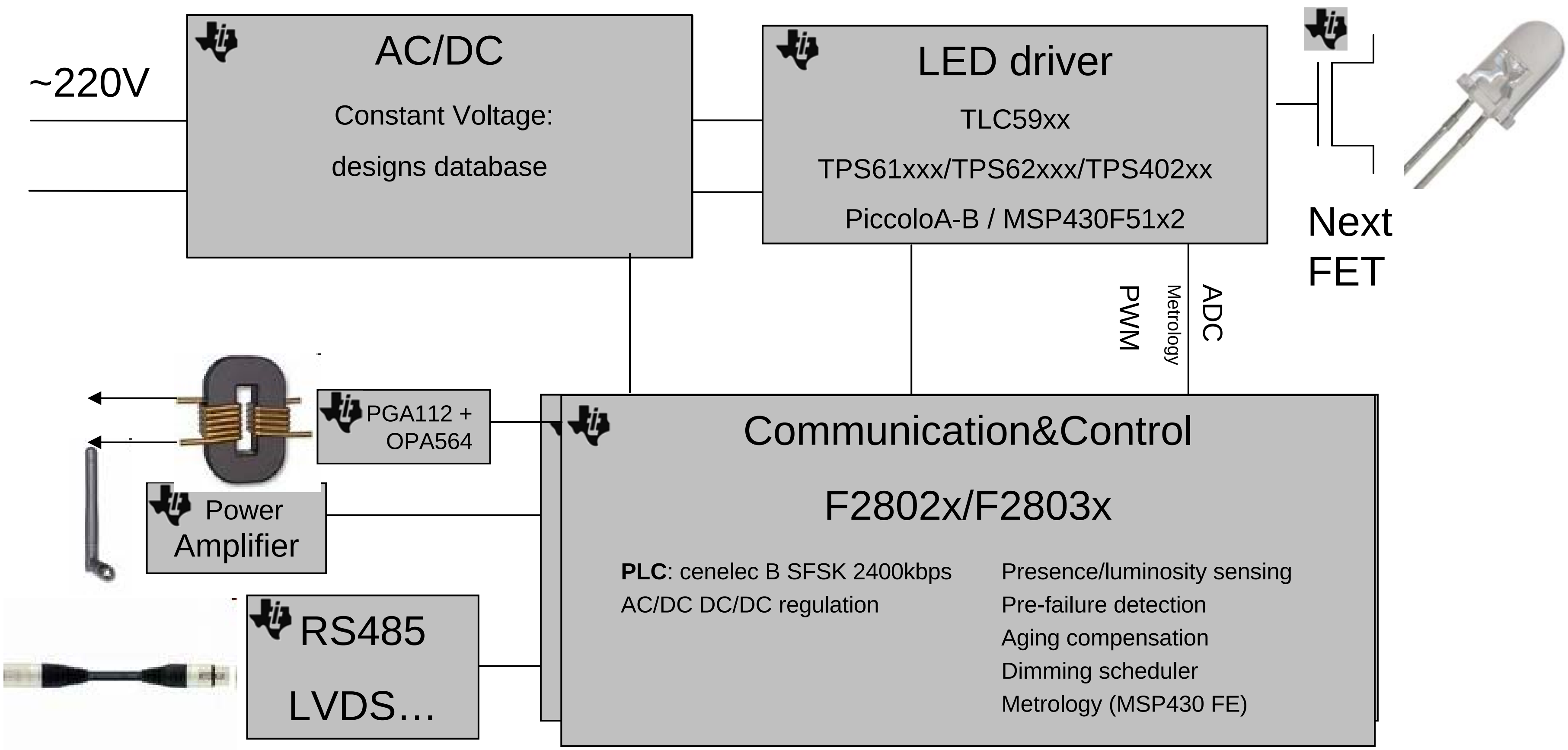


Portfolio strength in...

- AC/DC, isolated DC/DC
- Power factor correction
- Multi-Channel LED Driver
- LCD backlight (LED, CCFL)
- Off-Line LED Lighting Drivers
- Digital platforms
- Communication (DMX, PLC, DALI, etc…)

Full System Solutions

Main Block Diagram



Light Characteristics

- Luminous Flux (lumens)   1 lumen = 683 * W * Vλ

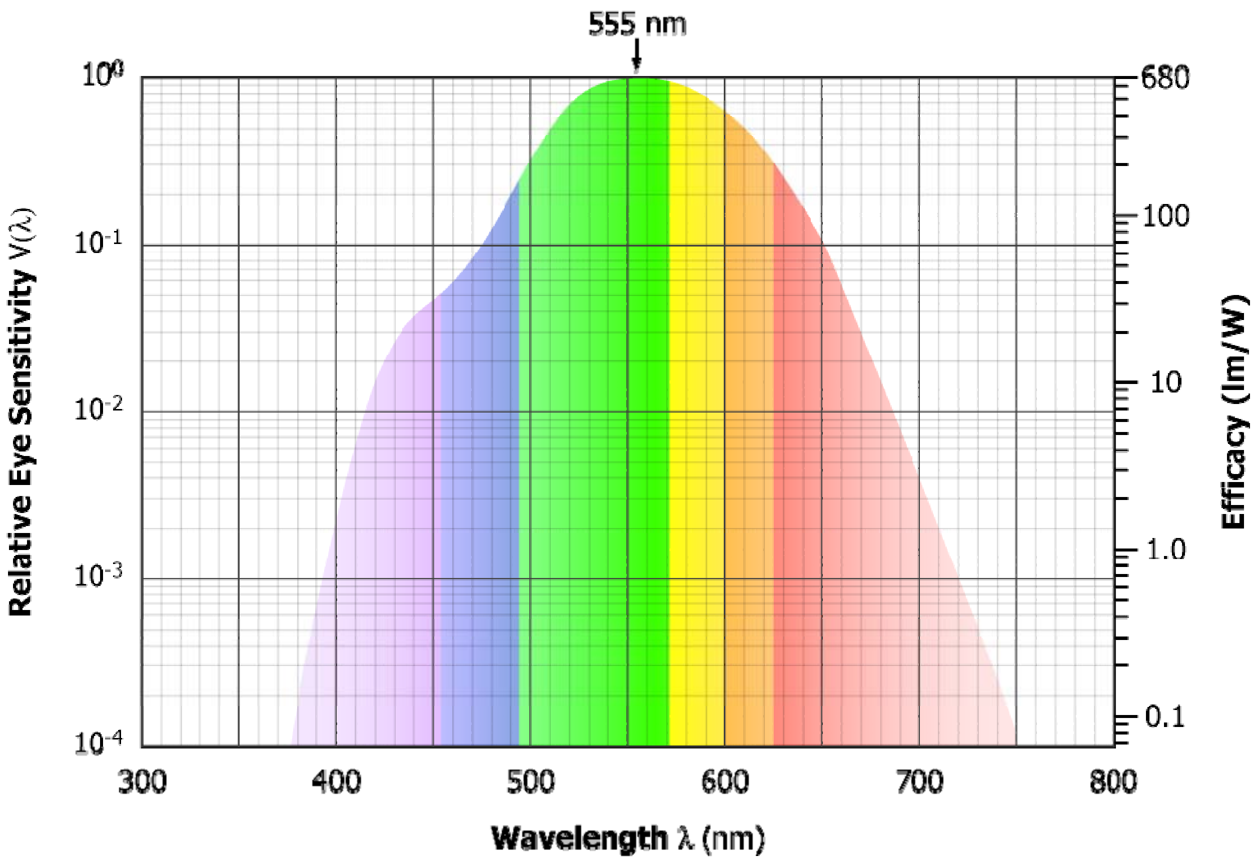
40W = 500 lm
60W = 850 lm
75W = 1,200 lm
100W = 1,700 lm
150W = 2,850 lm

1,200,000 lm

5,000 – 10,000 lm

1,000 lm

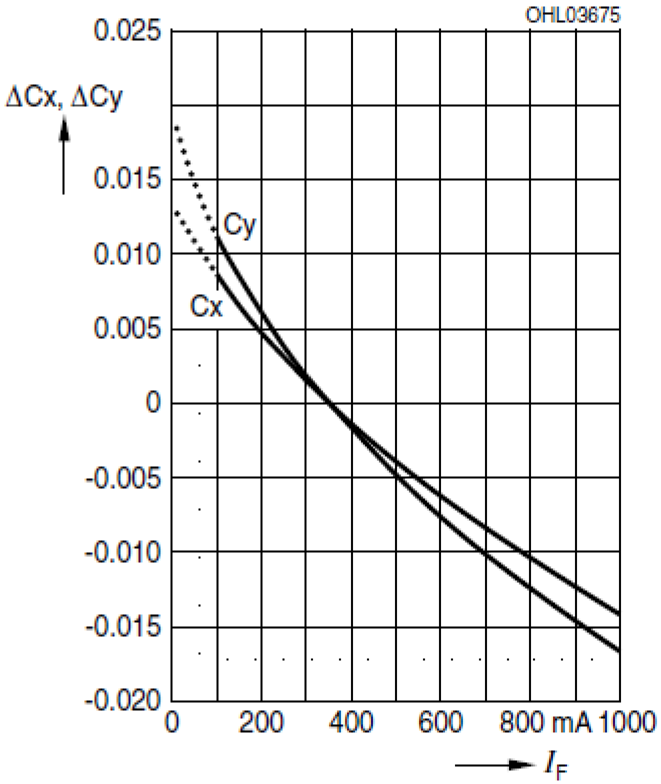
Human Eye Sensitivity to Color



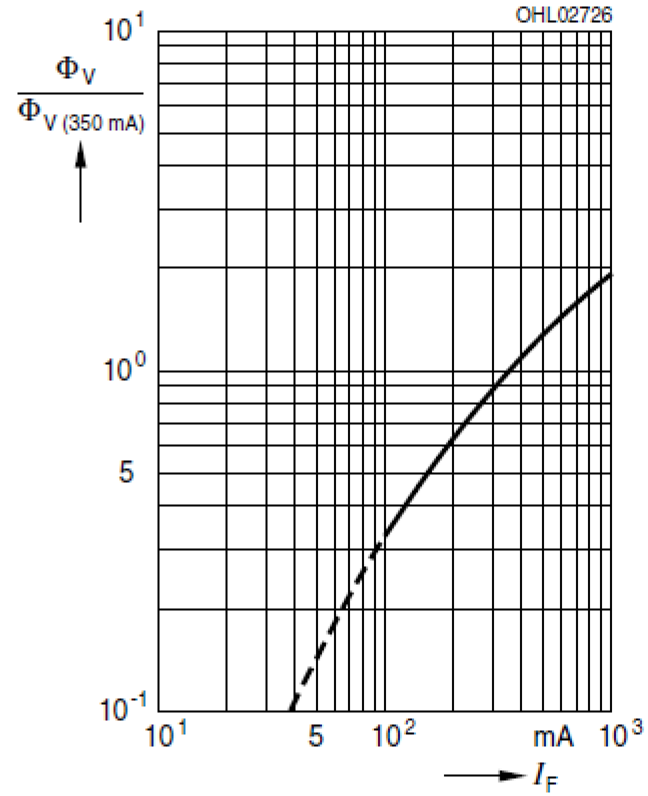
- The human eye does not perceive every wavelength of light equally
  - The average eye perceives green light to be the brightest
- V-λ function, also called the Photopic curve, or standard luminosity function.
- The Photopic curve becomes the Scotopic curve in low light levels, ~50nm shift to the left.

Current Effects on LEDs

Farbortverschiebung[2)] *Seite 17*
Chromaticity Coordinate Shift[2)] *page 17*
x, y = $f\,(I_F)$; T_S = 25 °C
solid line: specified DC-range

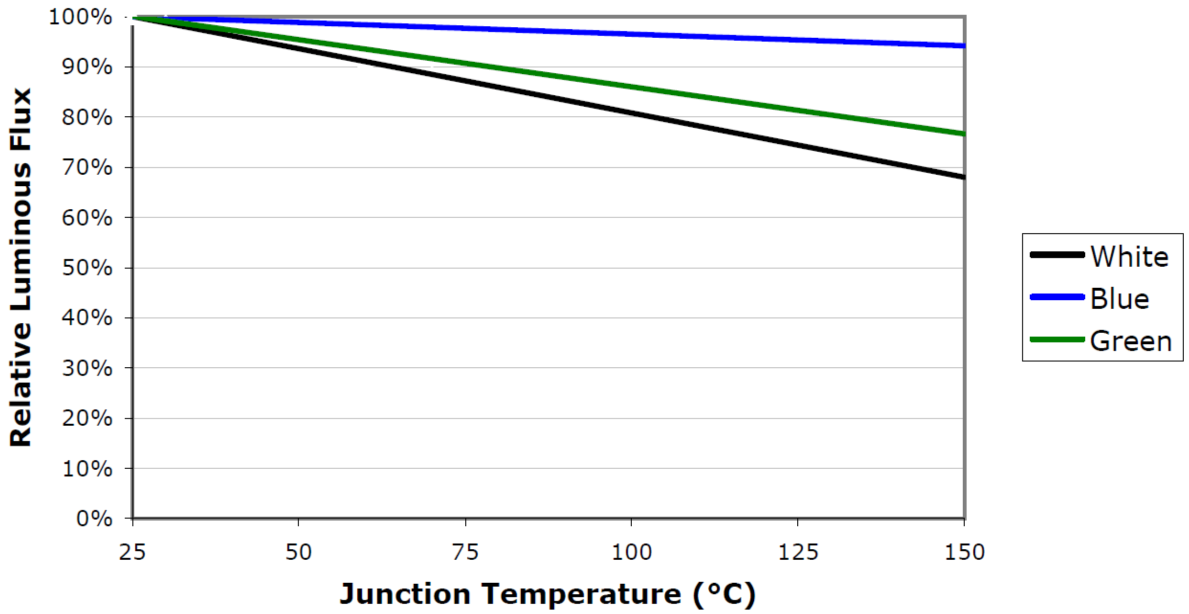


Relative Lichtstrom[2) 5)] Seite 22
Relative Luminous Flux[2) 5)] page 22
Φ_V/Φ_V(350 mA) = $f\,(I_F)$; T_S = 25 °C



All Diagrams on this page from from OSRAM Golden Dragon Data Sheet

Luminous Flux and T_J



Increasing T_J results in:

- Decrease in light output (luminous flux)
- Wavelength will increase (shift towards red)
- Forward Voltage, V_f, will decrease

All Diagrams on this page from from CREE® XLamp® XR-E Data Sheet

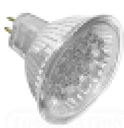
AC/DC solutions
DC/DC solutions
Adding intelligence to LED systems

LED General Illumination

Applications

LED Lighting

Residential
< 25W or
3,000 lm


MR16


E14


E27/A19


PAR38

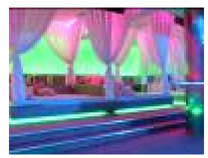
Driver Topologies

Buck, Boost, Buck Boost, SEPIC and Flyback

LED String configuration
single string

Commercial
15W – 75W or
1000 lm - 10000 lm


Display Case


Retail Display


Architectural

Driver Topologies

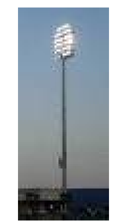
Buck, Boost, Buck Boost, SEPIC and Flyback

LED String configuration
single string, some parallel

Outdoor and Infrastructure
35W – 250W
2500 lm - 30,000 lm


Street Light


Area Light


Flood Light

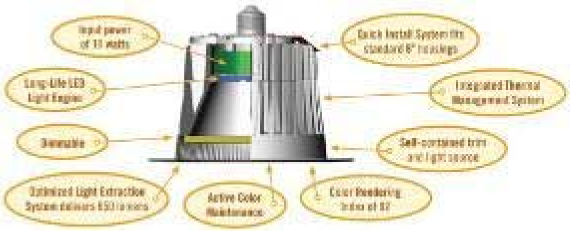
Driver Topologies

PFC Boost, Flyback Half-Bridge, Buck, Multi-string

LED String configuration
single string, some parallel,
Individual control of many strings

Residential Lighting LED Driver Solutions

- < 25W
- Low Cost
- TRIAC Dimming
- Power Factor Correction
- High Efficiency
- Color Quality
- Safety
- Long Life



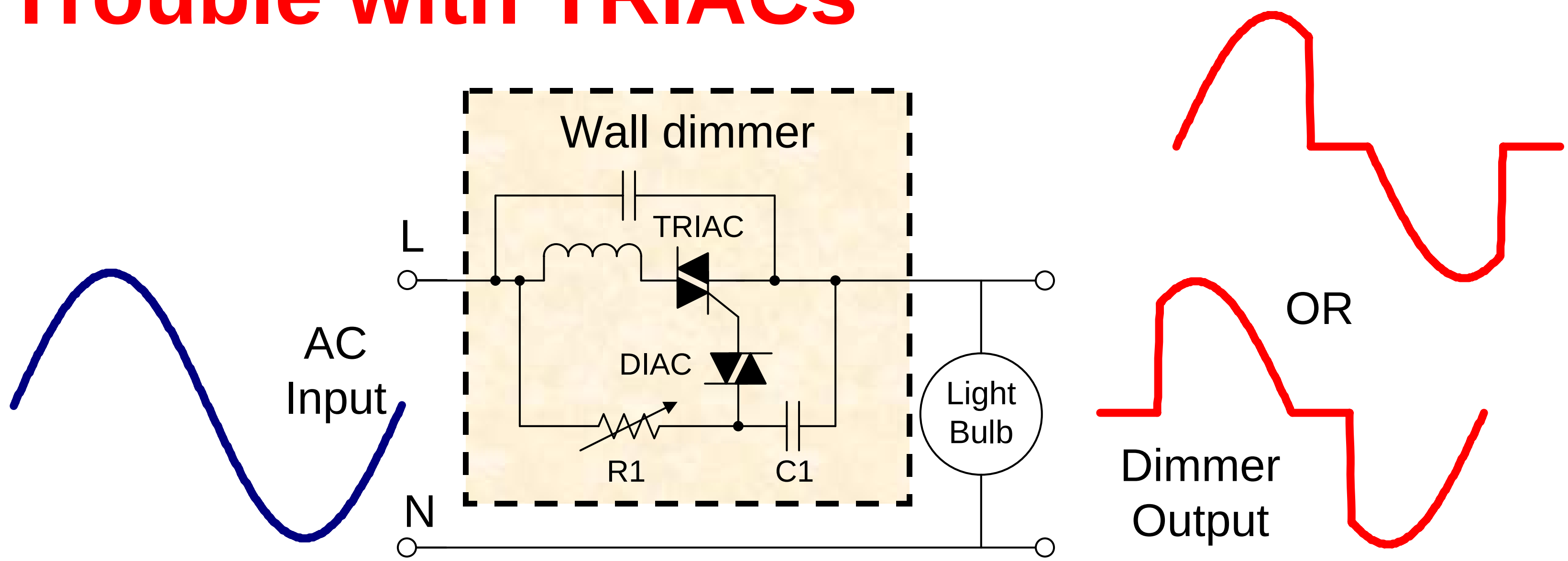
Reference Design & Roadmap - Residential

Description	Parts	Vin Range VAC		Vout (DC) Range		# of LEDs	Iout Max	Pout (max)	Eff.	PFC	ISO	Dim In	Dim Out	Status (1)
TPS92010 EVM - High Performance dimming and High Efficiency Offline LED lighting driver	TPS92010 TL431 LM358	100 180	130 265	9	18	3 to 5	325mA	7W	80%	N	Y	TRIAC	Linear	EVM April'10
TPS92210 EVM - High Efficiency, PFC and TRIAC dimmable LED lighting driver	TPS92210	90 180	130 265	32	40	9 to 11	350mA	12.5W	85%	Y	Y	TRIAC	Linear	EVM May '10
PMP4891 Low cost TRIAC dimmable LED lighting driver	TPS92001 TL331	108	132	22	32	5 to 9	350mA	11W	77%	0.8	N	TRIAC	PWM 120Hz	Board
PMP5163 - PMP4891 with no Aluminum Capacitors	TPS92001 TL331	108	132	22	32	5 to 9	350mA	11W	77%	0.8	N	TRIAC	PWM 120Hz	Board
PMP5100 Modification to PMP4981	TPS92001 TL331	108	132	15	20	6	500mA	10W	85%	0.8	Y	TRIAC	PWM 120Hz	Board
PMP5014 isolated dimmable, 20Watt	TPS92001	108	132	26	36	7 to 10	700mA	20W	85%	0.9	Y	TRIAC	PWM 120Hz	Board
PMP5013 isolated dimmable, 10Watt	TPS92001	108	132	26	36	7 to 10	350mA	10W	82%	0.8	Y	TRIAC	PWM 120Hz	Board
PMP3522 Wide Input Range PFC LED driver - SEPIC converter	TPS92010	90	300	12	21	4 to 6	350mA	8W	82%	Y	N	No	N/A	Board
PMP3562 Wide Input Range PFC Dimmable LED driver - SEPIC converter	UCC28810	90	300	12	21	4 to 6	350mA	8W	82%	Y	N	Yes	Linear	Board

And many more…

(1) EVM: Web orderable evaluation module **Board:** Test results available from the factory
Paper: Conceptual design with schematic and simulation

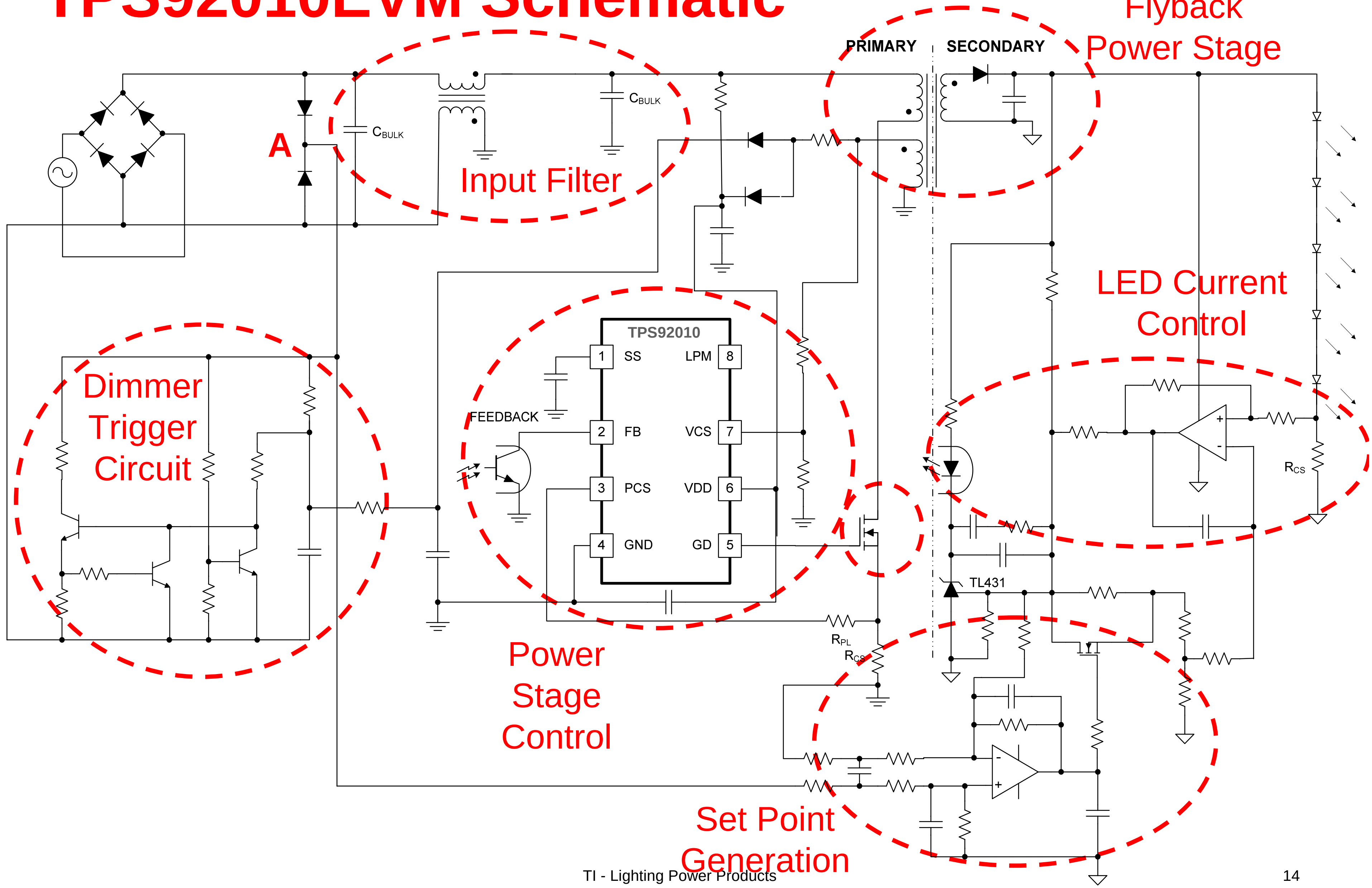
The Trouble with TRIACs



- Start of AC cycle TRIAC initially off
  - C1 charges through R1 and light bulb
- When voltage on C1 exceeds DIAC threshold voltage the TRIAC conducts
  - R1 controls when TRIAC turns ON, dimming function
- Light bulb load must maintain TRIAC holding current
  - TRIAC turns off close to zero crossing and cycle repeats
- LED lights do not always consume enough power to keep TRIAC ON
  - Need to solve this with extra circuitry

