



Innovative LED Lighting Electronic Design

—新型多串半桥谐振高效LED驱动解决方案及其应用

电源参考设计中心

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LED General Illumination

LED Lighting

Residential

< 25W or
3,000 lm



MR16 E14 E27/A19 PAR38

Commercial

15W – 75W or
1000 lm - 10000 lm



Display Case Retail Display Architectural

Outdoor and Infrastructure

35W – 250W
2500 lm - 30,000 lm



Street Light Area Light Flood Light

**Low Cost, TRIAC Dimming, PFC,
High Efficiency, Color Quality,
Safety, Long Life**

TPS92010
TPS92210
TPS92001/2

TPS92010EVM-592 (110V)
TPS92010EVM-631 (230V)
TPS92210EVM-613

**PFC, High Efficiency,
Dimming, Early Payback, Color
Quality, Safety, Maintenance, Eco-
friendly**

UCC28810
UCC28811
TPS92020

UCC28810EVM-002
UCC28810EVM-003

**PFC, High Efficiency,
Early Payback, High Brightness,
Safety, Maintenance, Eco-friendly**

UCC25710 *new*
UCC28810/1
TPS92020

UCC28810EVM-003
UCC25710

Careabouts

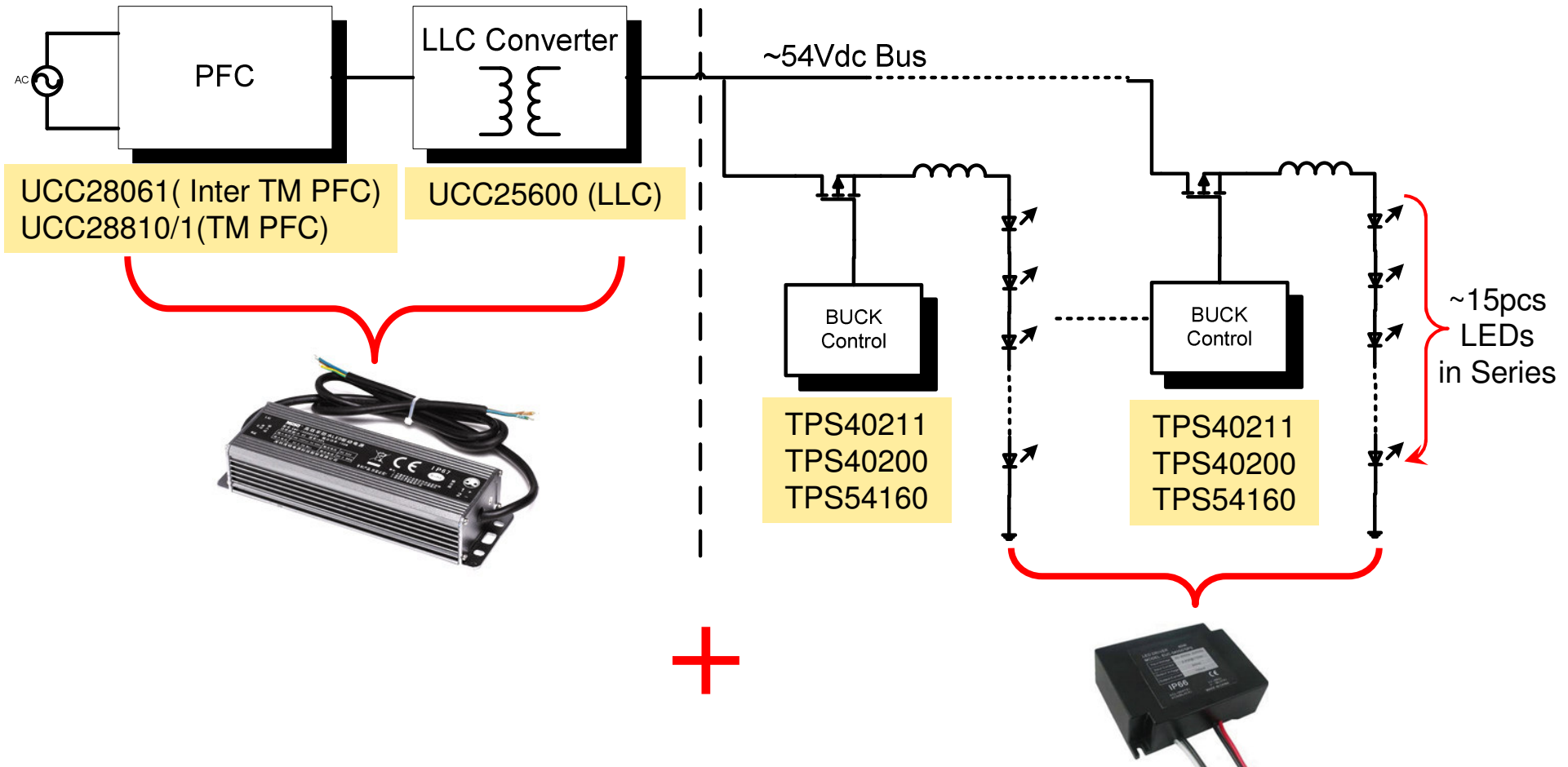
Devices