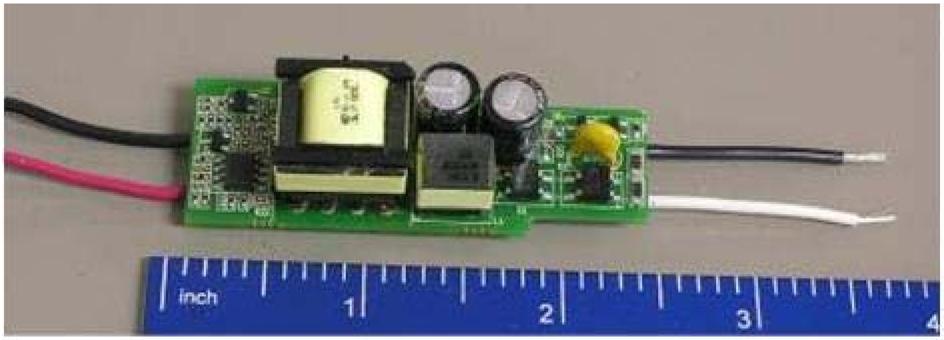
Special care is required when making LED lighting compatible to standard TRIAC dimmers

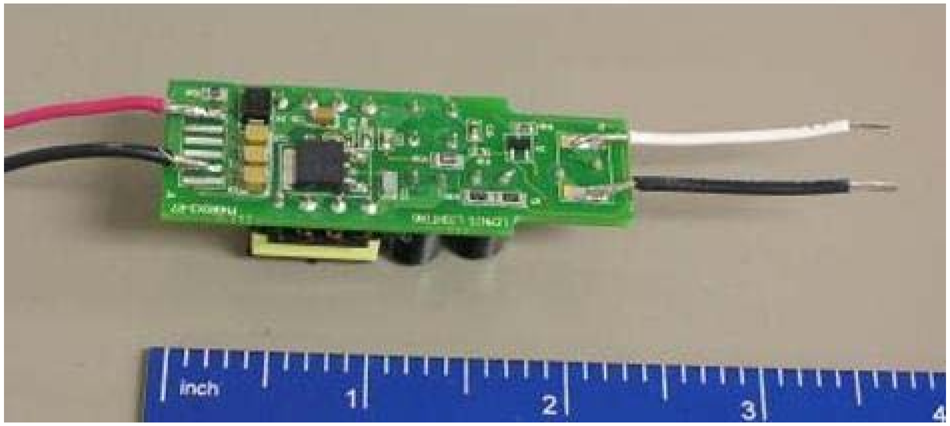
TPS92010EVM Schematic



TPS92010EVM 7Watt LED Lighting Driver

- 120V and 230V input designs
- Tightly Regulated LED current
- Compatible with standard TRIAC Dimmers
- Active holding-current feature
- High Efficiency
  - Maintained during dimming





Texas Instruments

TPS92010EVM-631 Specification

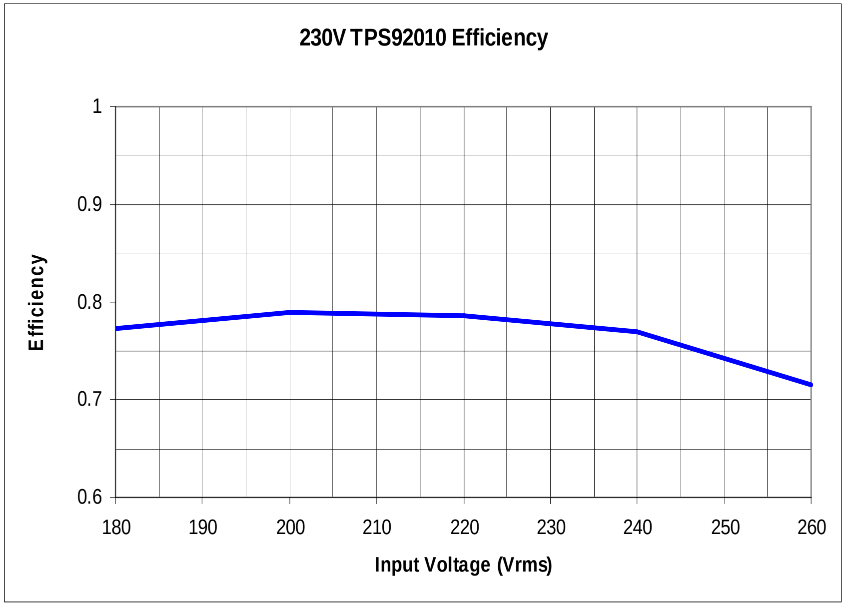
Specification	Value	Unit
LED configuration	5 Ser.	
Input Voltage	185 - 265	VAC
Efficiency	85	%
Power	6	W
Power Factor	0.55	
Output Voltage	14 - 17	VDC
Output Current	325	mA
LF Output Ripple	0	mVpp
Isolation	Yes	

Specification	Value	Unit
Dimming Input	Triac	
Dimming Level	0-100	%
Current Sensing	Res.	
Current Ref Accuracy	3	%
Temp. Range	-20 to 50	°C
Lifetime*	35000	Hrs
Turn on time	150	mS
EMC Regulation	FCC B	
Safety Regulation	No	
Driver Dimensions	60 X 20	mm

Note: *Lifetime assumes 35°C internal temp. rise from ambient.

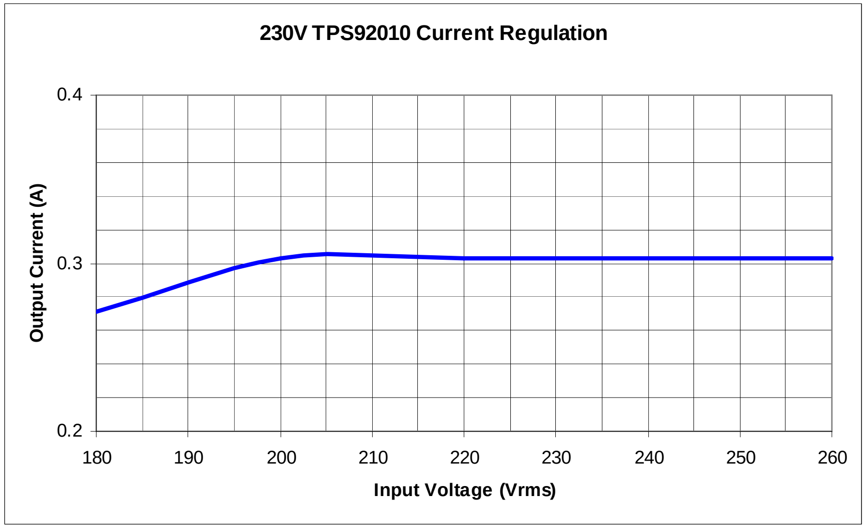
TPS92010EVM Efficiency (230V Version)

- Efficiency Measured with a 5 LED Series String at 300mA
- Voltage across the string is approximately 16.25V



TPS92010EVM Regulation (230V Version)

- Measured with a 5 LED Series String at 300mA
- Voltage across the string is 16.25V
- Direct output current sensing eliminates line variation effects

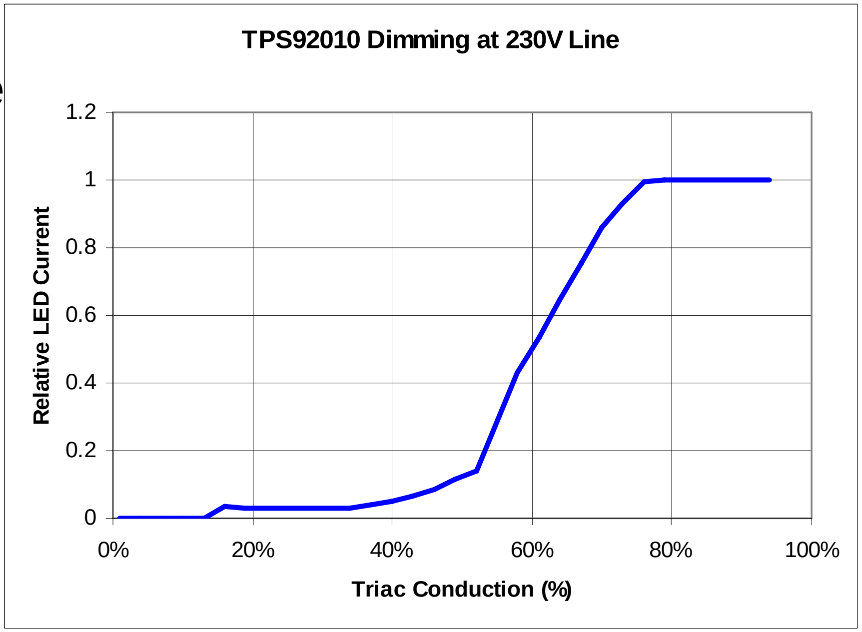


- Light output independent of line voltage fluctuations
- Tight Current Regulation diminishes color variation between different fixtures

TEXAS INSTRUMENTS

TPS92010EVM Dimming Performance (230V)

- Traditional problems TRIAC triggering and holding currents with LED lighting are solved.
- Dimmer triggering provides loading of the TRIAC at AC line crossover for proper dimmer operation.



- DC current during dimming
  - No Stroboscopic effect
  - No audible noise
- Steady deep dimming
  - Two Step dimming pleasing to eye

TEXAS INSTRUMENTS

TPS92010 Lighting Solution Summary

For low power lighting applications that
Do Not require Power Factor Correction

Triac Dimmable for light bulb replacement applications

- Small form Factor - 3W to 12W applications
- High efficiency
- Deep Dimming Capability

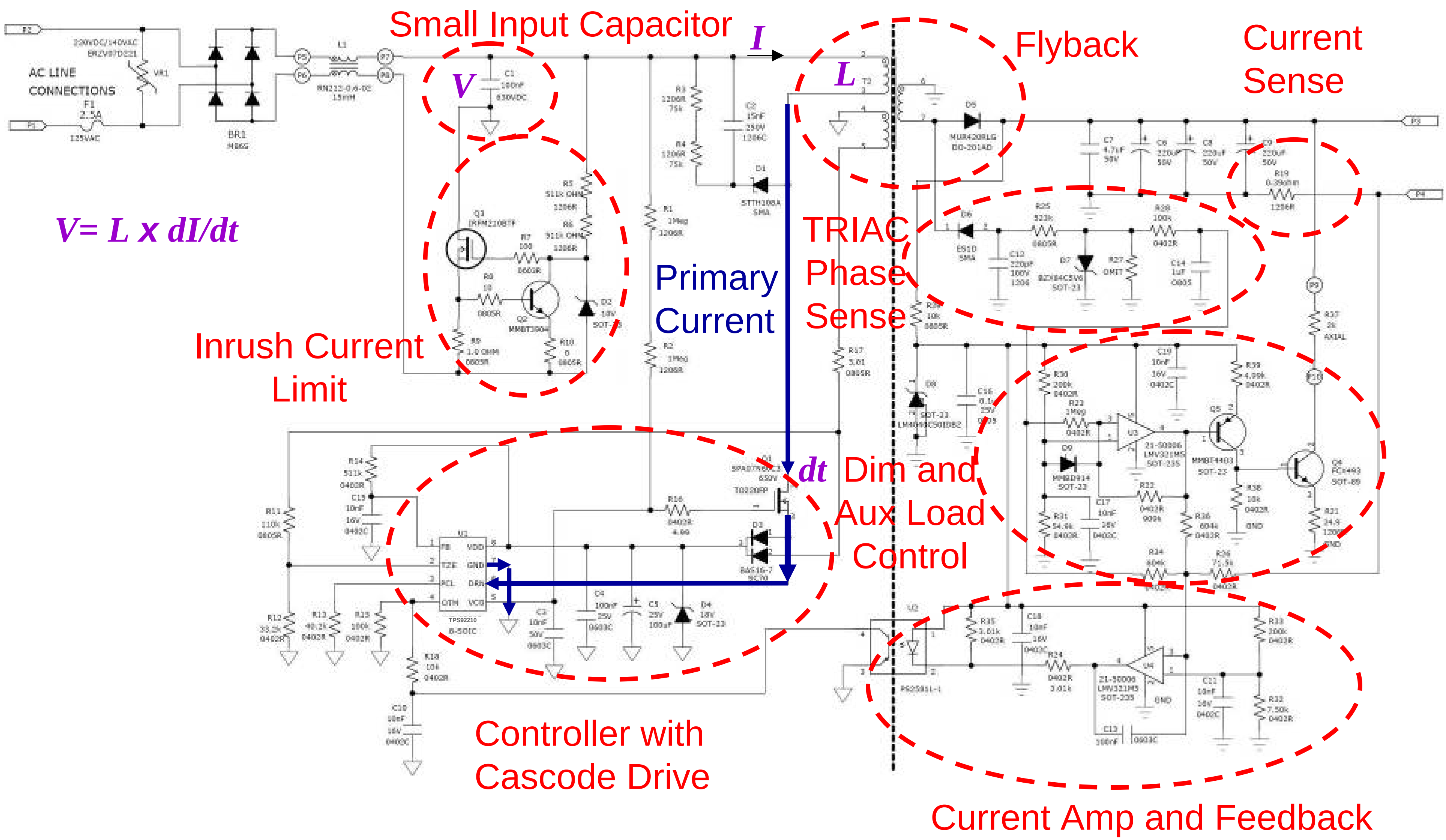
Key Differentiator

- Licensed IP for Lossless Dimming Circuit

  Competitors dimming techniques dissipate more power at deep dimming levels than the power consumed driving the LEDs!

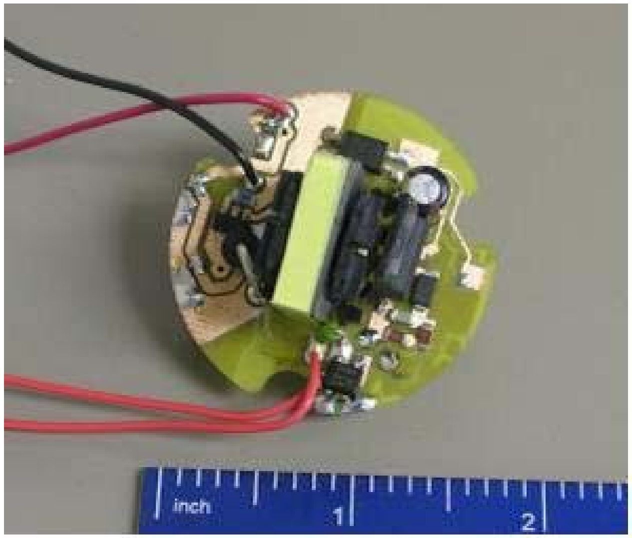
  The Losses in the dimming circuit also adds to the heat which reduces system life and reliability

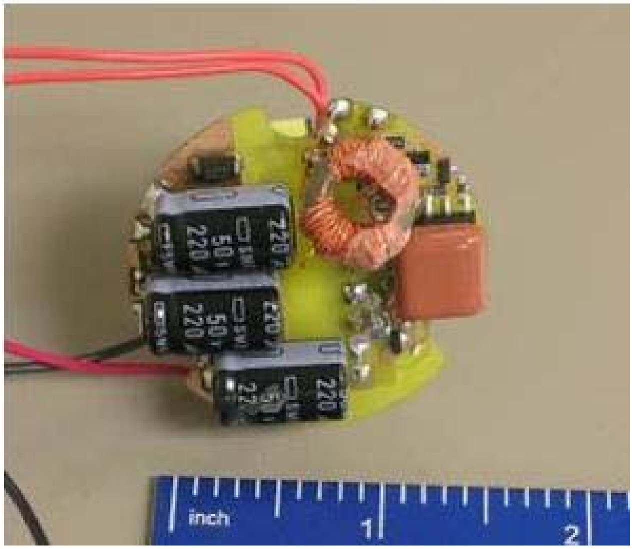
TPS92210EVM Schematic



TPS92210EVM 14Watt LED Lighting Driver

- High PFC with on time modulation
- Tightly Regulated LED current
- Compatible with standard TRIAC Dimmers
  - 0% to 100%
  - Maintains TRIAC holding current
- High Efficiency
  - Maintained when dimmed
  - Flat over line input range
- Cascode drive for main switch
  - Very fast – helps efficiency
  - Isolates high voltage from control chip
- Active Inrush limiting provides EMI filter compatibility with TRIAC





TPS92210EVM Specification

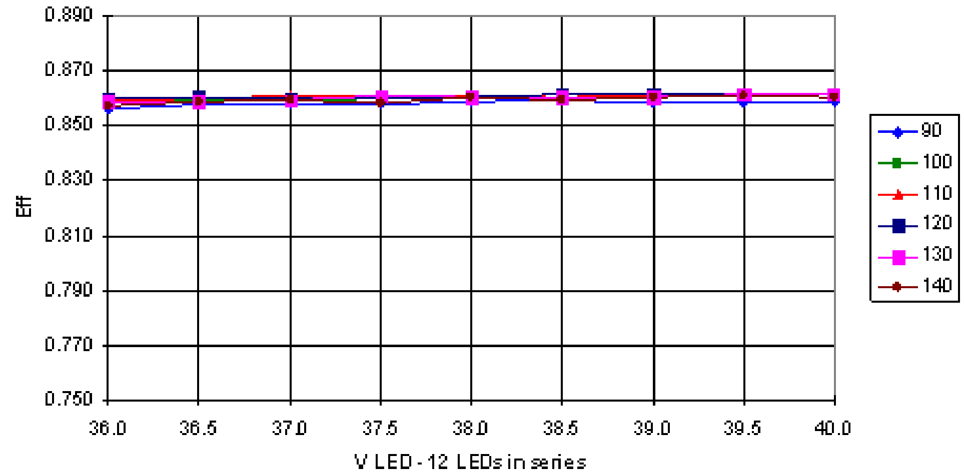
Specification	Value	Unit
LED configuration	9-11	
Input Voltage	90-130 180-264	VAC
Efficiency	85	%
Power	12.5	W
Power Factor	0.99	
Output Voltage	38	VDC
Output Current	350	mA
LF Output Ripple	300	mVpp
Isolation	2500	VAC

Specification	Value	Unit
Dimming Input	TRIAC	
Dimming Level	0-100	%
Current Sensing	Res	
Current Ref Accuracy	3	%
Temp. Range	-20 to 50	°C
Lifetime*	35000	Hrs
Turn on time	150	mS
EMC Regulation	FCC B	
Safety Regulation		
Driver Dimensions	34 dia	mm

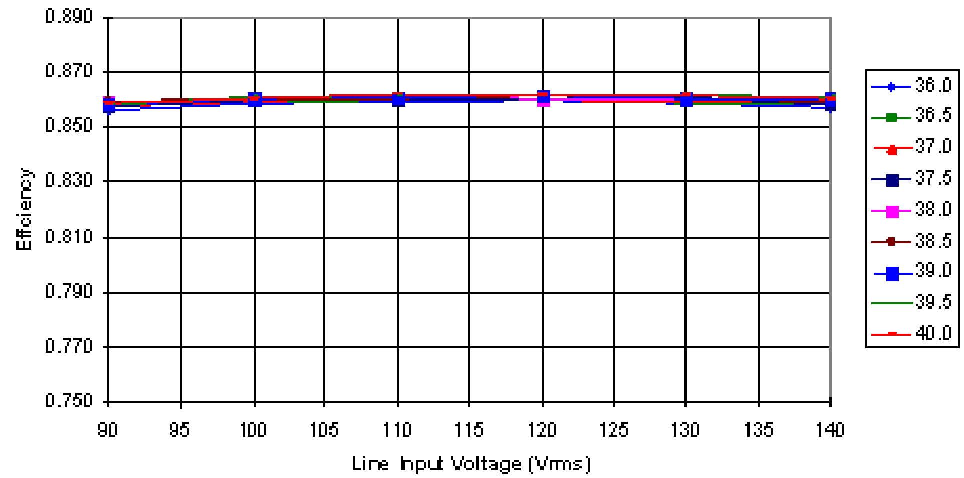
Note: *Lifetime assumes 35°C internal temp. rise from ambient.

TPS92210EVM Efficiency

- Efficiency Measured with 12 LED Series String at ~ 350mA.
- V_{LED} variation caused by different LED forward voltages



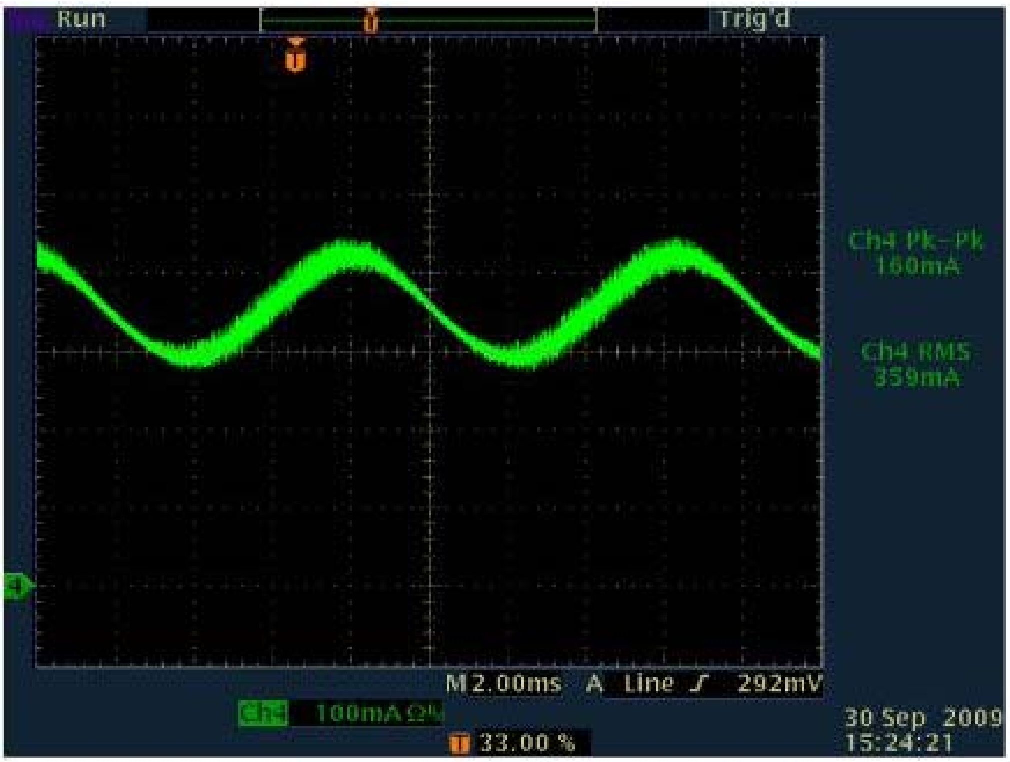
- AC line input voltage varied to test effect on driver efficiency
- Efficiency independent of line voltage



Best In Class AC LED driver efficiency

TPS92210EVM Output Current

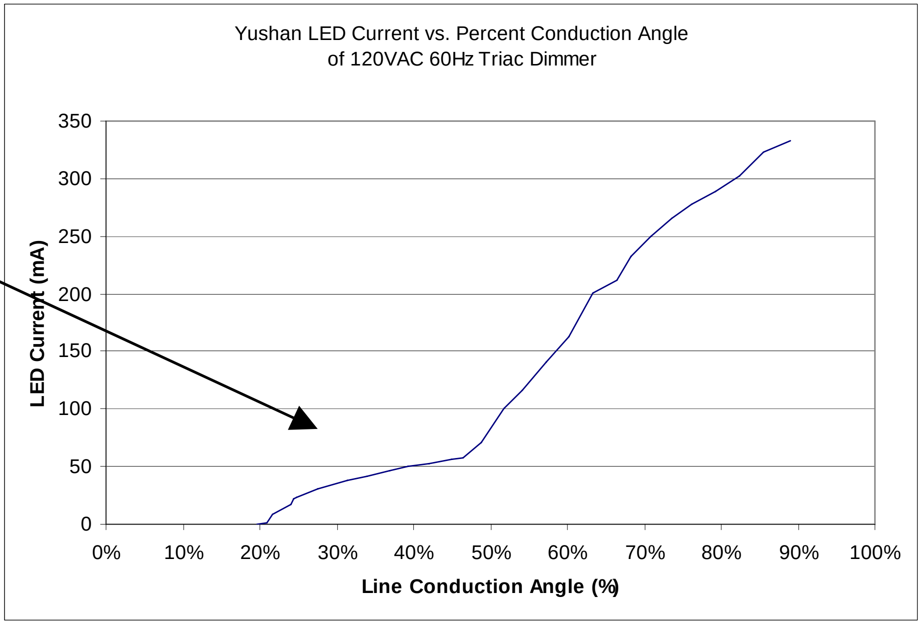
- Output current at 0.1A/Div



LED cur 120VAC 350mAout

TPS92210EVM Dimming Performance

- Operation with existing TRIAC dimmers requires a minimum current to maintain conduction
- Dual slope feature improves low angle dimming
- Flicker is eliminated by driving LED's with DC current.
- Audible noise can occur with PWM dimming. However, this reference design controls DC current to eliminate audible noise



Smooth dimming performance with high range of motion and no step variation in light output

TPS92210EVM Lighting Solution Summary

For low to medium power lighting applications
that require Power Factor Correction

Triac Dimmable for light bulb replacement applications

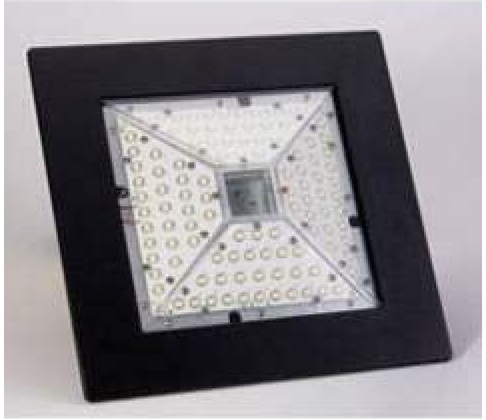
- Single Stage Solution (PFC + LED Current Regulation)
- Small form Factor - 12W to 25W applications
- High efficiency
- Deep TRIAC Dimming Capability

Key Differentiator

- Single power conversion stage meets regulatory power factor requirements and provides tight LED current regulation with deep TRIAC dimming, lower total system cost!

Commercial Lighting LED Driver Solutions

- 15W to 75W
- PFC
- High Efficiency
- Dimming
- Early Payback
- Color Quality
- Safety
- Maintenance
- Eco-friendly



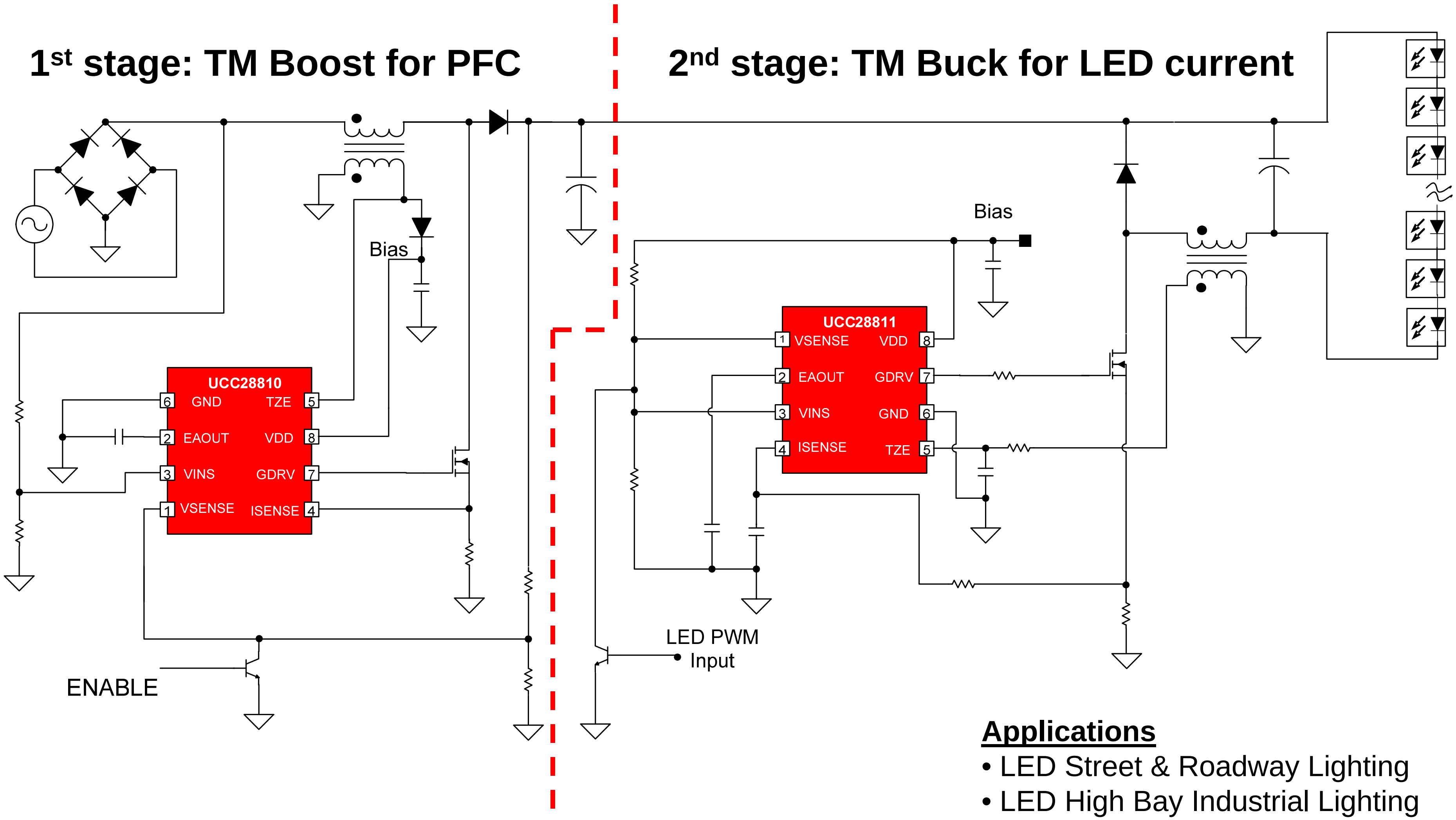
Reference Design & Roadmap - Commercial

Description	Parts	Vin Range VAC		Vout (DC) Range		# of LEDs	Iout Max	Pout (max)	Eff.	PFC	ISO	Dim In	Dim Out	Status (1)
UCC28810 EVM001 25W PFC dimmable LED Driver	UCC28810 TPS3808	85	305	33	38	10	700mA	25W	89%	Y	Y	TRIAC	Linear	EVM
UCC28810 EVM002 100W LED lighting Driver	UCC28810 UCC28811	90	265	55	100	15 to 30	900mA	100W	93%	Y	N	PWM	PWM	EVM
TPS92210 EVM 2- High Efficiency, PFC and TRIAC dimmable LED lighting driver	TPS92210	90 180	130 265	5	7	1 to 3	1.75A	17W	85%	Y	Y	TRIAC	Linear	Board Jan-09
PMP4501 Isolated Flyback LED Driver w/ sec. side current control	UCC28810 TL103W	180	265	10	48.5	3 to 13	700mA	34W	89%	Y	Y	No	N/A	Paper
150W SEPIC LCD backlight	C2000 UCC27323	90	180	0	180	8X (8-70)	20A	100W	91%	N	N	PLC	PWM	EVM Jan 09
UCC28060 Interleaved PFC flyback	UCC28060	85	265		35	10	1.7A	60W	87%	Y	Y	No	N/A	Paper TBD

Description	Parts	Vin Range VDC		Vout (DC) Range		# of LEDs	Iout Max	Pout (max)	Eff.	PFC	ISO	Dim In	Dim Out	Status (1)
TPS40211 EVM352 Boost Current Regulator for LED Drive	TPS40211	8	18	20	35	6 to 10	700mA	25W	94%	-	N	PWM	PWM	EVM
TPS54160 EVM535	TPS54160	18	30		14.8	4	700mA	10W	90%	-	N	PWM or Analog	PWM or Linear	1Q10

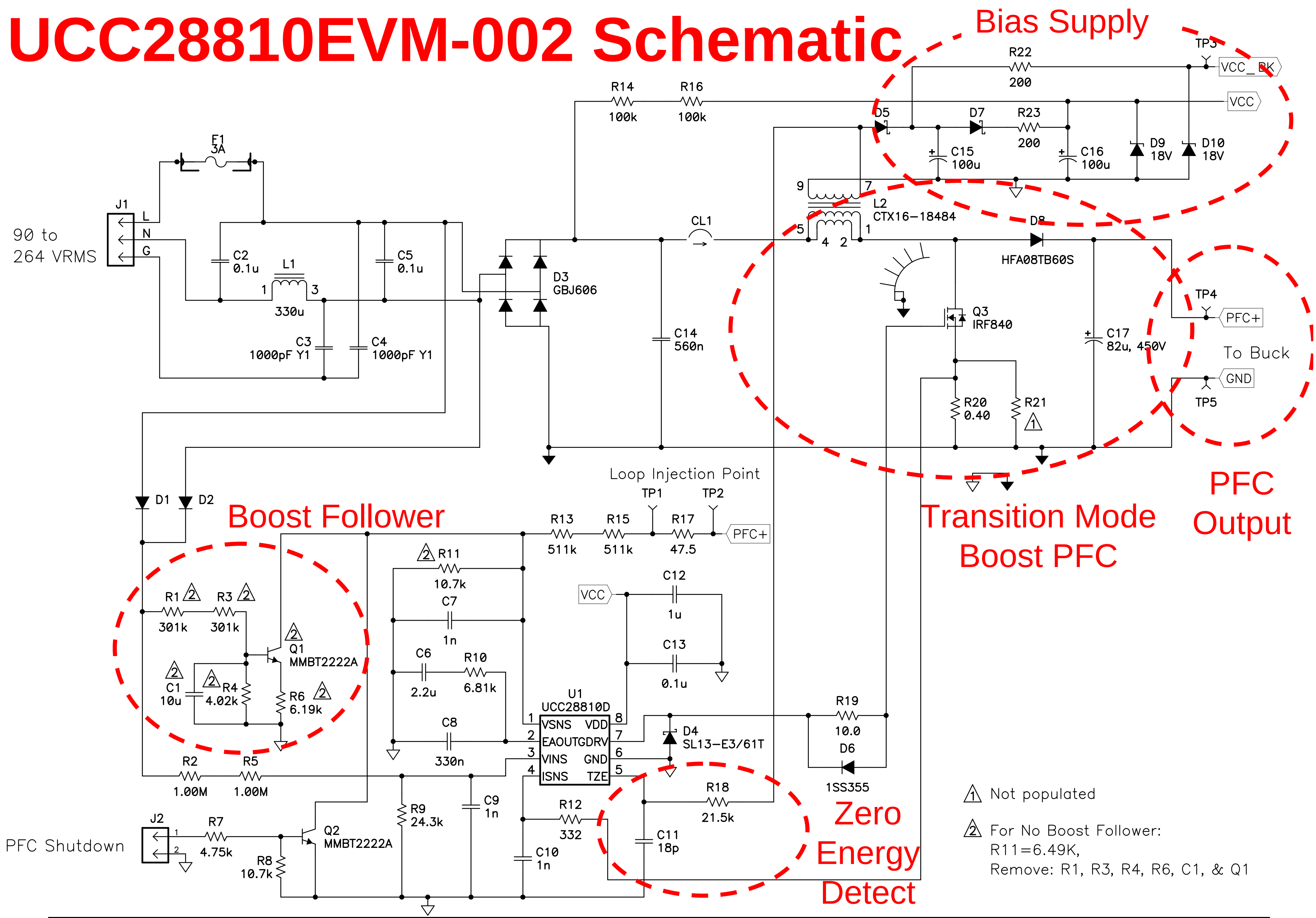
(1) EVM: Web orderable evaluation module **Board:** Test results available from the factory
Paper: Conceptual design with schematic and simulation

UCC28810EVM-002 Block Diagram

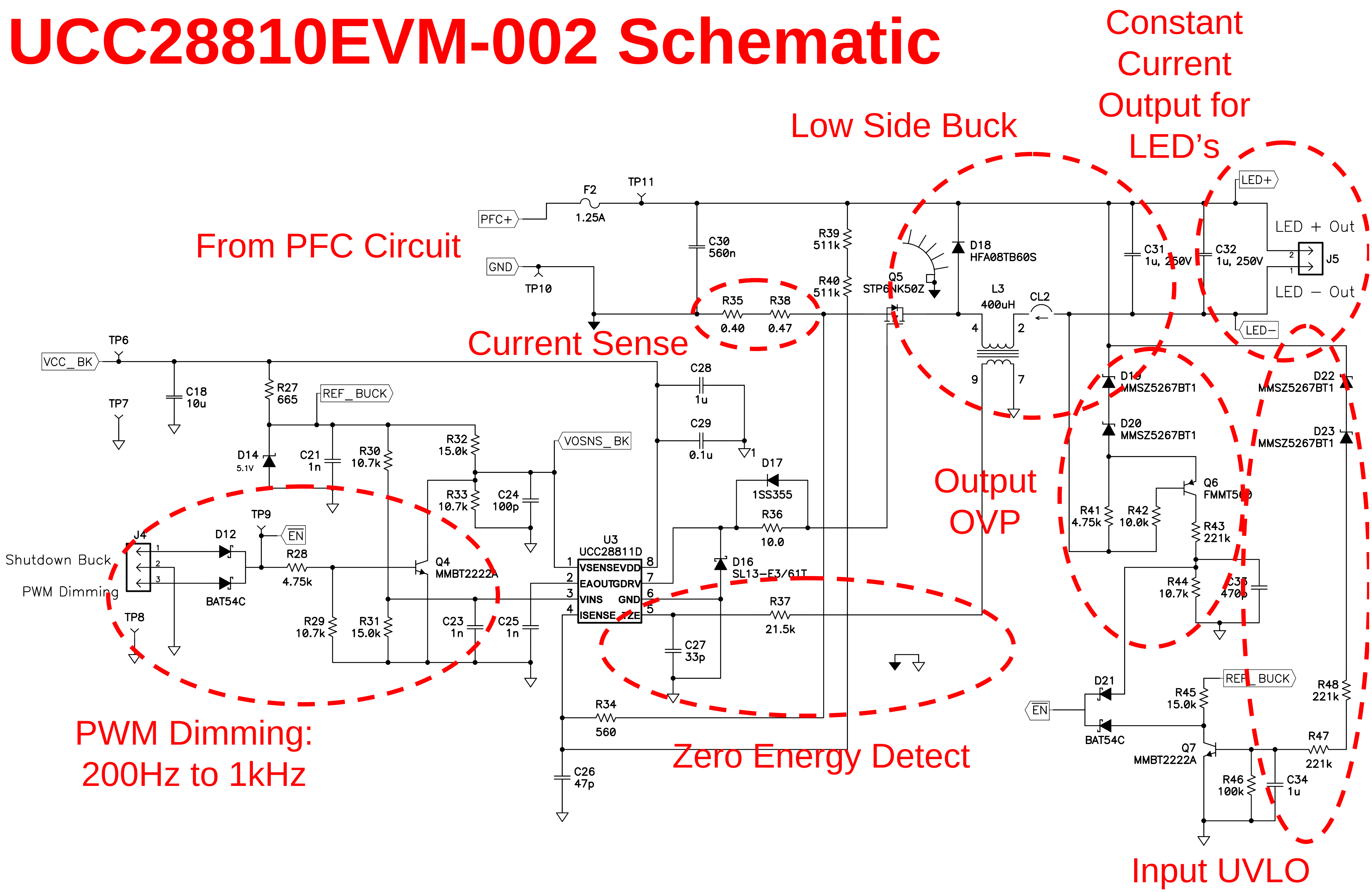


Applications
- LED Street & Roadway Lighting
- LED High Bay Industrial Lighting
- DTV LED backlighting

UCC28810EVM-002 Schematic



UCC28810EVM-002 Schematic



UCC28810EVM-002 Specification

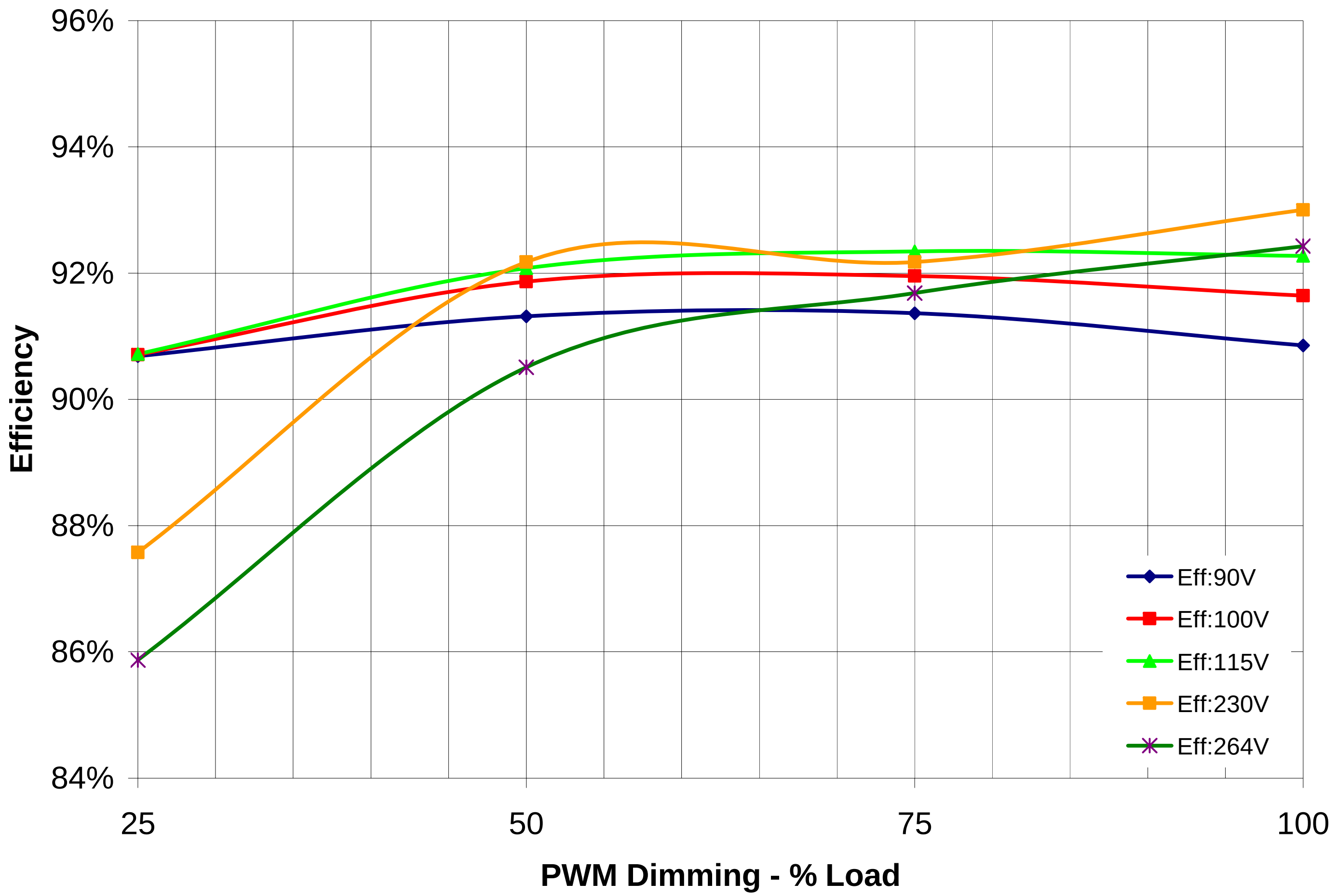
Specification	Value	Unit
LED configuration	15 to 30	
Input Voltage	90 to 264	VAC
Efficiency	93	%
Power	100	W
Power Factor	0.97	
Output Voltage	109	VDC
Output Current	900	mA
LF Output Ripple	0	mVpp
Isolation	None	

Specification	Value	Unit
Dimming Input	PWM	
Dimming Level	10 to 100	%
Current Sensing	Res	
Temp. Range	-20 to 40	ºC
Lifetime*	40,000	Hrs
EMC Regulation	No	
Safety Regulation	No	
Driver Dimensions	265 x 51	mm

Note: *Lifetime assumes 35ºC internal temp. rise from ambient.

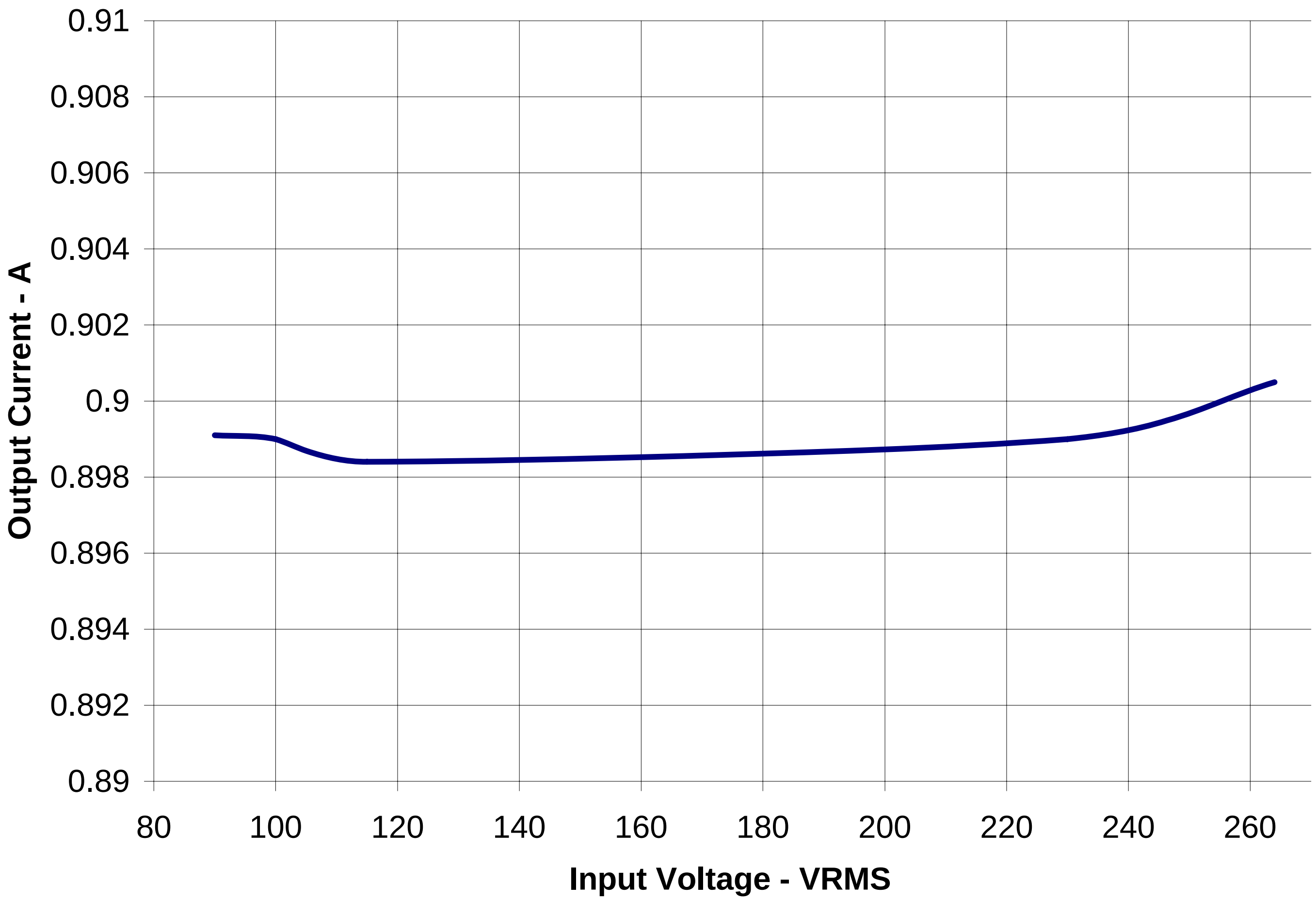
UCC28810EVM-002 Efficiency

- Using 30 LED's at 0.9A



UCC28810EVM-002 Regulation

- Using 30 LED’s at 0.9A



UCC28810EVM-002 100Watt LED Lighting Driver

- Universal input non isolated design
- Regulated LED current
- PWM Dimming, 200hz to 1kHz
- High Efficiency
  - Maintained during dimming
- Active power factor correction

Outdoor Lighting LED Driver Solutions

- 35W to 250W
- PFC
- High Efficiency
- Early Payback
- High Brightness
- Safety
- Maintenance
- Eco-friendly

Reference Design & Roadmap - Outdoor

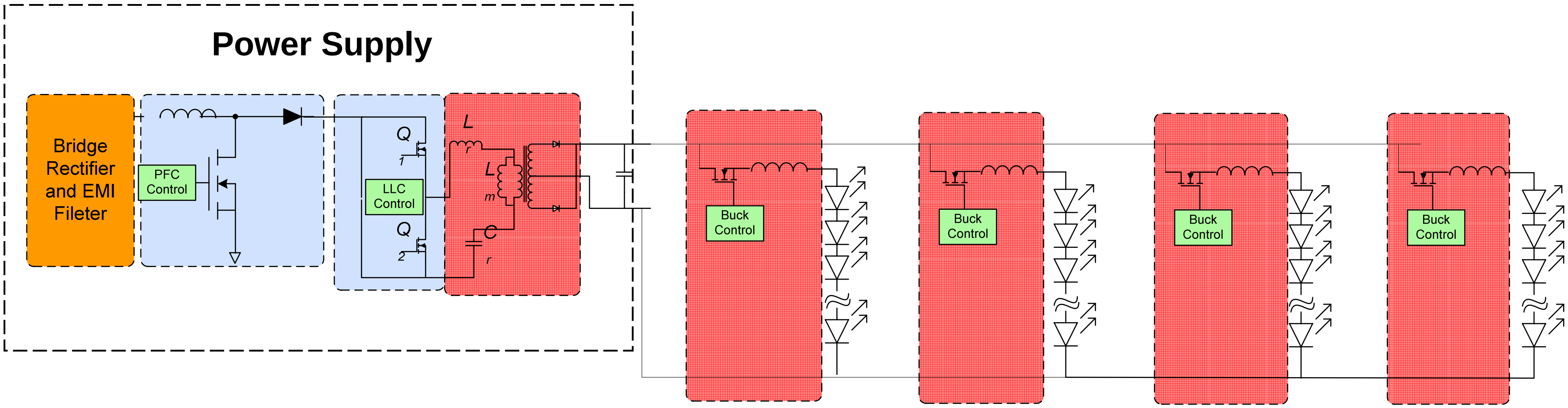
Description	Parts	Vin Range VAC		Vout (DC) Range		# of LEDs	Iout Max	Pout (max)	Eff.	PFC	ISO	Dim In	Dim Out	Status (1)
UCC28810 EVM002 100W LED lighting Driver	UCC28810 UCC28811	90	265	55	100	15-30	900mA	100W	93%	Y	N	PWM	PWM	EVM
UCC28810 EVM003 100W SIMPLEDrive Multi-string LED driver	UCC28810 UCC28811 UCC25600	90	265	22	60	4X (7-15)	500mA	100W	91%	Y	Y	PWM	PWM	EVM
PMP3976 Single Stage PFC SEPIC converter LED Driver	UCC28810	150	265	250	300	70 - 80	350mA	100W	91%	Y	N	N	N/A	Board
150W Piccolo street light 8 Strings with communications	C2000 UCC27323	90	265	0	180	8X (8-70)	20A	100W	91%	Y	Y	PLC	PWM	Demo 1Q10
150W Multi-string transformer	C2000	90	265	22	60	4X (7-15)	500mA	100W	91%	Y	Y	PLC	PWM	Demo 1Q10
UCC28060 Interleaved PFC flyback	UCC28060	85	265		35	10	1.7A	60W	87%	Y	Y	No	N/A	Paper TBD
PMP3560 Isolated SEPIC for Street Lighting	TPS92010	100	270	60	90	15 - 24	400mA	24W	92%	Y	Y	N	N/A	Board

Description	Parts	Vin Range VDC		Vout (DC) Range		# of LEDs	Iout Max	Pout (max)	Eff.	PFC	ISO	Dim In	Dim Out	Status (1)
PMP3543 Solar Street Light	TPS40211	10	28	30	59	10-15	700mA	38W	92%	N	N	N	N/A	Board

(1) EVM: Web orderable evaluation module **Board:** Test results available from the factory
Paper: Conceptual design with schematic and simulation

High Light Output Drivers
Traditional Solution – Power Supply with PFC and Low Voltage DC output
LED Strings Driven with Multiple Buck Regulators

Traditional Implementation:



PFC Stage	- Required in any implementation
DC-DC Stage	- Provides constant voltage and isolation stage
Multiple Bucks	- Provides constant current to each LED string

Benefit:

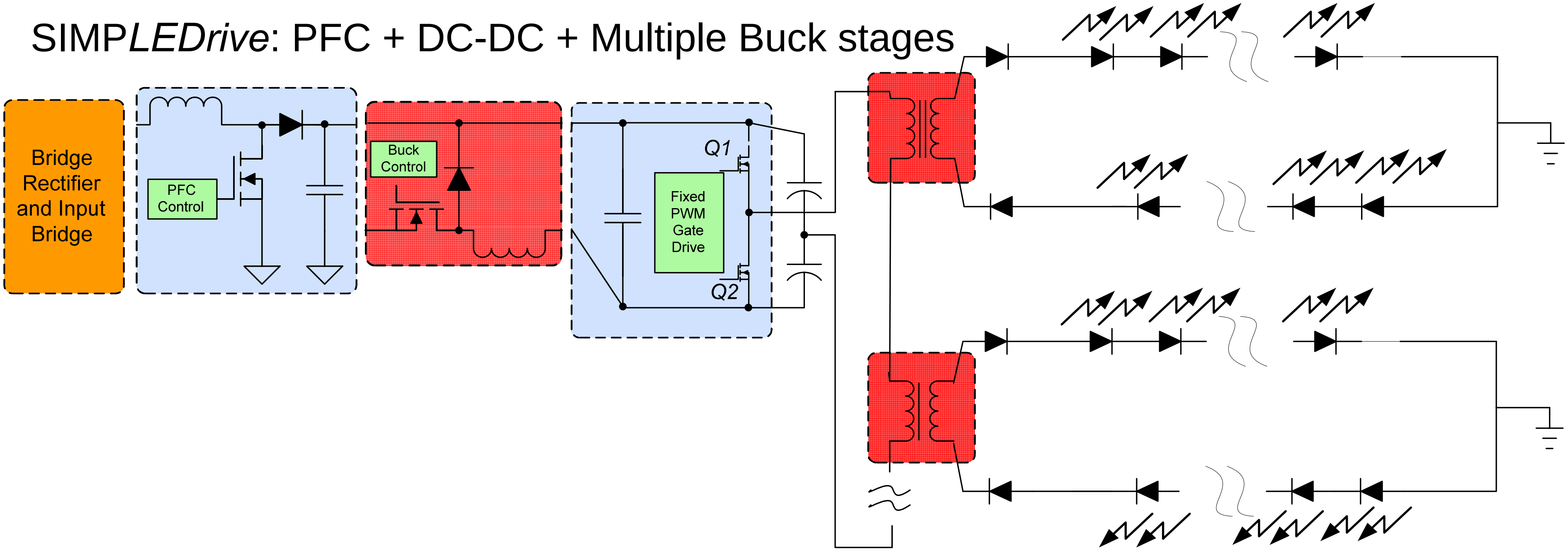
- Allows for individual string dimming

Drawbacks:

- Controller and MOSFET and Inductor required for each LED string
- Decreased reliability due to many extra converters (N-1 compared to SIMP*LEDrive)*

High Light Output Drivers – PFC + Buck + Multiple Strings

SIMP*LEDrive*: PFC + DC-DC + Multiple Buck stages



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

Benefit:

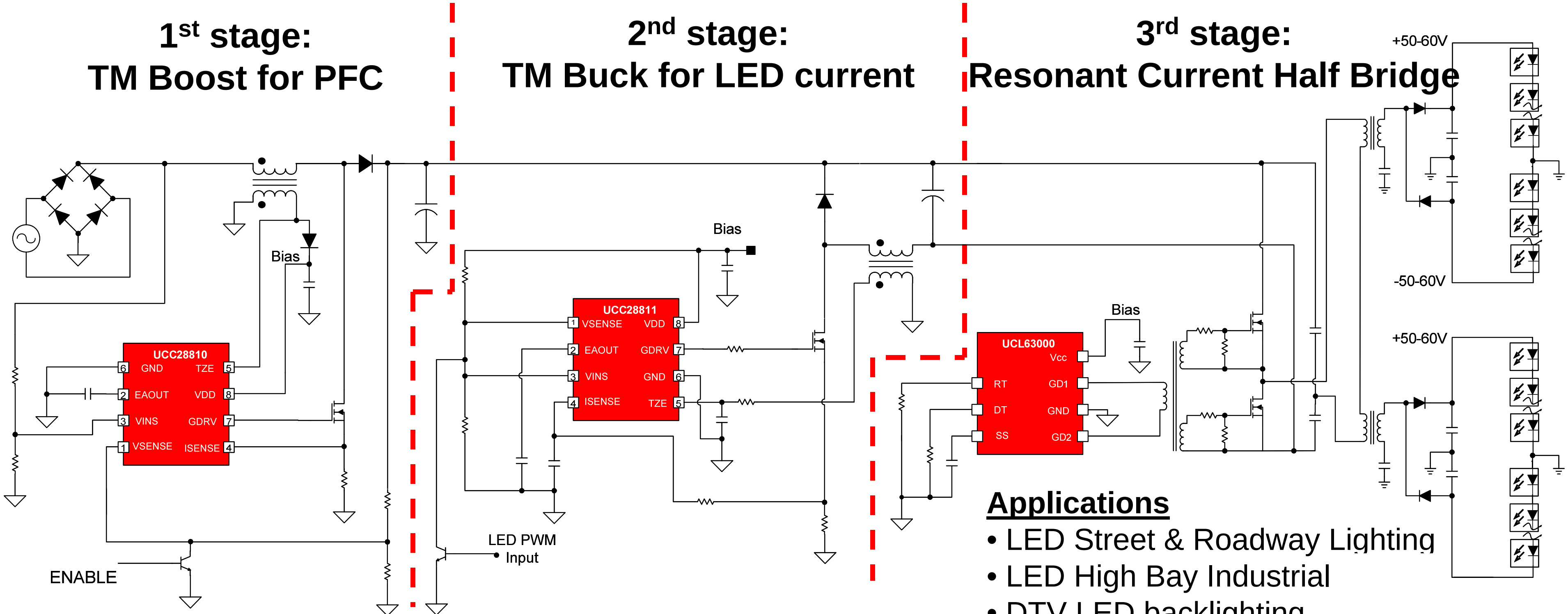
- One control section for all string currents,
- Lower part count, higher reliability and lower cost

Drawback:

- All strings will be dimmed simultaneously (if individual dimming is required)

UCC28810 EVM003 - SIMP*LED*rive

Series Input, Multiple Parallel Equivalent LED Drive (SIMP*LED*rive)



Applications

- LED Street & Roadway Lighting
- LED High Bay Industrial
- DTV LED backlighting

http://focus.ti.com/docs/toolsw/folders/print/ucc28810evm-003.html

SIMP*LED*rive features

- Single, primary referenced current control & dimming (AM or PWM) for all LEDs.
- Effectively a large number of LEDs connected in series
- Voltage on LEDs is safe (low) and isolated from the AC line
- More cost effective than constant voltage + 1 Buck per string architecture
- Readily scalable to higher power levels
- Excellent LED current matching between strings – 1%
- High Efficiency (~90%), Power Density and Power Factor
- Simple and Robust - Open and Short LED string protected
- Design Tool to calculate key critical parameters for change in # of LEDs, # of String, LED current or Vin
- Patent Pending architecture

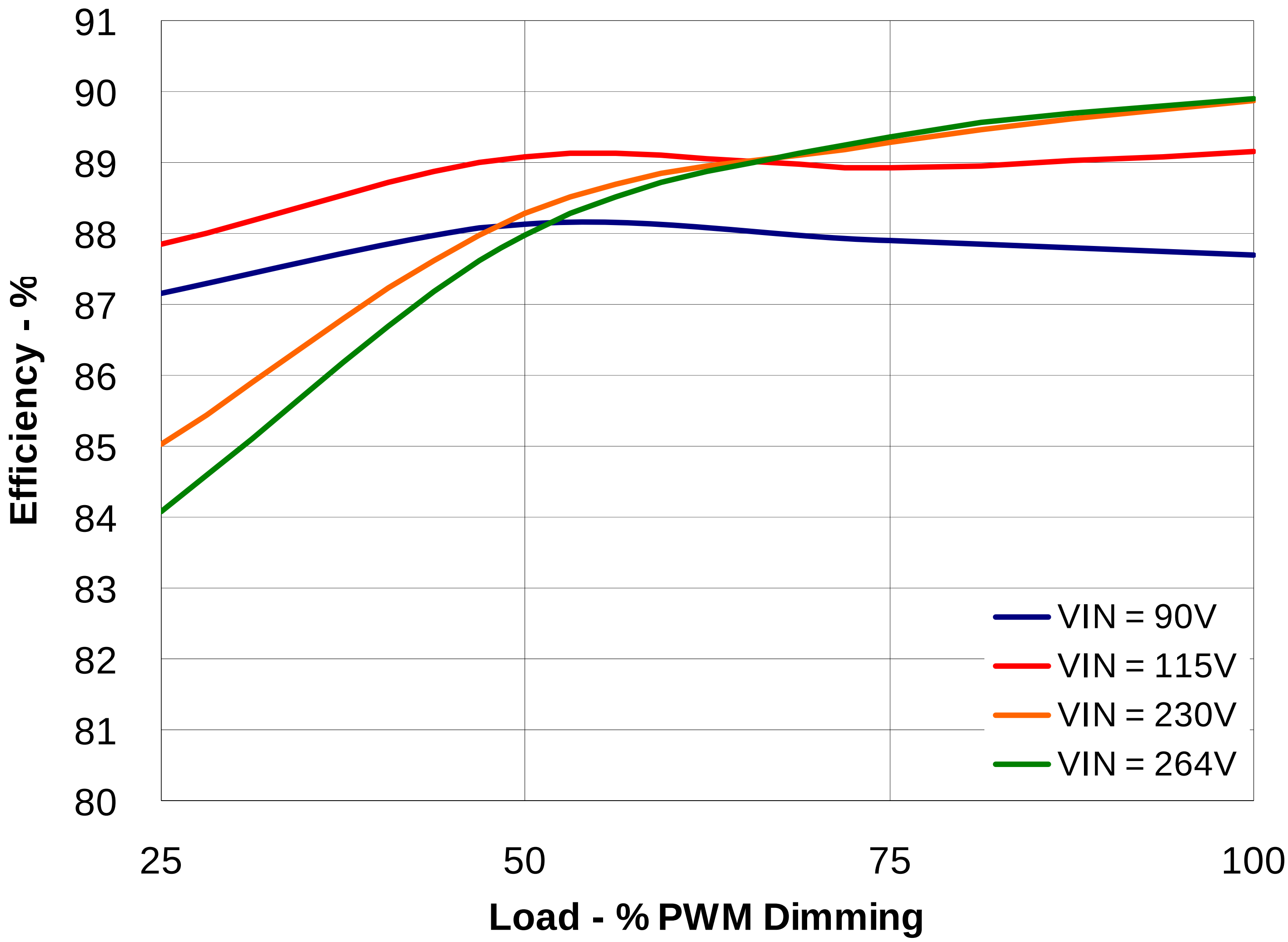
UCC28810EVM-003 Specification

Specification	Value	Unit
LED configuration	4x 15	
Input Voltage	90 to 264	VAC
Efficiency	90	%
Power	100	W
Power Factor	0.97	
Output Voltage	54.5	VDC
Output Current	500	mA
LF Output Ripple	0	mVpp
Isolation	Yes	

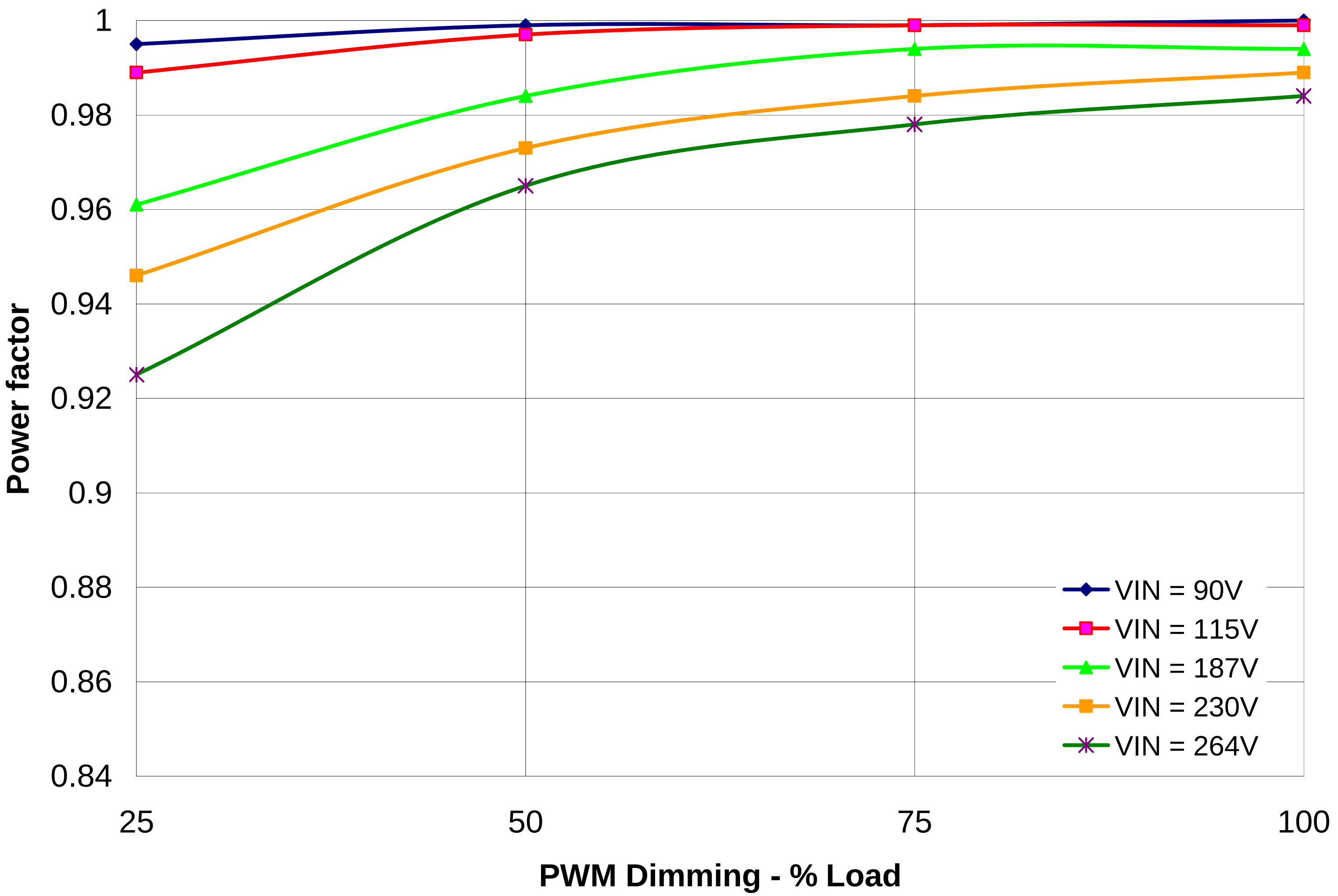
Specification	Value	Unit
Dimming Input	PWM	
Dimming Level	10 to 100	%
Current Sensing	Res	
Temp. Range	-20 to 40	ºC
Lifetime*	40,000	Hrs
EMC Regulation	No	
Safety Regulation	Yes**	
Driver Dimensions	370 x 51	mm

Note: *Lifetime assumes 35ºC internal temp. rise from ambient.
** Designed with reinforced isolation to UL60950 but not certified

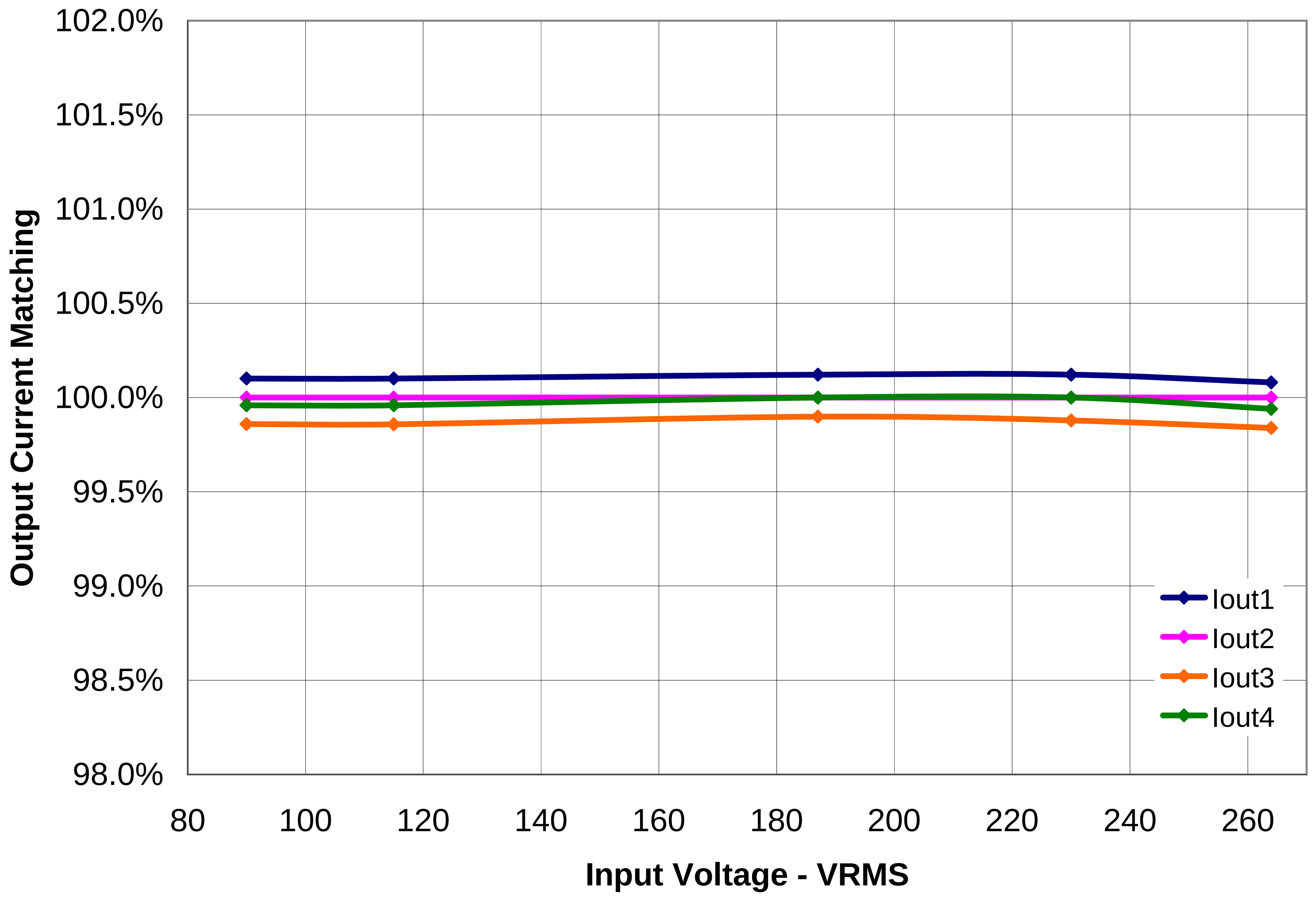
UCC28810EVM-003 using SIMP*LED*rive Efficiency



UCC28810EVM-003 using SIMP*LED*rive Power Factor

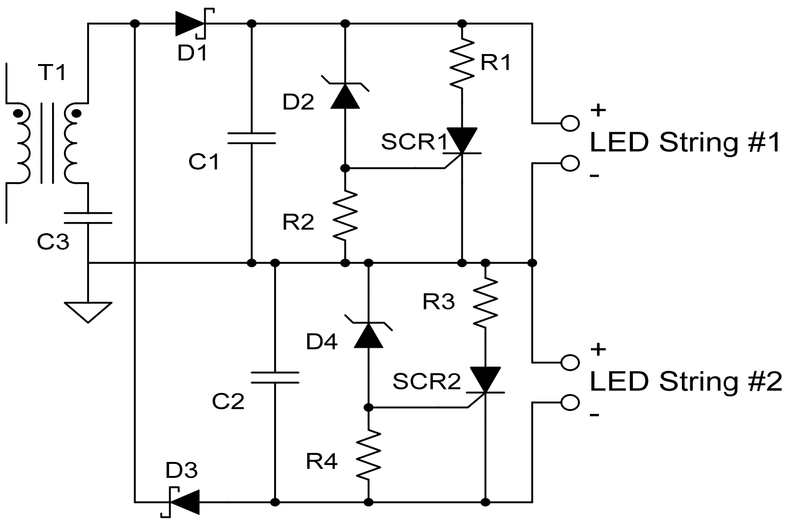


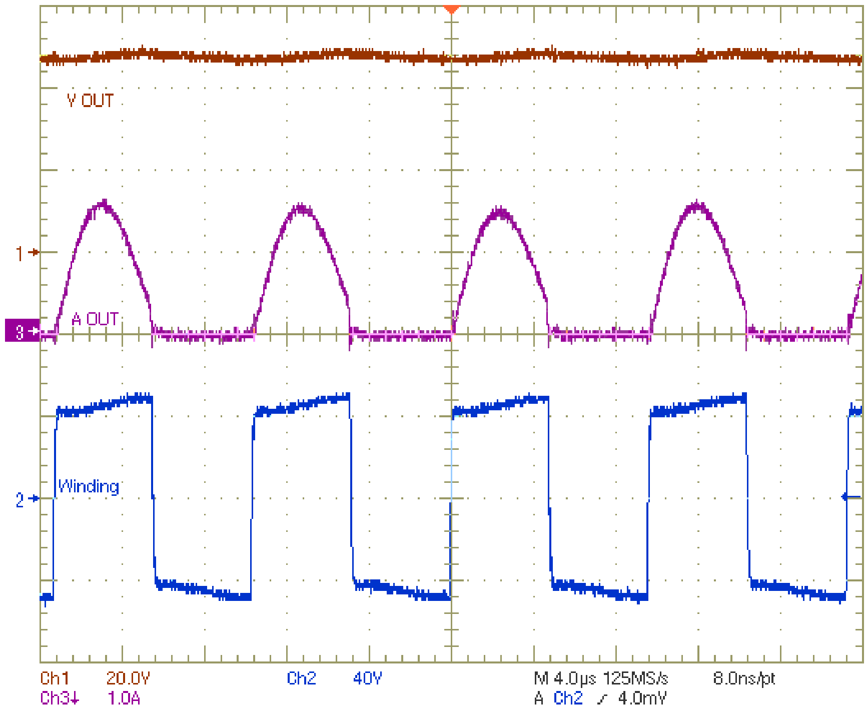
UCC28810EVM-003 using SIMP*LED*rive String Current Matching



UCC28810EVM-003 Open String Protection

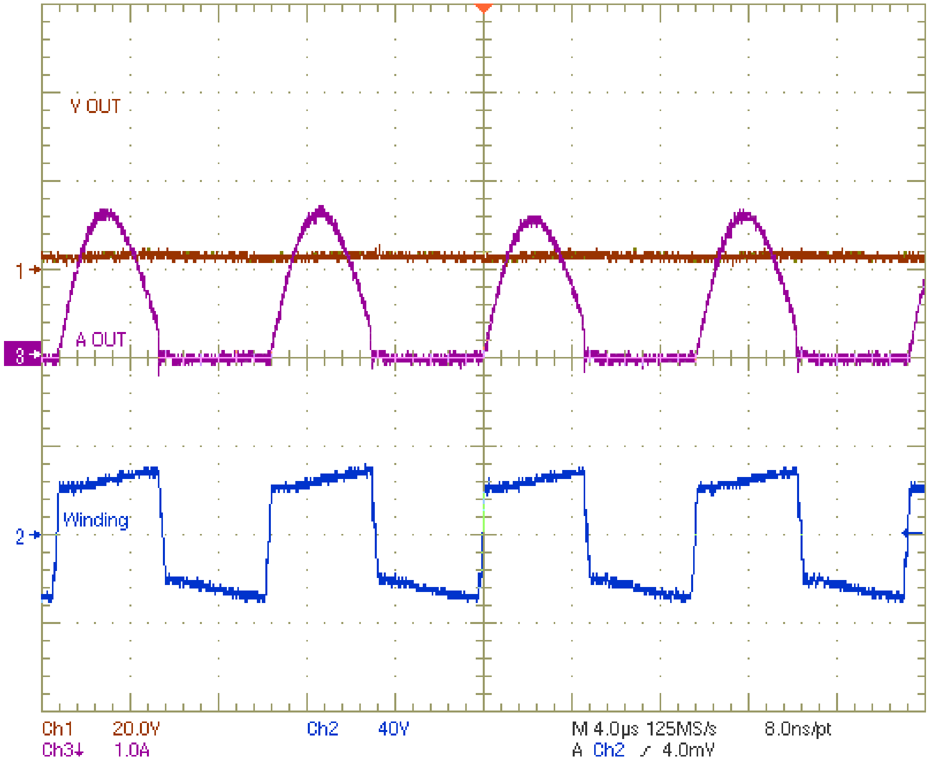
- If one string fails the other remain on.
- Each output incorporates a zener and SCR crowbar circuit
  - D2, SCR1, R1 and R2
- When string fails, zener voltage is exceeded and SCR latches on
- Transformer continues to deliver current to SCR and LED String #2





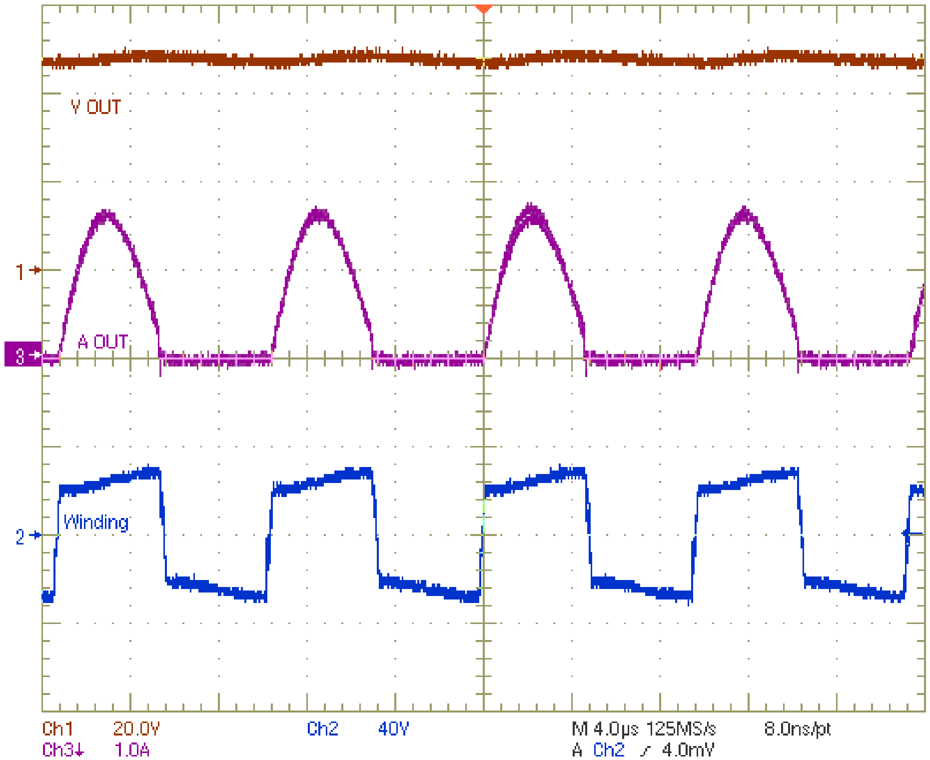
Waveforms During Normal Operation

UCC28810EVM-003 Open String Protection



LED String #1 Waveforms when Open Circuit

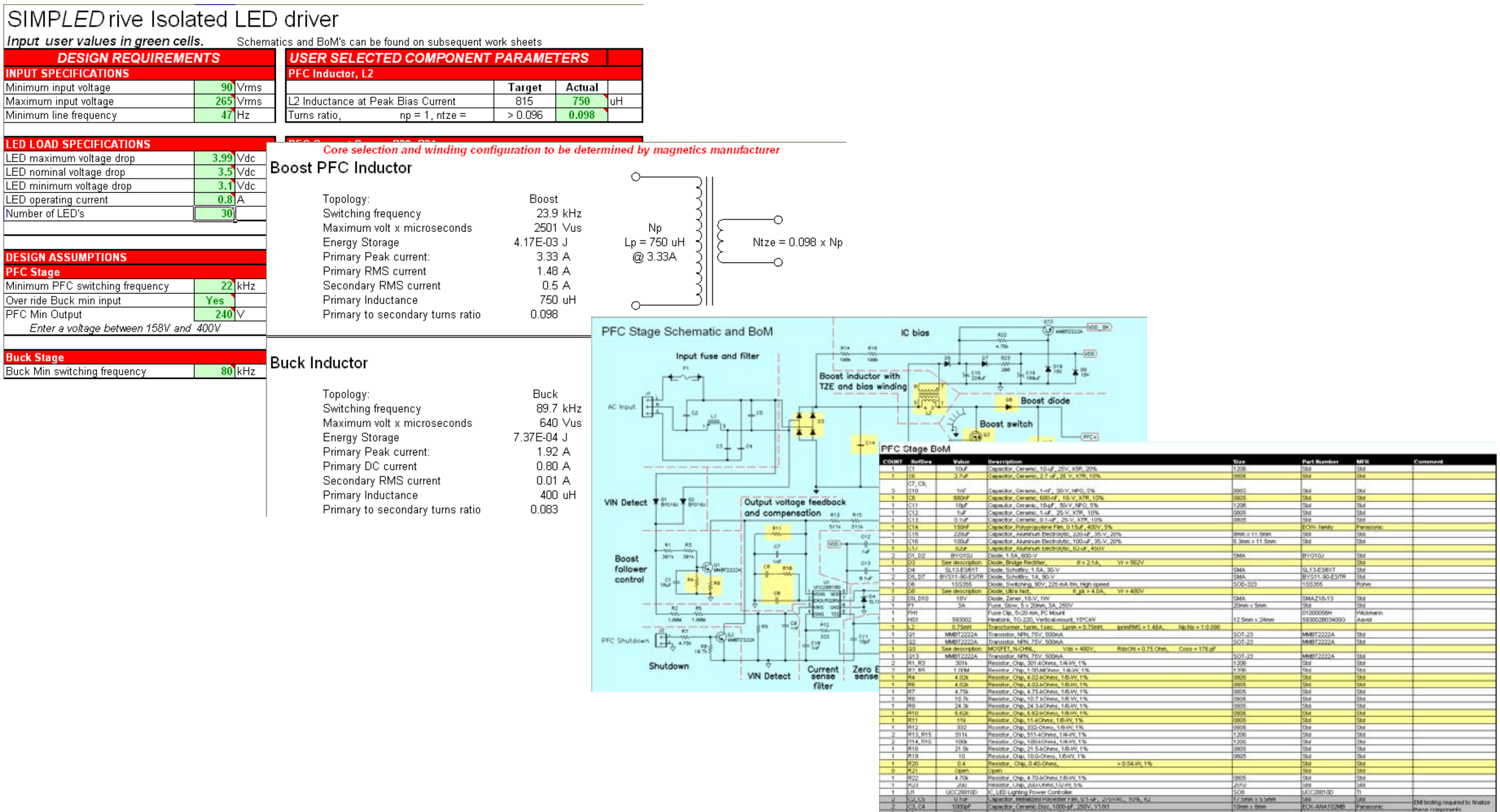
- VOUT and winding voltage clamped
- AOUT, transformer current continues to flow



LED String #2 waveforms when LED String #1 is Open Circuit

- VOUT OK, winding voltage clamped
- AOUT, transformer current continues to flow

UCC28810EVM-002 / 003 Design Tool
Sneak peek



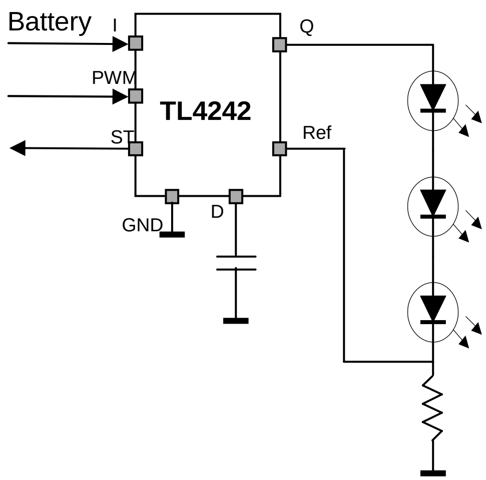
Texas Instruments

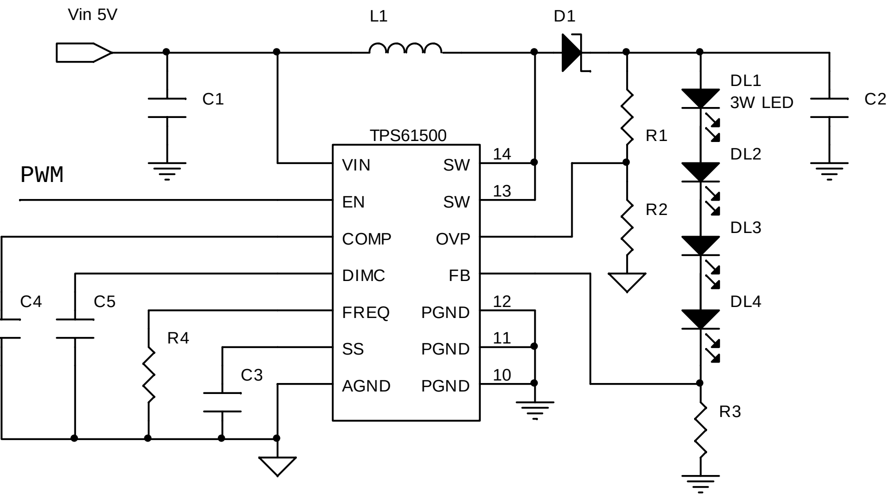
AC/DC solutions

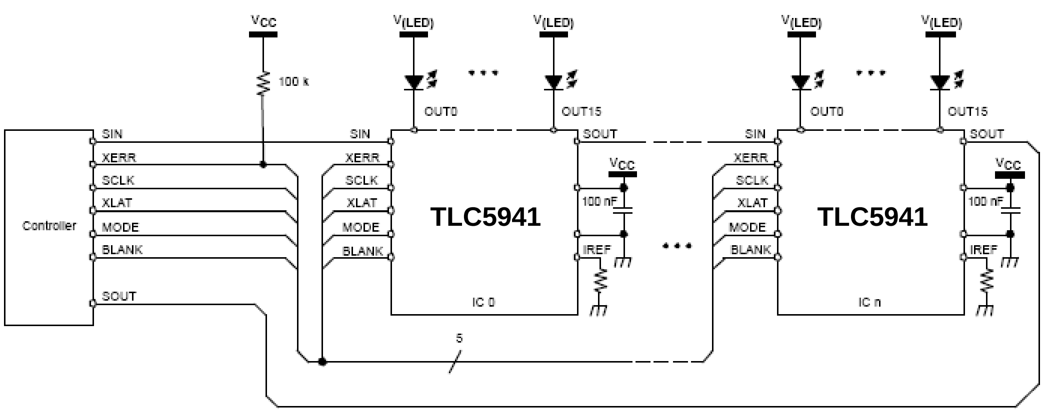
DC/DC solutions

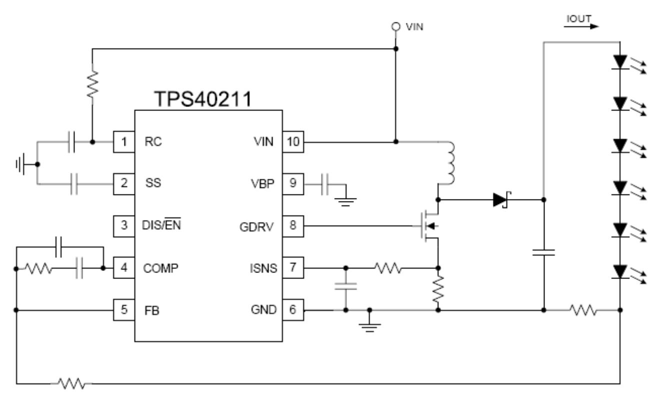
Adding intelligence to LED systems

Examples of LED driver types









Texas Instruments

BUCK - TPS54060/TPS54160/TPS54260

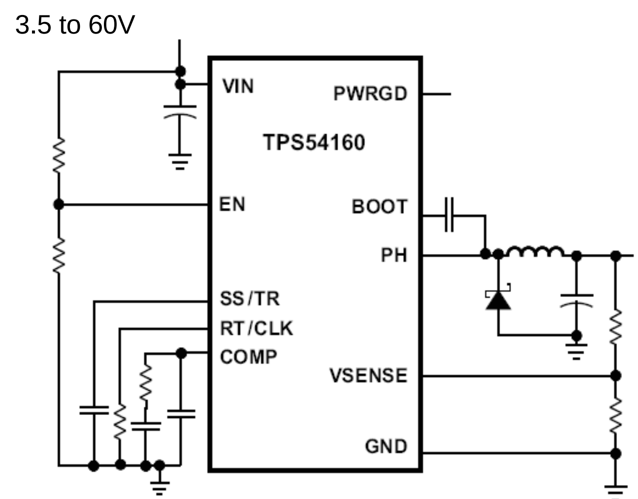
3.5 to 60V Input 0,5A/1.5A/2,5A DC/DC Converter - SWIFT™

Features

- **Integrated 200 mΩ High Side MOSFET**
  - **Simplifies design**
- **Pulse Skipping Eco-Mode™**
  - **Improved efficiency at low load**
- **Up to 2.5 MHz Switching Frequency**
  - **Small external inductors**
- **Adjustable Slow Start Time**
  - **Reduced inrush current**
- **100% duty cycle as long as the BOOT to PH pin voltage is greater than 2.1V**
  - **More LEDs per driver**
- **Power good**
  - **Versatile diagnostic pin**

Drawback ?

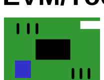
- **Vsense to be reduced:**
  - **Not necessarily a problem**
  - **Easily and cheaply fixed (Cf 2 solutions below)**



Applications

- RGBW application
- 12V, 24V and 48V DC driven Lighting application

EVM/Tool



•TPS54160EVM-230
•Switcher-Pro Tool

TPS40200 – Wide Input, Low Pin Count Buck Controller

Features

- 4.5V to 52V operation
- Voltage Mode Control with Feed Forward Compensation
- 700mV Voltage Reference - 1% accuracy
- Internal Under-Voltage Lockout
- Programmable Frequency (35kHz-500 kHz)
- Programmable Overcurrent Protection
- Frequency Synchronization
- Closed Loop Soft Start
- Integrated Driver
- Package - 8 pin SOIC

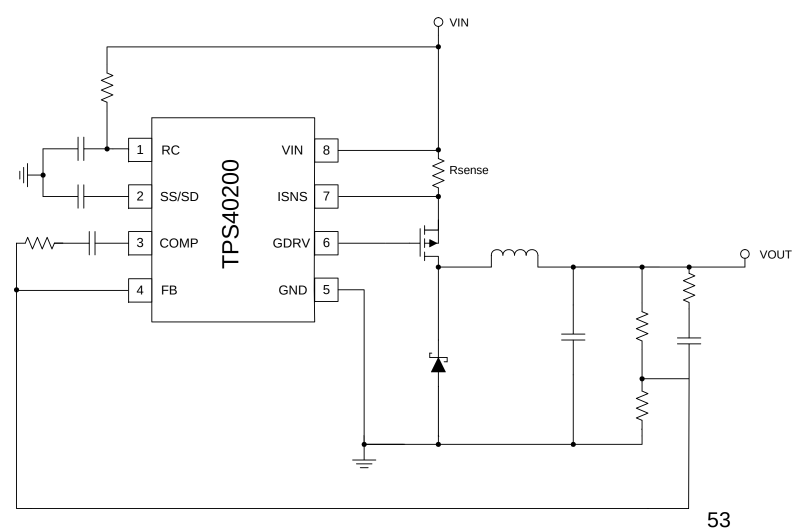
Benefits

- Wide input range for use in many applications
- Voltage feed forward – great line regulation, fast transient response
- Programmable features allows flexible design; frequency, overcurrent protection, under voltage lockout
- Softstart provides smooth, well controlled power up
- Simple configuration- minimal external components

Applications

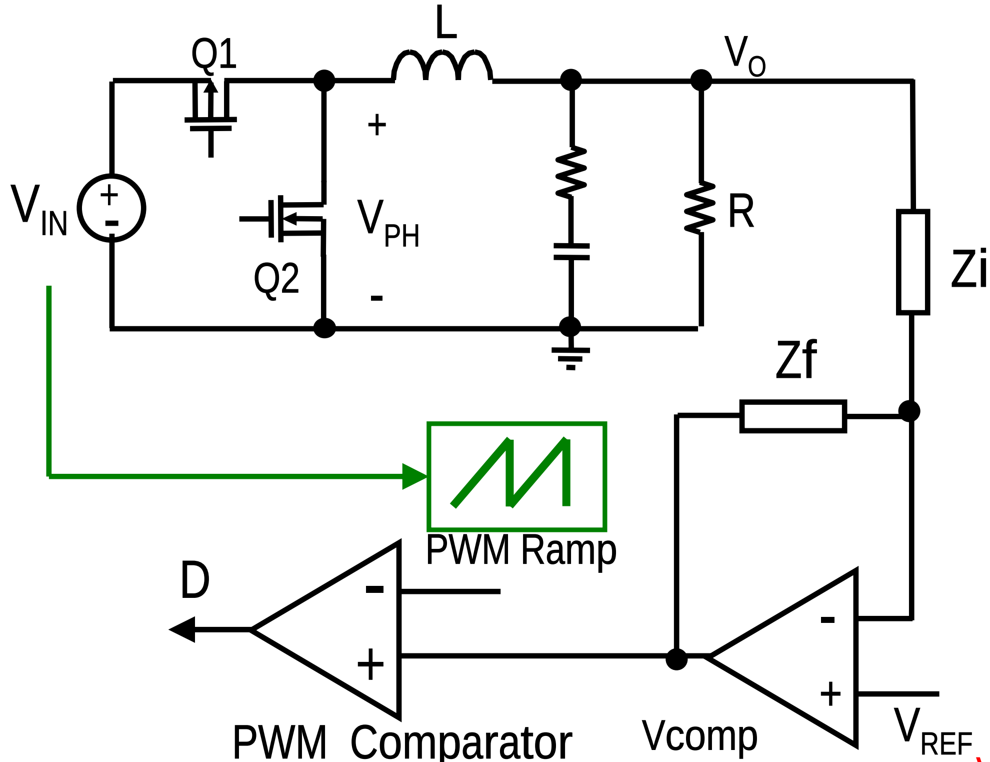
- Industrial control
- Distributed Power Systems
- DSL/Cable modem
- Scanners

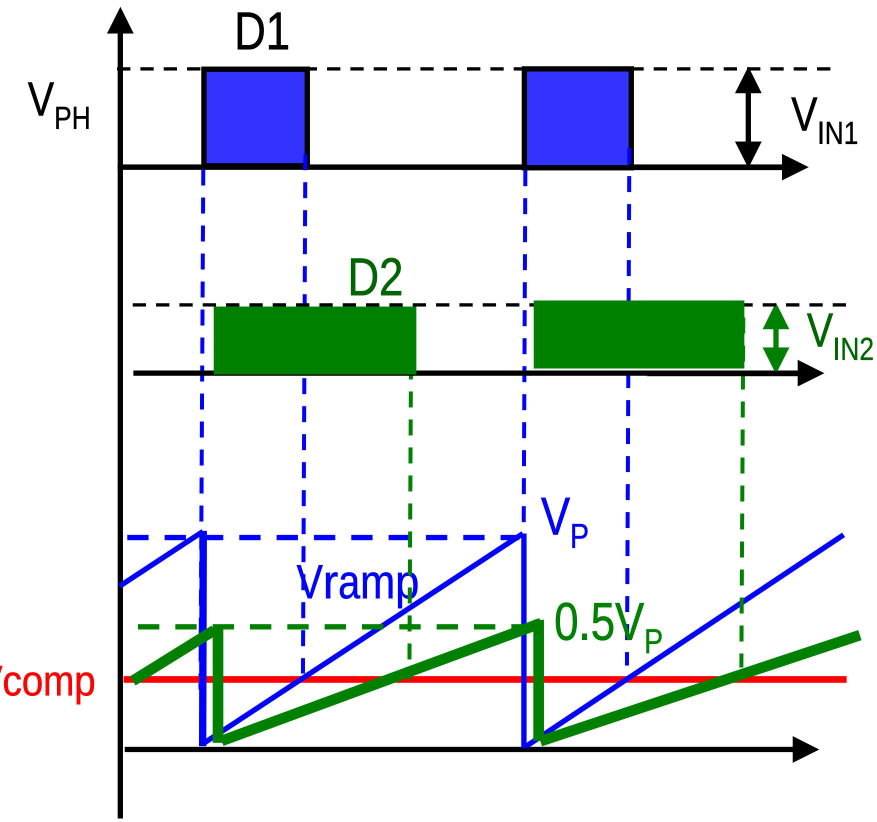
Only 11 R's/C's required!



How Win with TPS40200?

Input Voltage Feed-Forward Function





- PWM Ramp amplitude is proportional to V_{IN}
- Fast Line Step Transient Response
  Does Not rely on the regulation loop

TPS40211

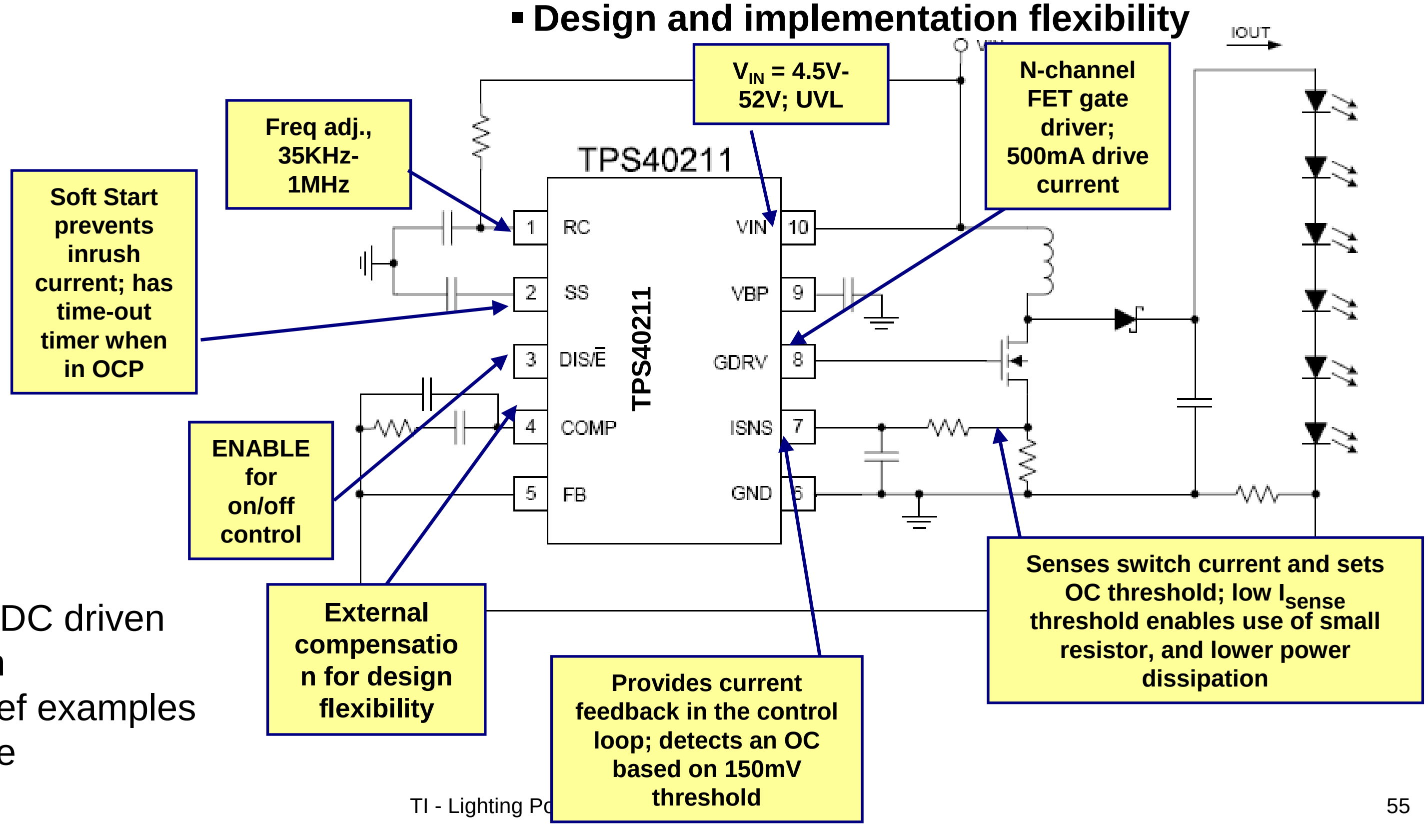
4.5 to 52V Input Current Mode Boost Controllers for LEDs

Features

- Soft Start
- Enable function
- Externally compensated
- Overcurrent detection
- Supports Boost, Flyback, and SEPIC topologies
- 260mV ISENSE

Benefits

- Prevents inrush current
- On/off control
- Design flexibility
- Enables use of small Isense resistors with lower power dissipation
- Design and implementation flexibility



Applications

- RGBW application
- 12V, 24V and 48V DC driven Lighting application
- 13 boost / SEPIC ref examples in Design DataBase

TPS61500

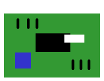
High Power White LED Driver with 3A Switch

Features

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

Applications

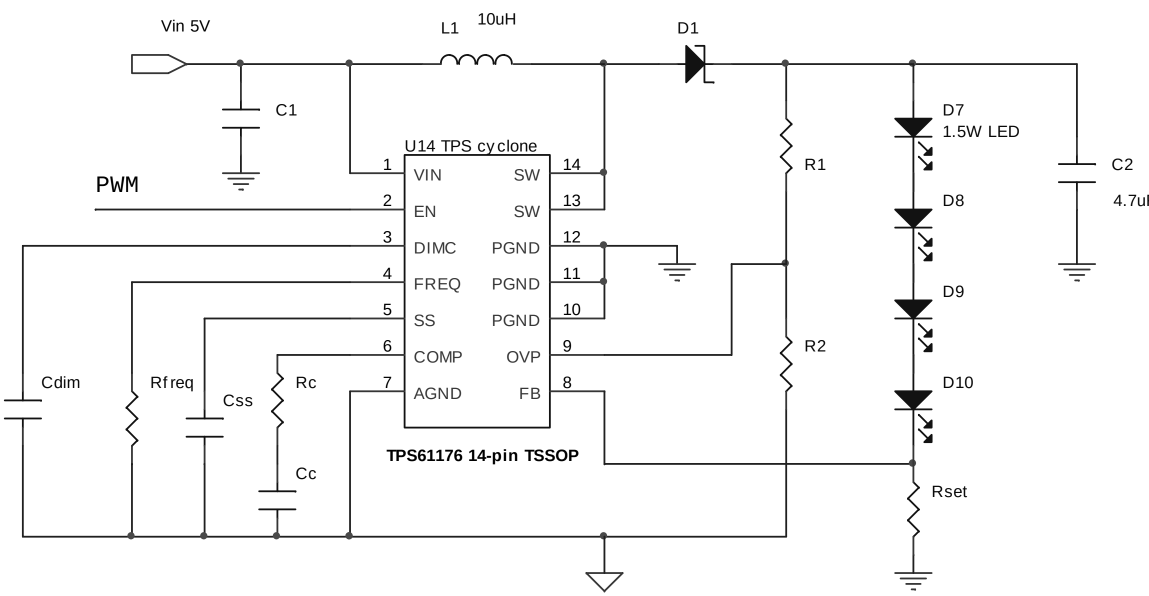
- High brightness LED lighting
- High power LED supply



EVM: TPS61500EVM-

Benefits

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

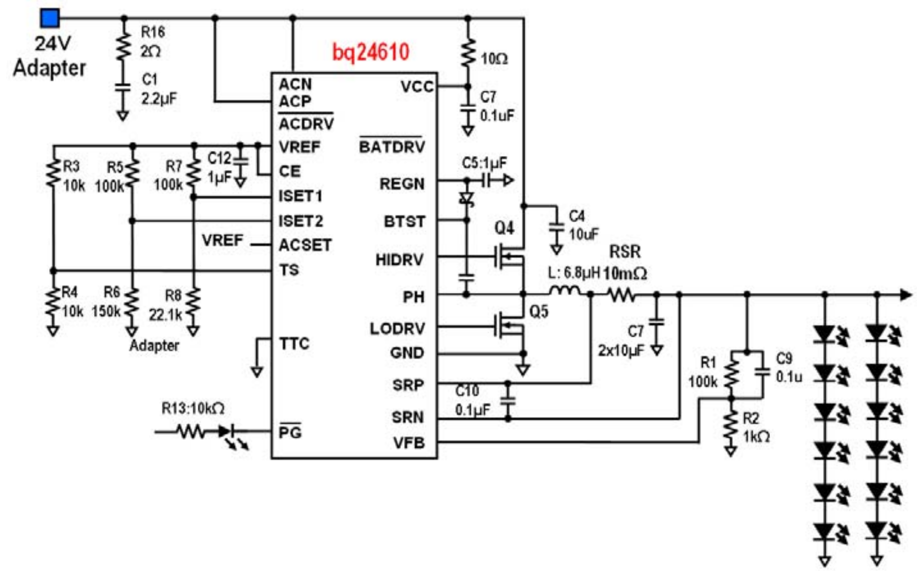


Bq24610

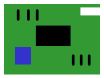
10A Synch Switching Step-down LED Driver

Features

- 12V and 24V input rail
  - (5-28V adapter voltage)
- Synchronous switching Step down
  - 600kHz
- PWM or Analog dimming
- Support up to 7 Series LEDs
- Support up to 10A LED
- 3% high accuracy for LED current
- 4x4 QFN-24

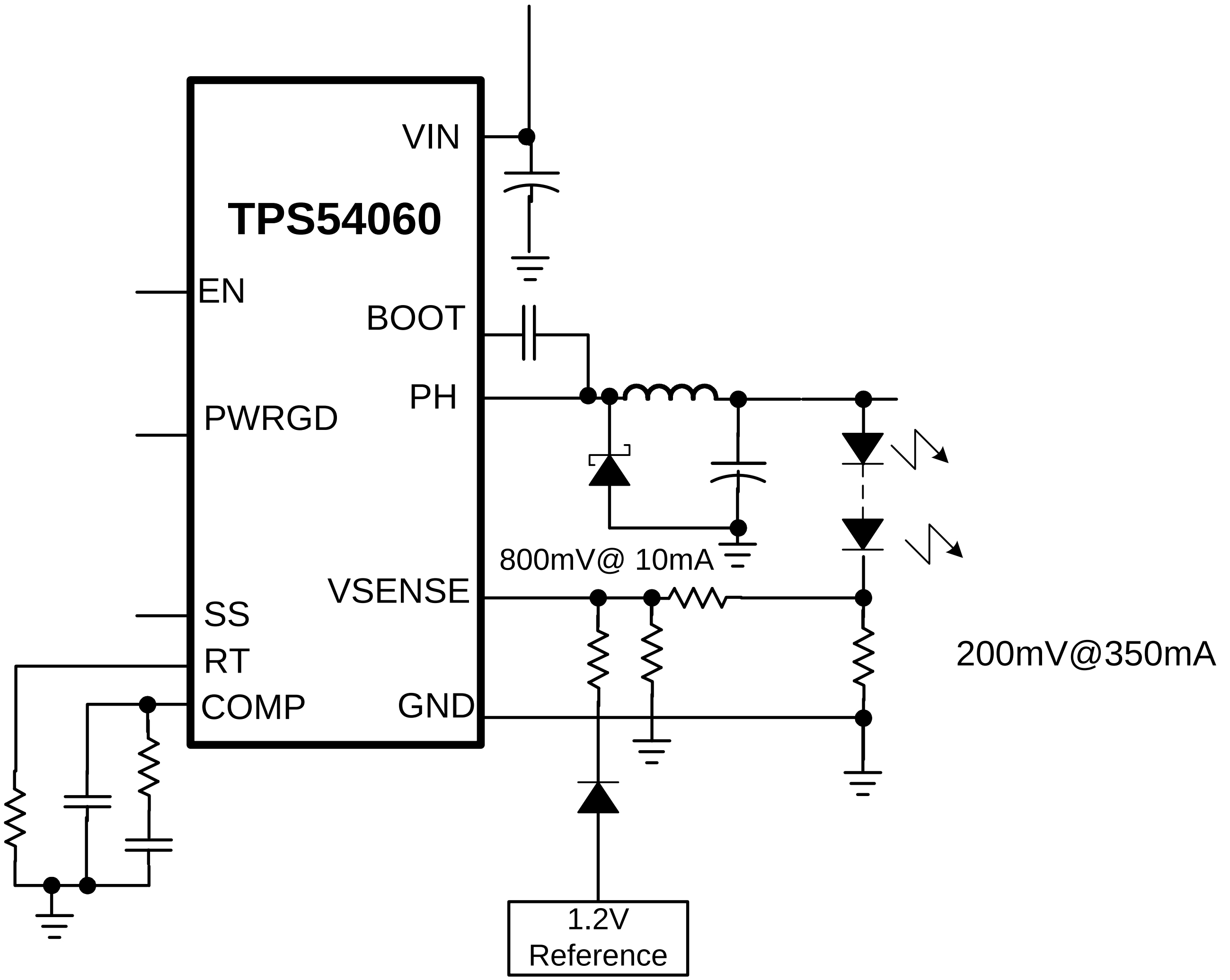


EVM/Tool



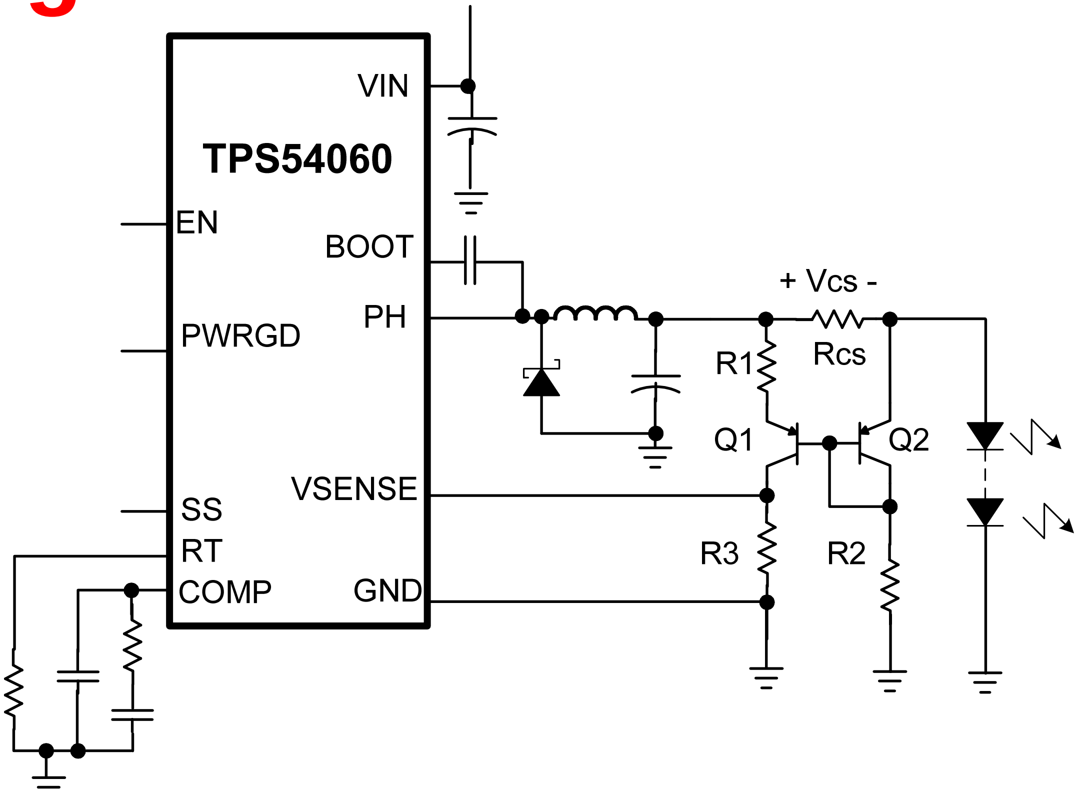
EVM Available – please contact local sales

Voltage reference technique



See App Note SLEA004 on how to offset the internal reference

High Side Current Sense



- $0,10 Circuitry level Shift and Amplify the Vcs signal
- Vcs = VR1
- IR1=IR3
- If R3=4xR1 then VR3=4xVcs

Example:

200mV for Vcs, will be 800mV across R3 (the internal reference for TPS54060).

R2 should be selected to match the currents in Q1 and Q2 to minimize Vbe error.

TL4242

1 Channel, 500mA with Open LED Detection

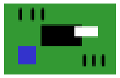
Features

- **Adjustable Current up to 500mA (+/-5%)**
- **Wide Input Voltage Range – Up to 42V**
- **LED Open Detection**
- **Channel Over-Temperature Protection**
- **Short Circuit Proof**
- **Reverse Polarity Proof**
- **Wide Operating Range: -40ºC to +150ºC**
- **Current Programmable by Sense Resistor**
- **QFN – 8 pin Power Package**

Applications

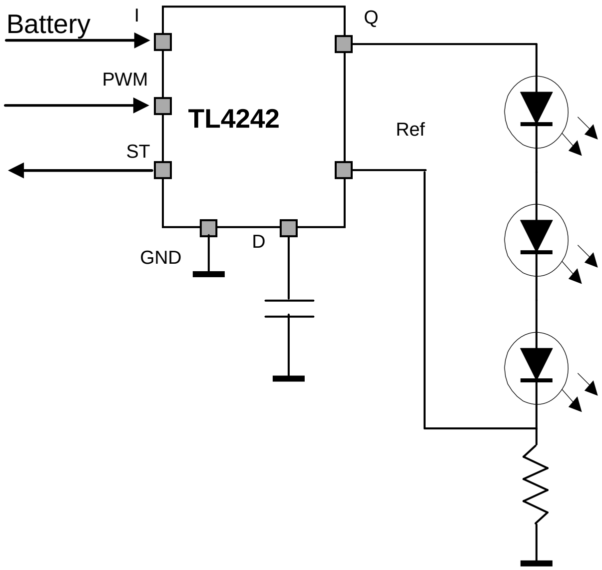
- **When EMI is a problem**
- **When the drop from Vin to Vout is small**

EVM



Benefits

- **Supply Voltage Independent constant current / brightness**
- **Programmable constant load current**
- **Fault Reporting**

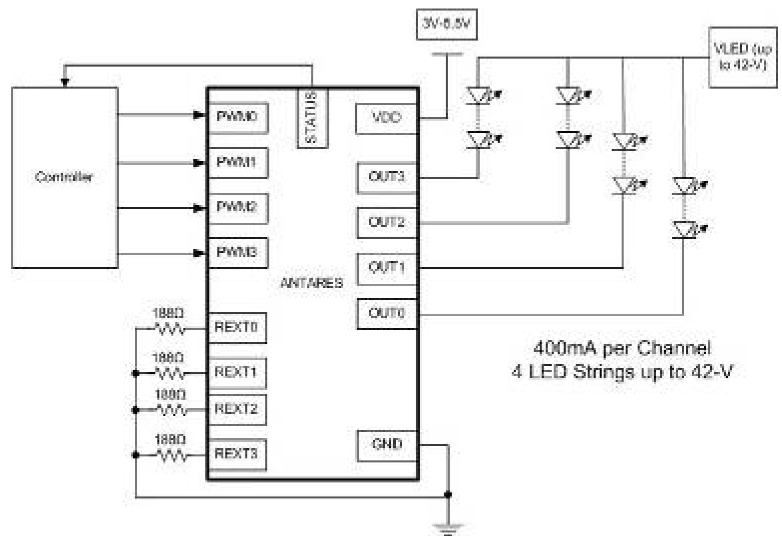


2Q11

ANTARES
4 Channel 42V, 400mA Linear LED Driver

Features
- 4 Channels
- Adjustable current up to 400mA per channel
- Combine outputs for single 1.6A channel
- Wide input voltage range – up to 42V
- LED Open Detection
- Die Over-temperature fold-back
- Short circuit proof, Reverse voltage protection
- Zero REXT current
- Wide operating temperature (-40ºC to +150ºC)
- PWP – 16-pin with power pad

Benefits
- Supply voltage independent current and brightness
- Fault reporting
- Programmable constant current load



Applications
- LED illumination and intensity control
- General Lighting
- Exterior: DRL, Fog light, turn lamp, headlamp
- Interior: vanity, map, courtesy

TLC5945

16 Channel LED Driver High Speed Video

Features

- 16 Channels, 12 bit PWM
- 6-bit (128 steps) Dot Correction
- 80mA Constant Current/Channel
- Chip to Chip Accuracy: 4% typ
- CH to CH Accuracy: 1%typ
- Two built-in Error flags
  (LED Open & Thermal error)
- No Delay Circuit version of TLC5941
- TLC5940/41 pin compatible

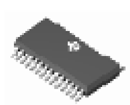
Benefits

- 68 million color capability
- Display brightness among OUT0~15
- Wide variety of LED types
- Color / Brightness uniformity
- Color / Brightness uniformity
- Provides safety and signaling for replacements

- Fast transition rates
- Utilize same layout / designs

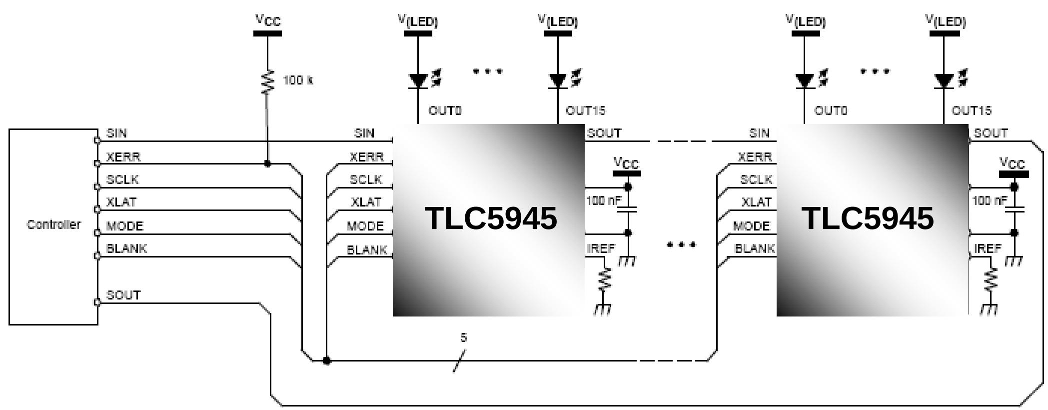
Applications

- Video Billboard LED Display
- Traffic LED Signs
- Commercial LED Signage

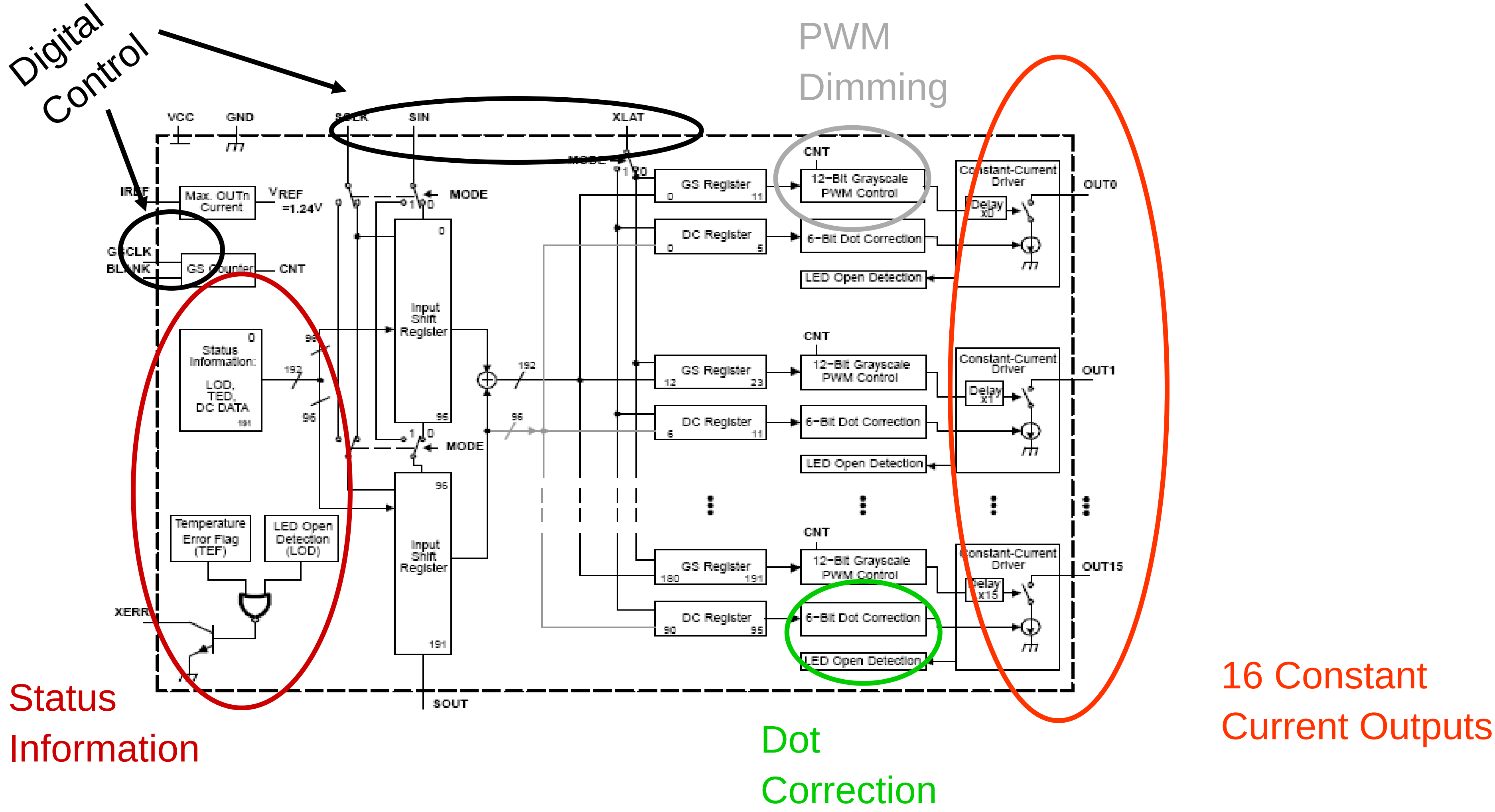


HTSSOP

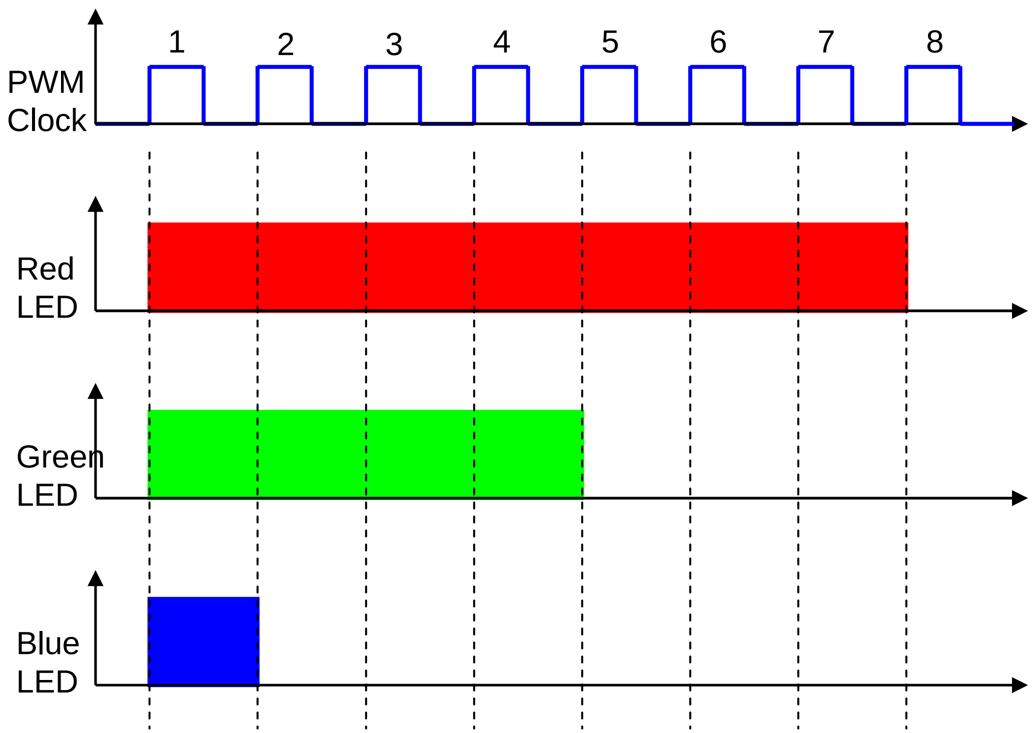
QFN



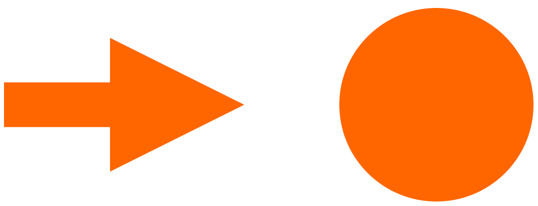
Basic TLC59xx LED Driver



PWM Dimming – Gray Scale

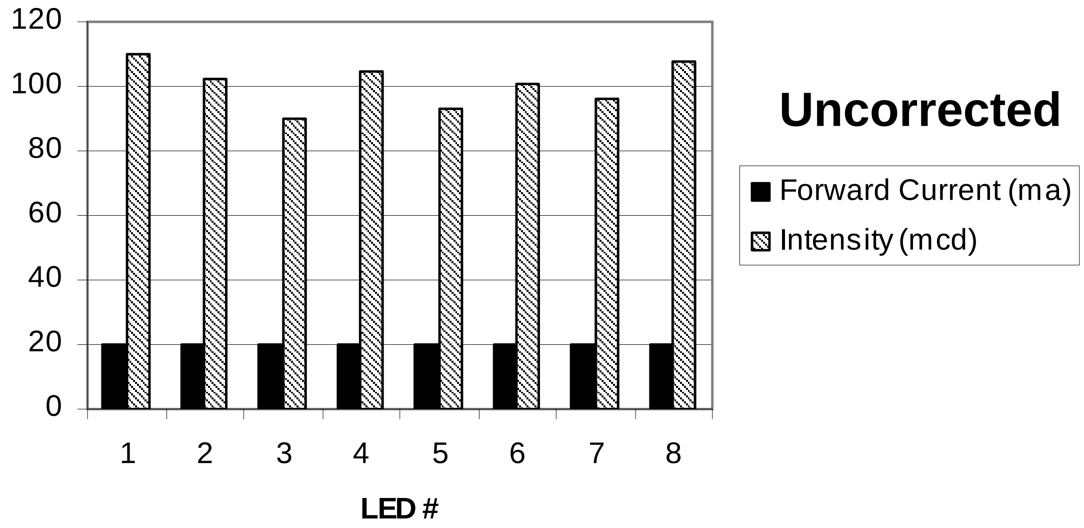


Makes an Orange Pixel



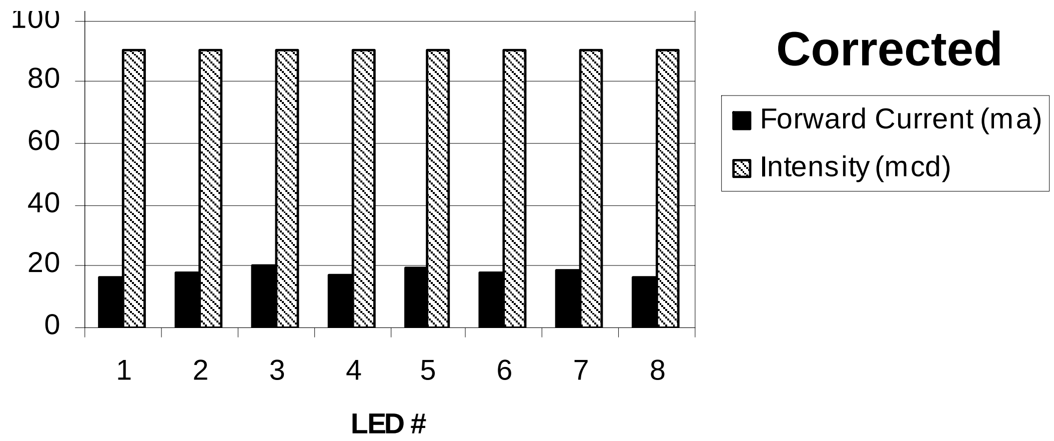
TLC5940 PWM Dimming → $2^{\wedge 12} * 2^{\wedge 12} * 2^{\wedge 12}$ = 68.7 billion color

Dot Correction Concept



Uncorrected

Top Graph: 8 LED's driven by the same forward current. Each LED has a different intensity due to manufacturing differences.



Corrected

Bottom Graph: 8 LED's after Dot Correction is applied. Now all have different forward currents but the same intensity.

TLC5925 (16 Channel, 45mA I_{LED})

Low Power/Cost Const. Current Sink LED Driver

Features

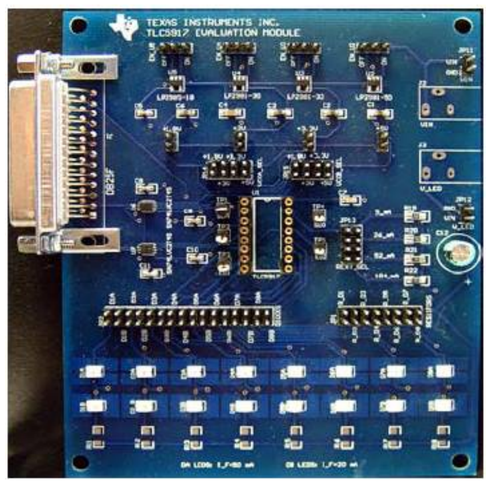
- 16 constant current outputs (3mA – 45mA)
- Current output programmable by external resistor (REXT)
- Current accuracy between channels ±3% (typ)
- Current accuracy between IC ±6% (typ)
- Protection and Diagnostic
  - Thermal Shutdown
- Serial interface (4 wire, Cascadable, 30MHz)
- Schmitt Trigger inputs
- Thermally enhanced packaging
- Optimized for low consumption
  - Supply 3.3V to 5V
  - Low Quiescent Current < 5mA
  - Vout min = 0.1V-0.3 (only one DMOS TR / output)

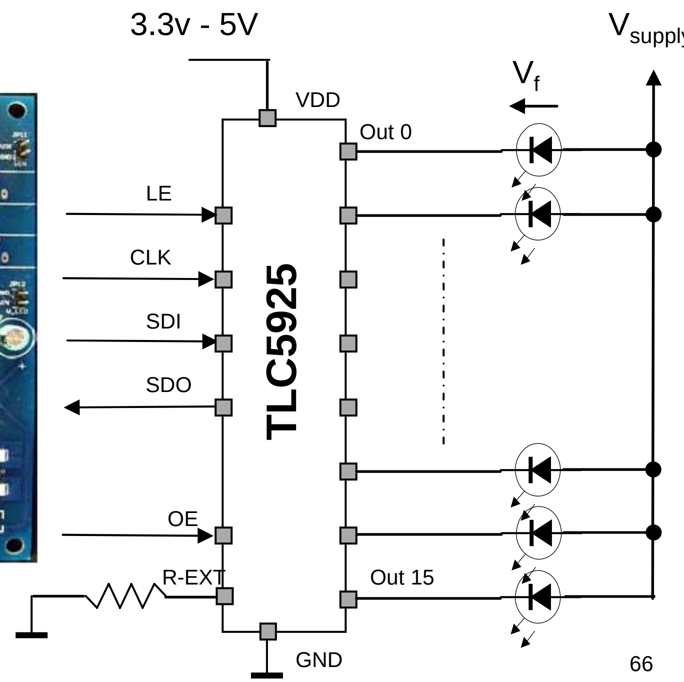
Benefits

- Programmable const. load current
- Fault reporting

Applications

- LED illumination and intensity control
- Video walls and signs
- Traffic signalization
- White Goods



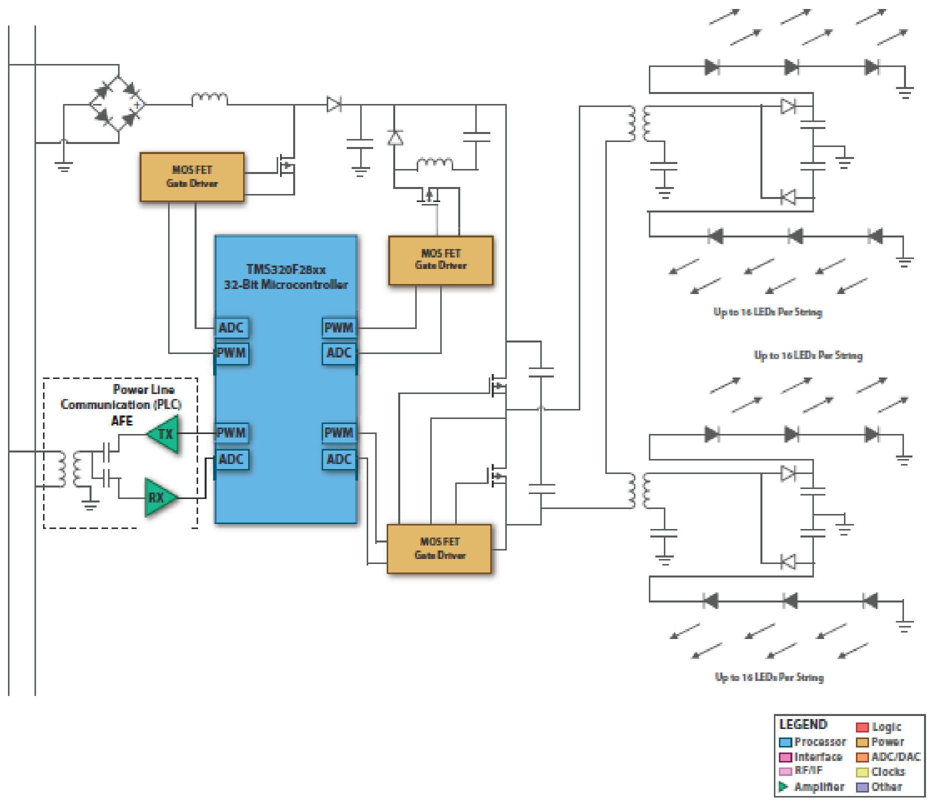


AC/DC solutions

DC/DC solutions

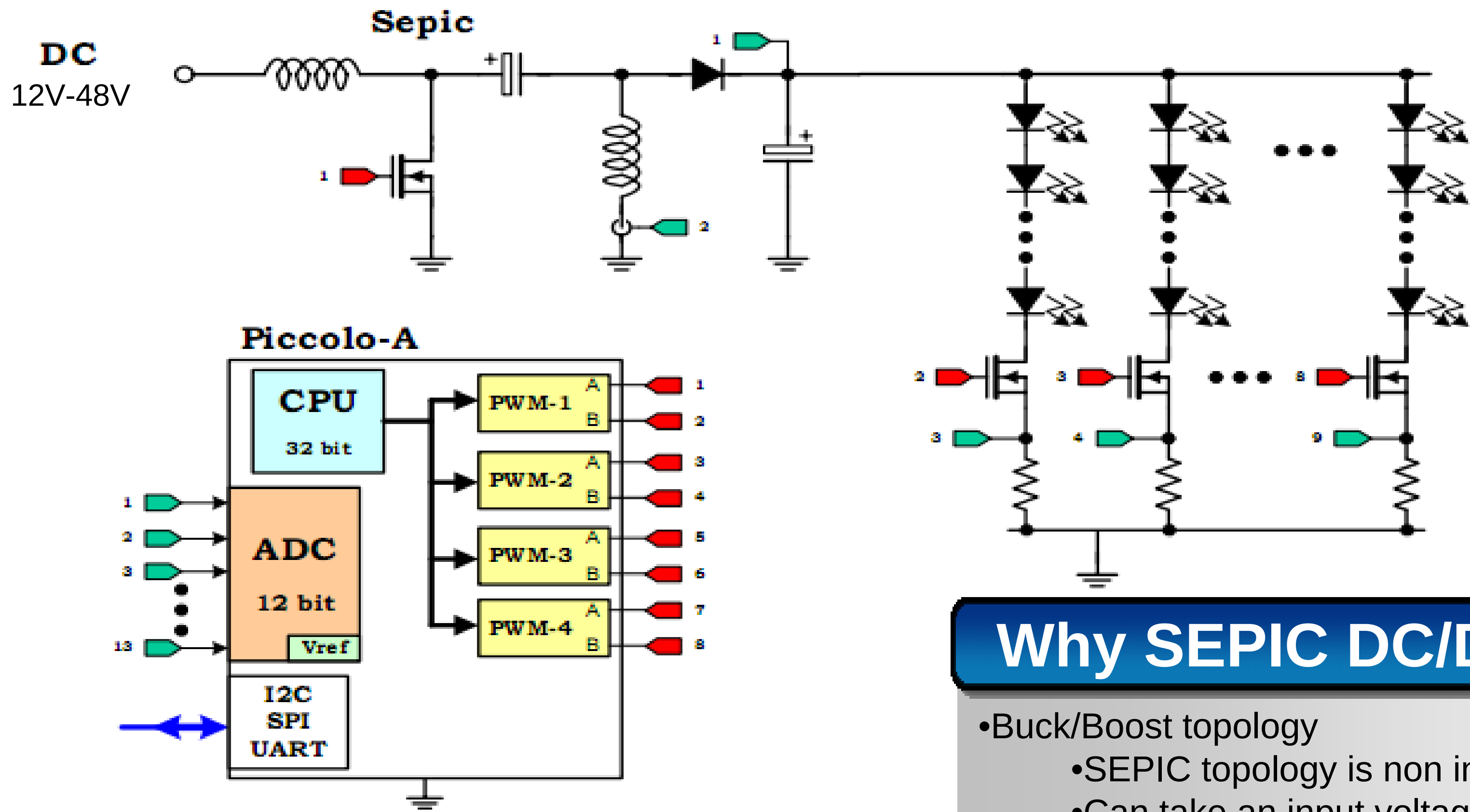
Adding intelligence to LED systems

Benefits of MCUs in lighting



- **Performs all power management functions needed**
  - Advanced power algorithms possible
  - PFC, AC/DC, DC/DC, current control, etc.
  - Up to eight independently controlled LED strings,
  - Interleaving, light load, …
- **Communications/control**
  - Wired—power line communications (PLC), DALI, DMX512, 0-10V, etc.
  - Wireless—ZigBee, 802.15.4, proprietary, etc.
- **Accuracy, precision and flexibility**
  - On-the-fly changes to brightness or color temperature
- **LED temperature sensing for increased reliability**
- **Adaptive dimming based on usage, aging, or ambient lighting conditions**
- **No separate housekeeping MCU required**

LED Lighting Developer's Kit Block Diagram



Based on Piccolo F28035 controlCARD

Why SEPIC DC/DC?

- Buck/Boost topology
    - SEPIC topology is non inverting
    - Can take an input voltage and raise or lower it
- Requires only 1 PWM and 1 MOSFET
- Limited efficiency
- Low component count

LED Lighting Developer's Kit

Hardware

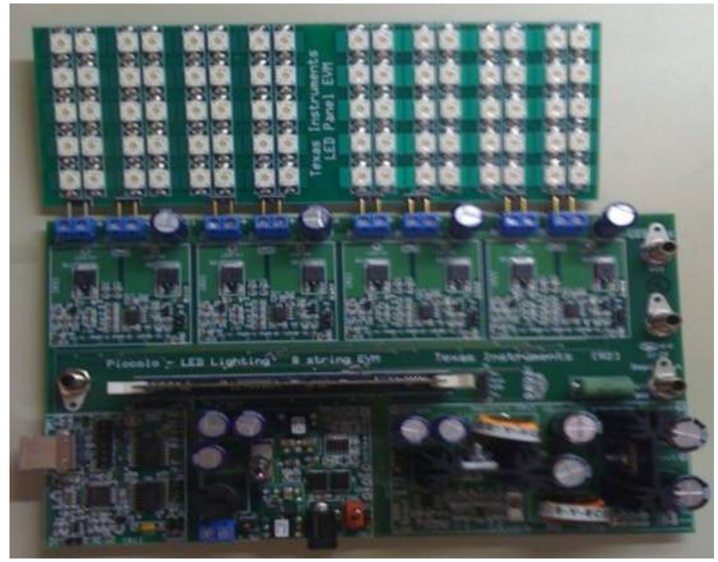
•Piccolo F28035

•12-48V DC input to SEPIC DC/DC stage 50V DC output

•8 strings of 30 watts

•Open source hardware, including gerber files, schematics, and BOMs

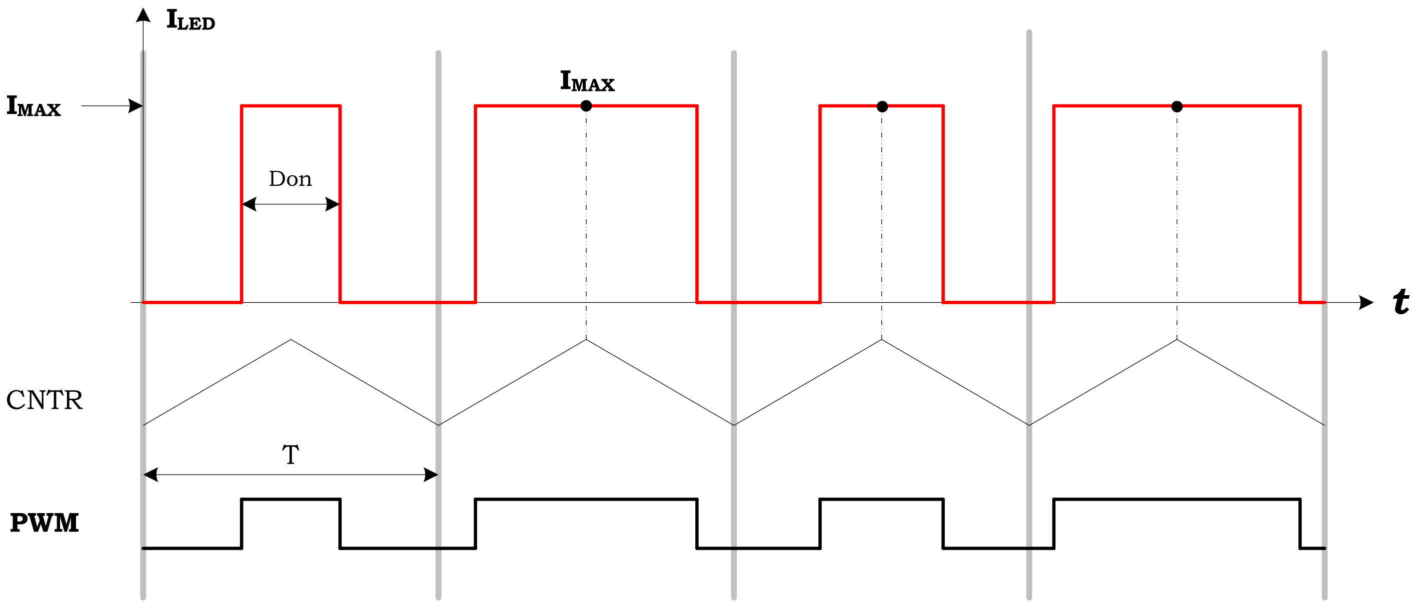
Price: $349
Part number: tmdsledbklkit
Available March2010



Software

•Digital DC/DC SEPIC closed loop regulated control
•Digital, closed loop LED driver stage control
•Digital independent brightness control of each string based on current
•Low CPU utilization gives headroom for other system related tasks

Pulsed current LED lighting (1 of 2)

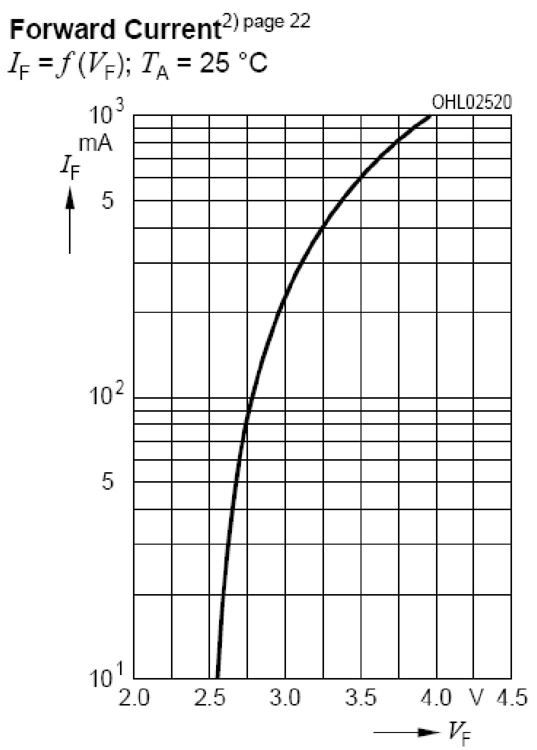


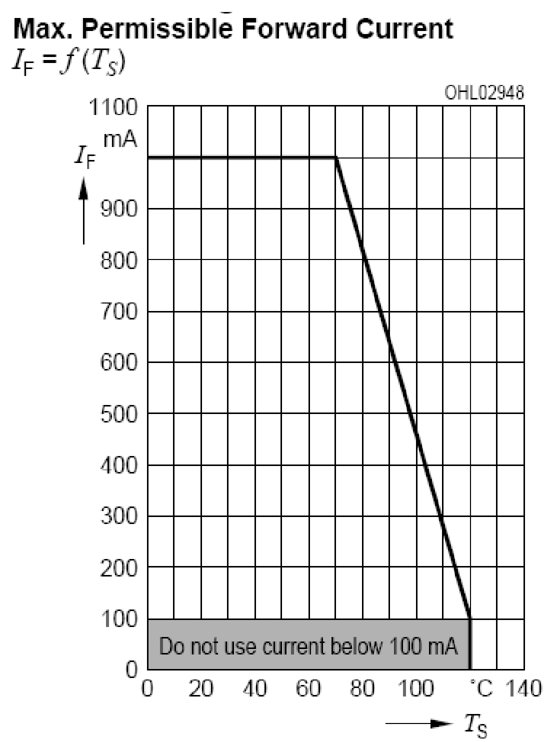
I_{AVG} = (I_{MAX} x D_{ON}) / T
IMAX = f (VF)
VF = VDC_{LED} / N
where N = number LEDs in string

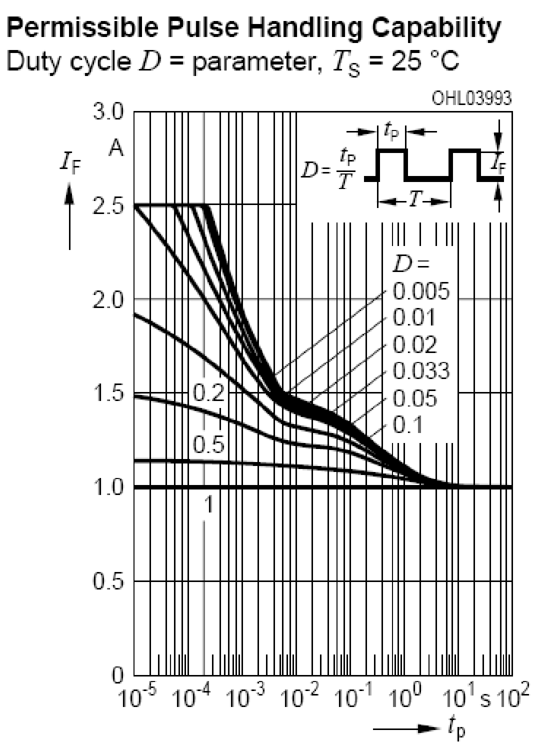
- I_{MAX} sets the color temp
- Can dim by adjusting D_{ON}
- IMAX can be adjusted by Sepic VDC_{LED}
- Limitation: common VDC_{LED} for all strings
- Advantage, no inductors / caps needed per string

Drawbacks ? 1 Vdc led for all the strings

Pulsed current LED lighting (1 of 2)

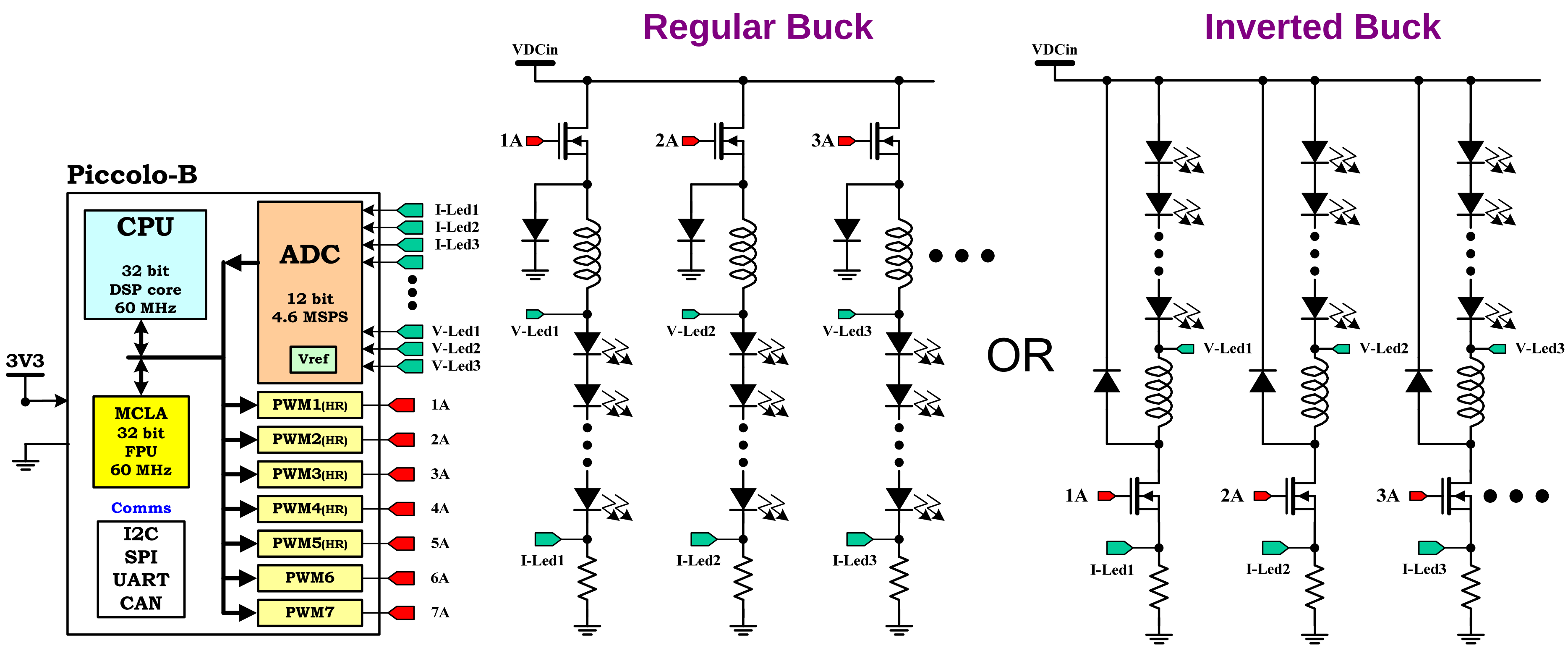




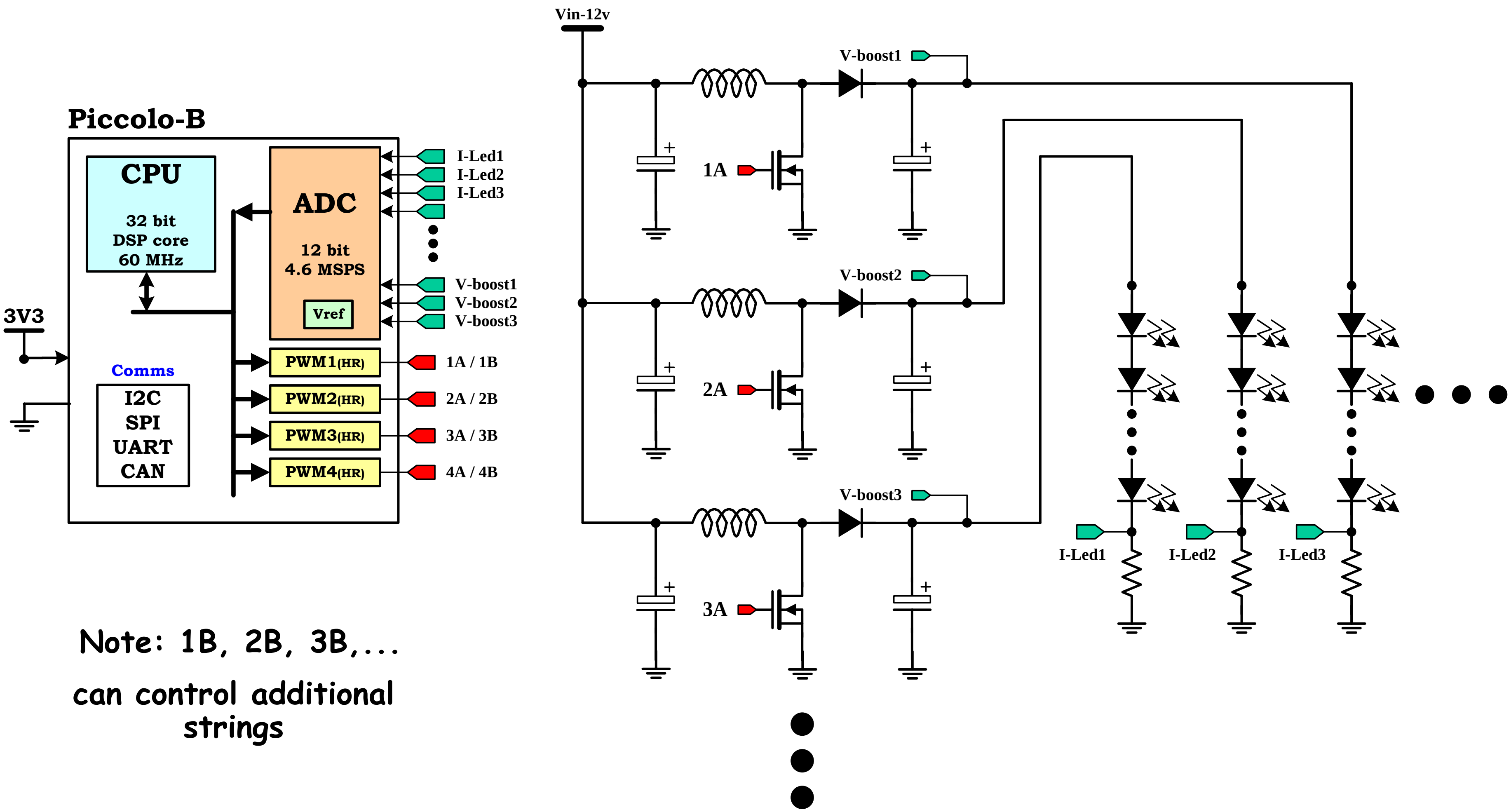


Texas Instruments

Multi-Buck current mode control



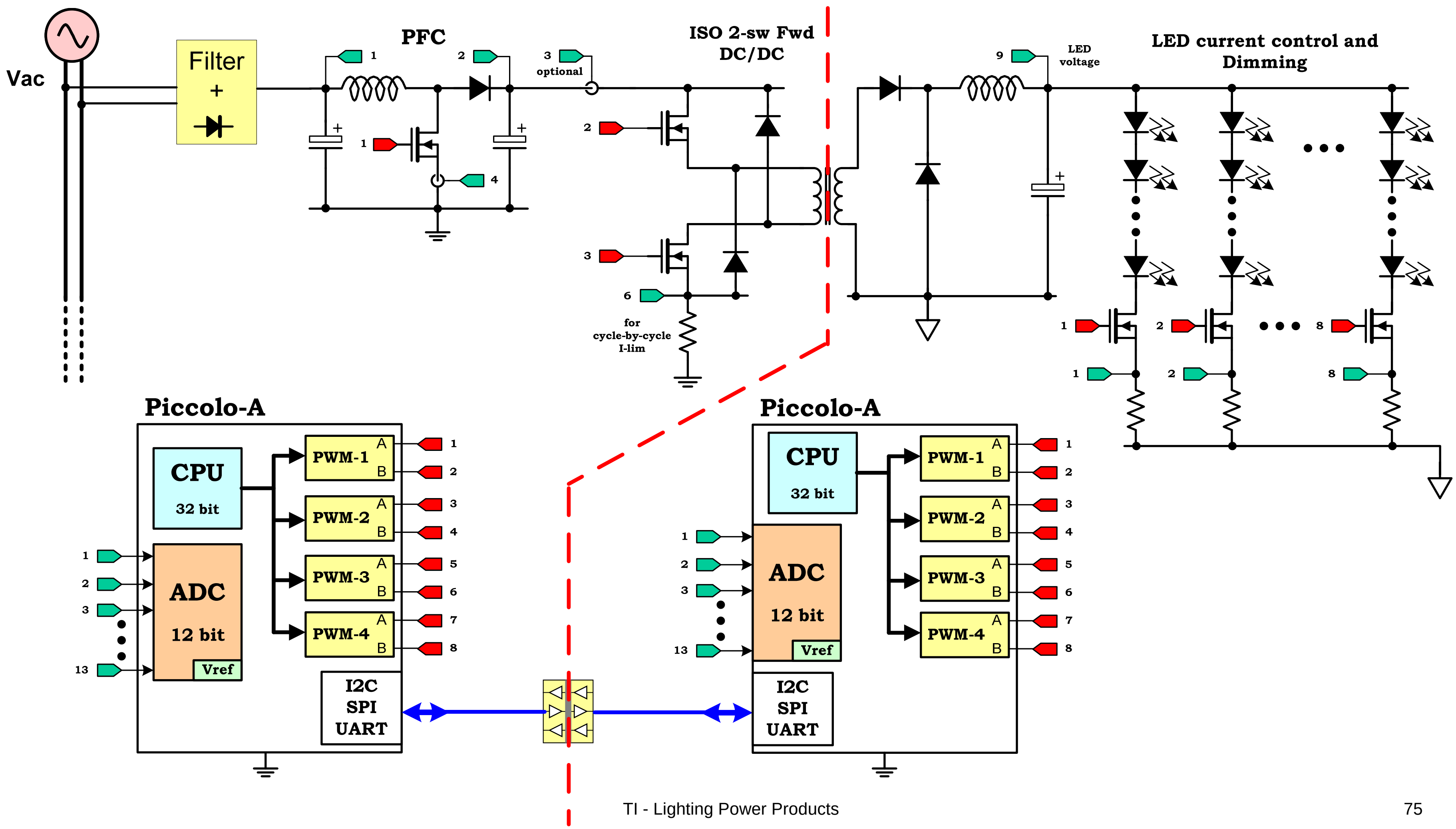
Multi-Boost current mode control



Note: 1B, 2B, 3B,...

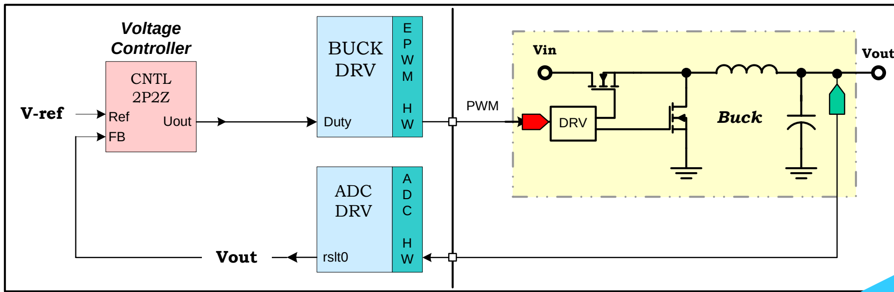
can control additional strings

Off-line: Dual Controller / Isolated

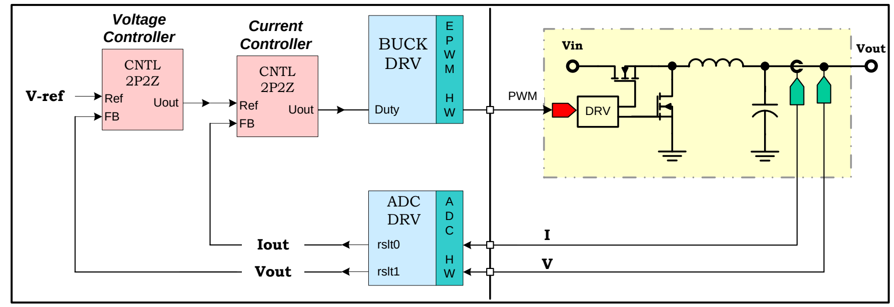


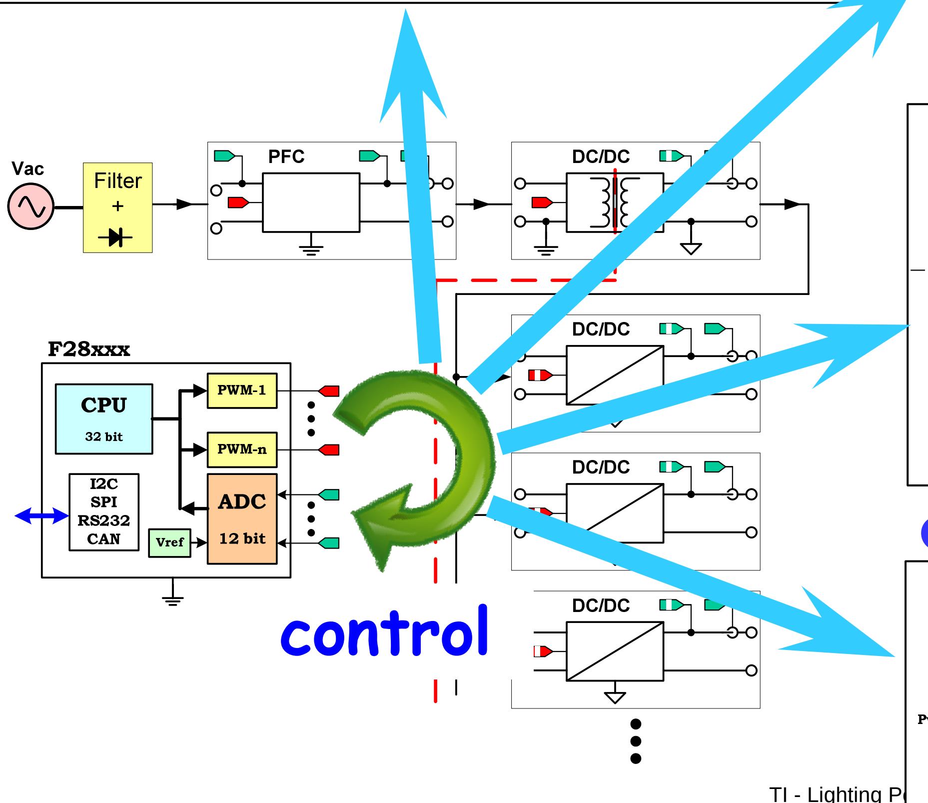
Power Stage – Loop Control

Voltage Mode

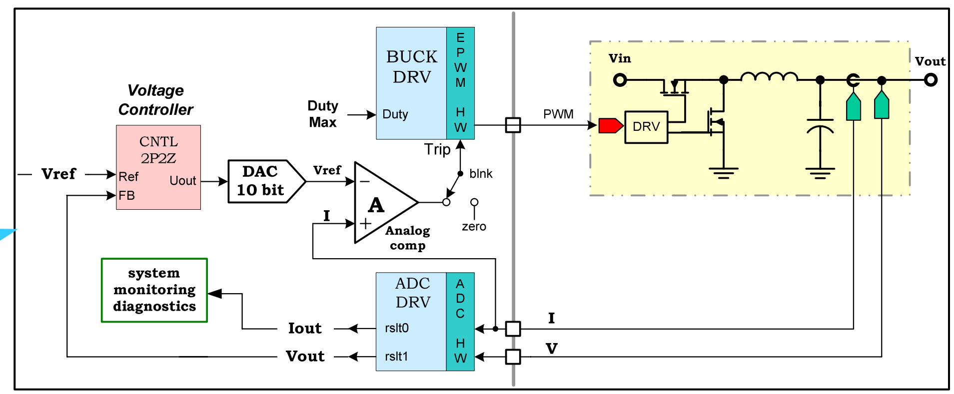


Avg Current Mode

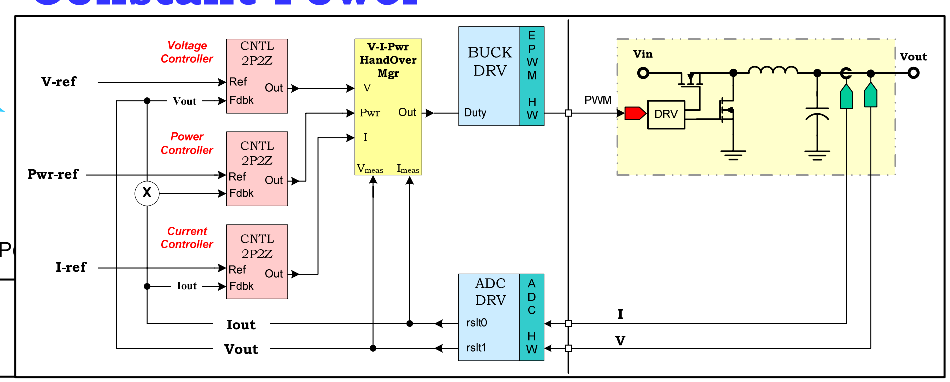




Peak Current Mode



Constant Power



Communication: TI unique positioning

PLC (piccolo):

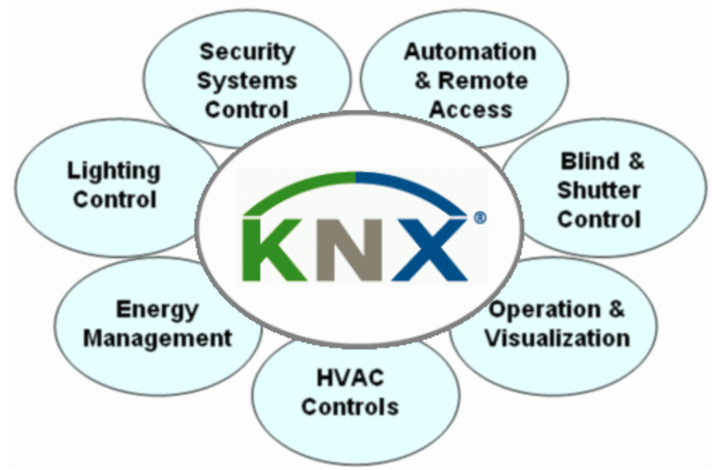
- LonWorks (Echelon locks the market)
- KNX over PLC (KD / ADDgrup)
- Dali-over-PLC (internal example code)

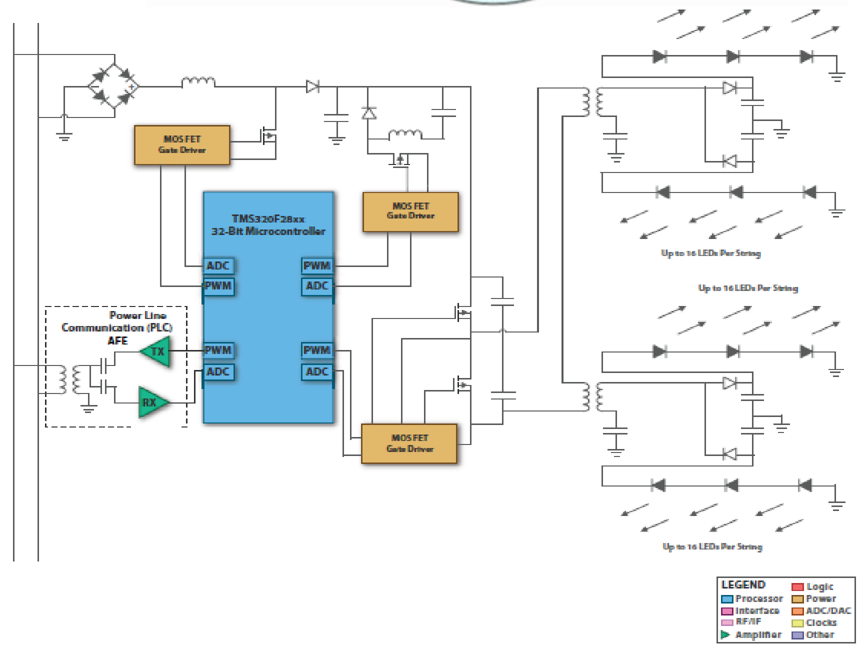
Wired (MSP430):

- KNX/Batibus (3P)
- Dali/DSI (internal example code)
- Bacnet (US TBC?)

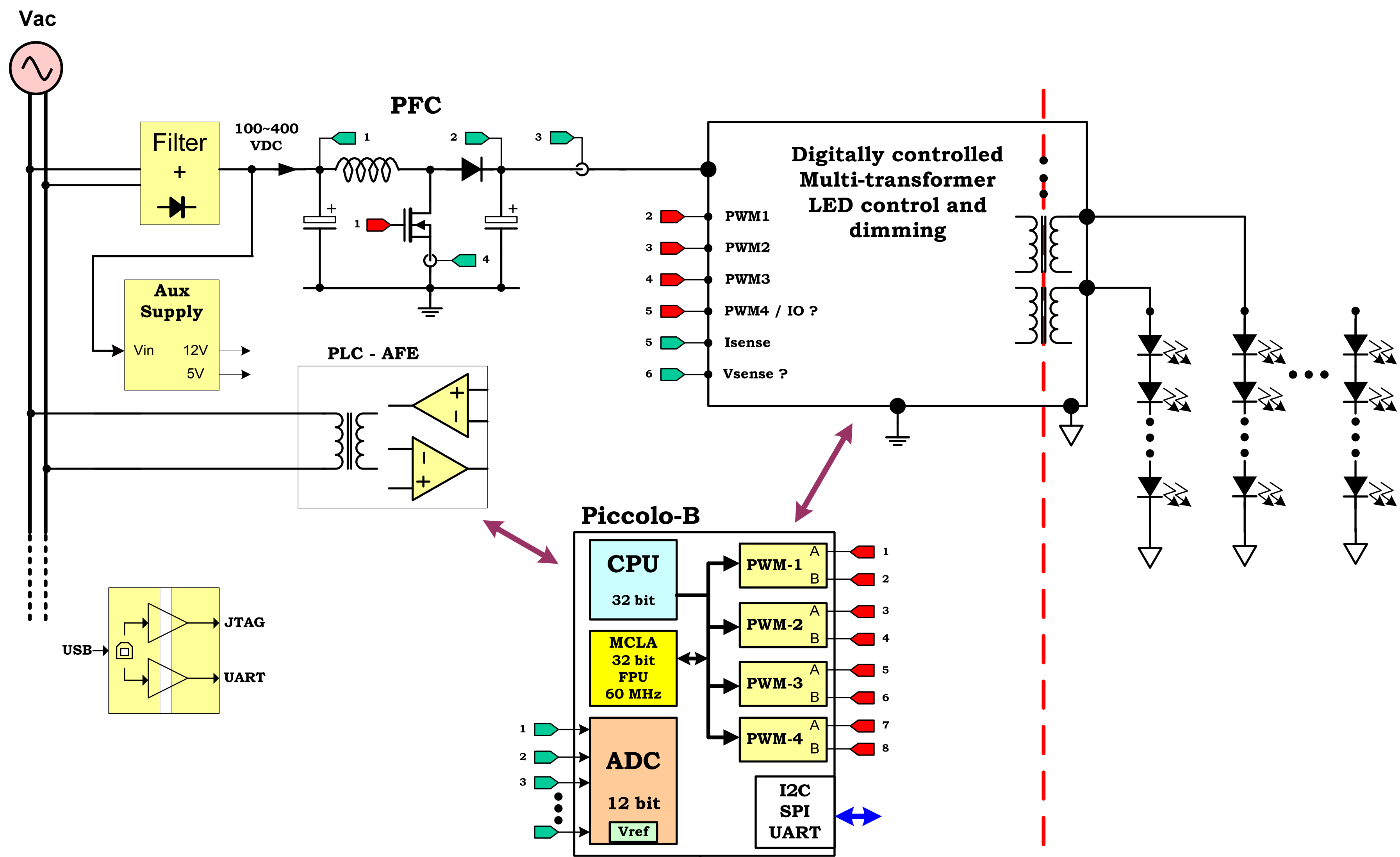
RF (LPW, MSP430):

- W-KNX (3P)
- SimpliciTI
- Zigbee HA
- 6LowPan (Sensinode)
- EnOcean





Street lighting with PLC



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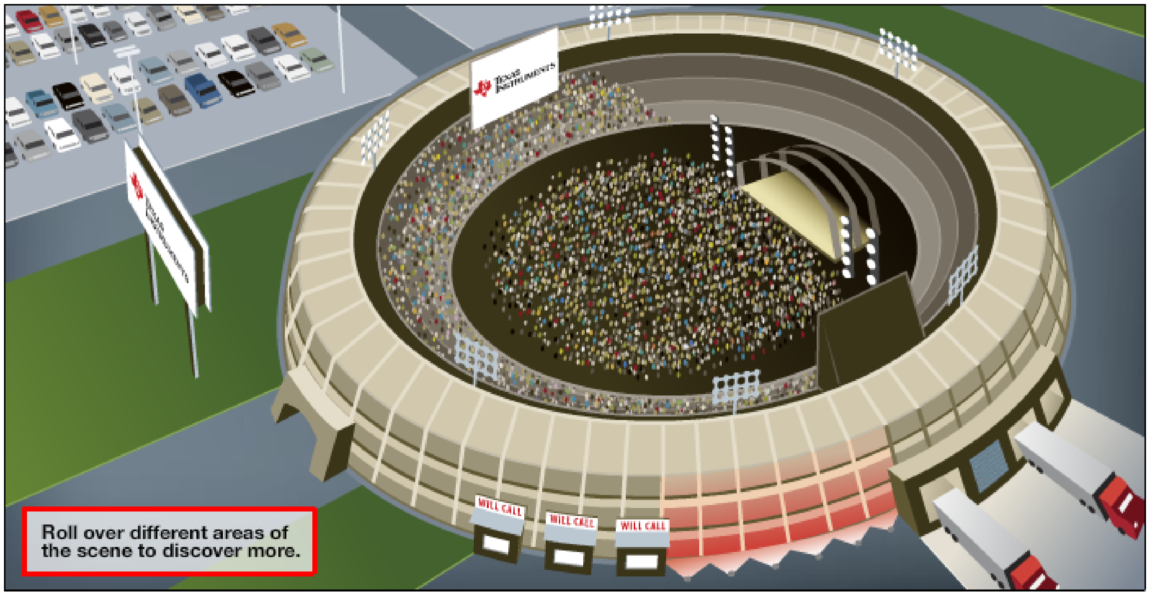

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TI eases design for energy-efficient and energy harvesting applications with expanded 16- and 32-bit MCU tools portfolio

New $39 Piccolo USB tools jumpstart 32-bit real-time control development

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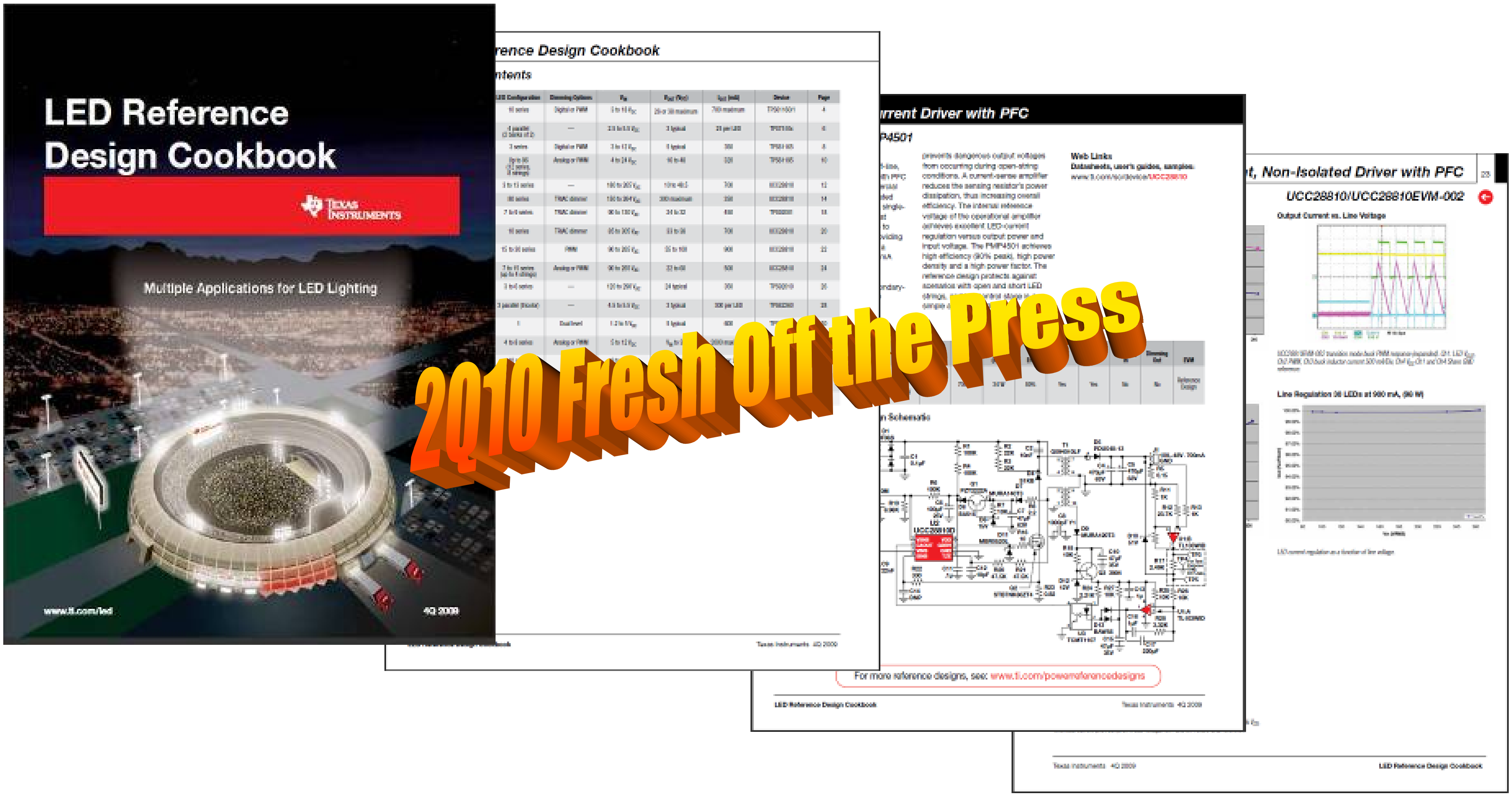
Contributed Articles

Reference Designs, Products, White Papers, Articles, Tools, Videos, etc.

LED Reference Design Cookbook (slyt349a)



http://focus.ti.com/lit/sg/slyt349/slyt349a.pdf

Thank you – any Questions?