Tools

High Watt (>100W) LED Lighting Driver Topology

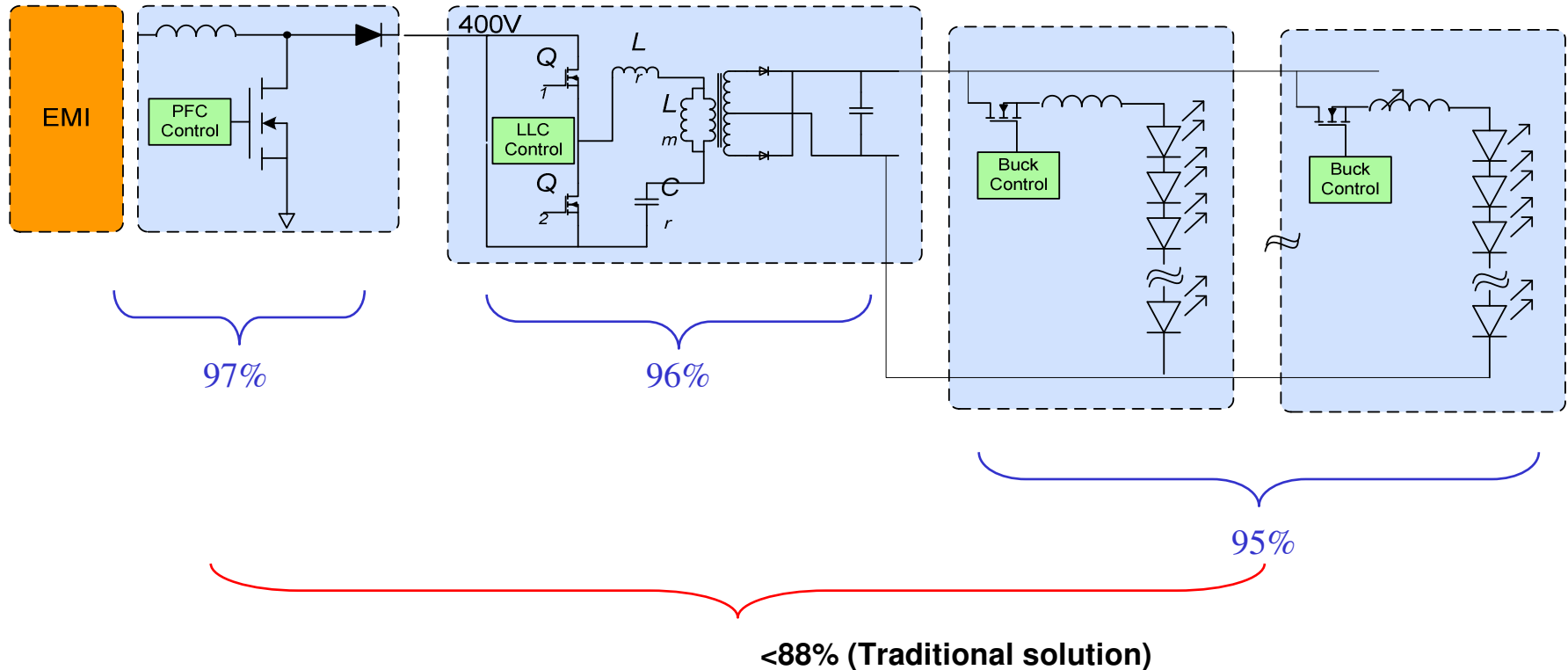
1. AC/DC Power Stage

2. Constant Current Driver Stage



High Watt (>100W) LED Lighting Efficiency Budget

Outdoor and Industrial >100W



Conventional Topology Issues:

- High cost
- Low efficiency (<~88%)
- Low reliability



TI UCC28810EVM-003 - SIMPLERdrive™

Series Input, Multiple Parallel Equivalent LED Drive (SIMPLERdrive)

1st stage:

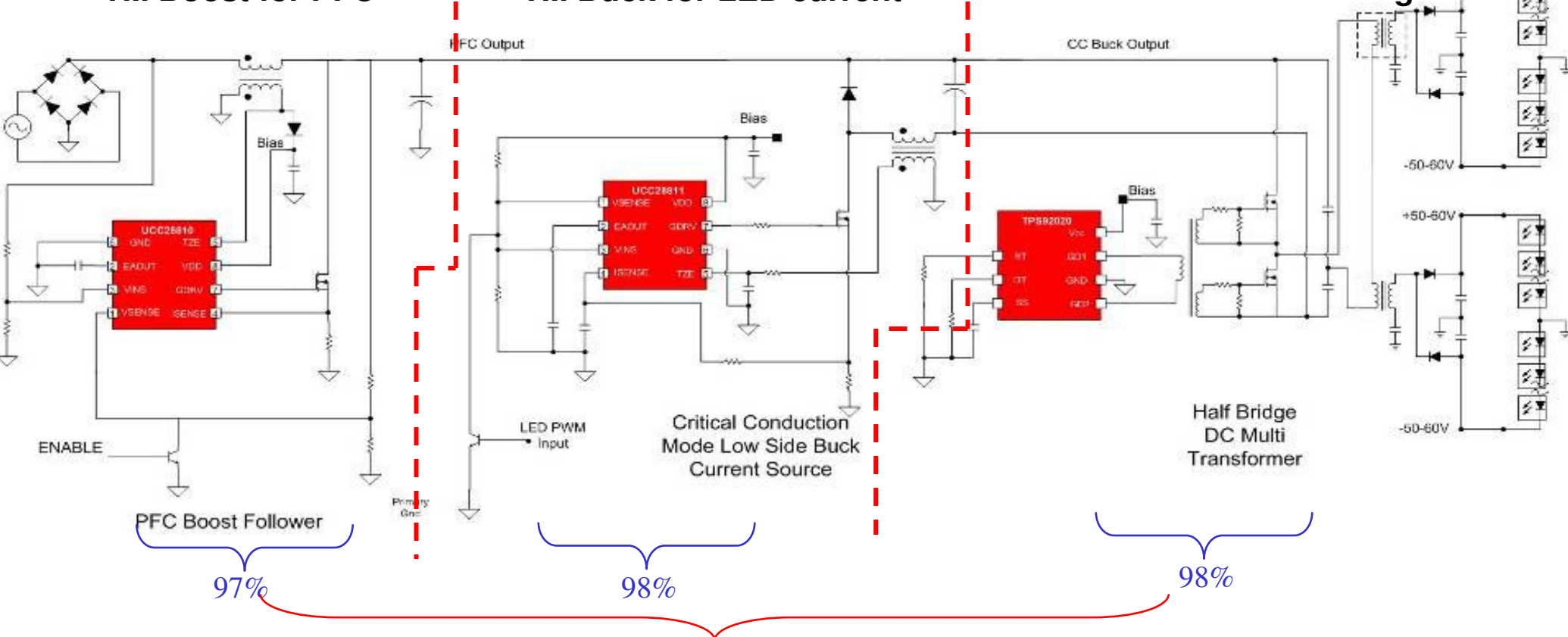
2nd stage:

3rd stage:

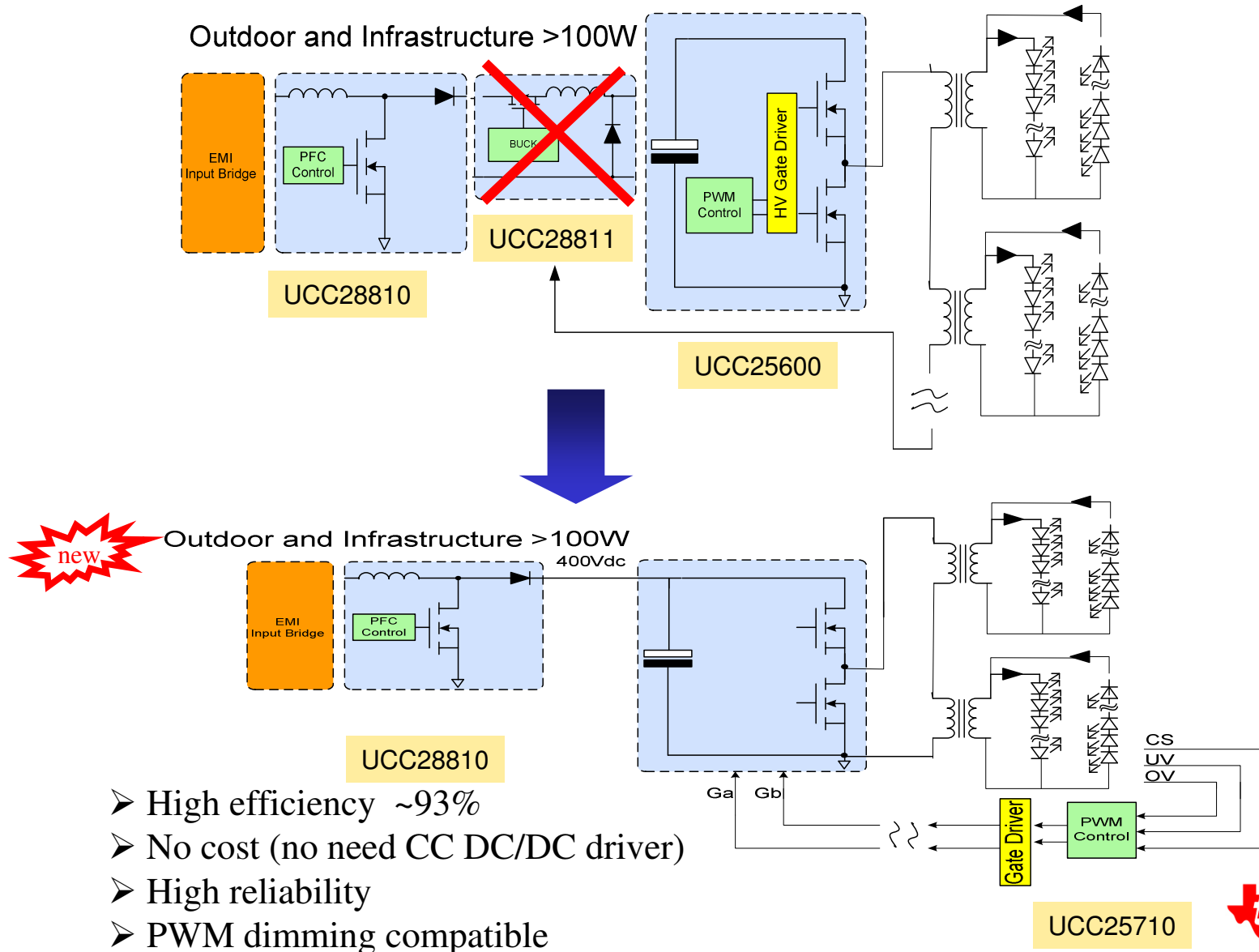
TM Boost for PFC

TM Buck for LED current

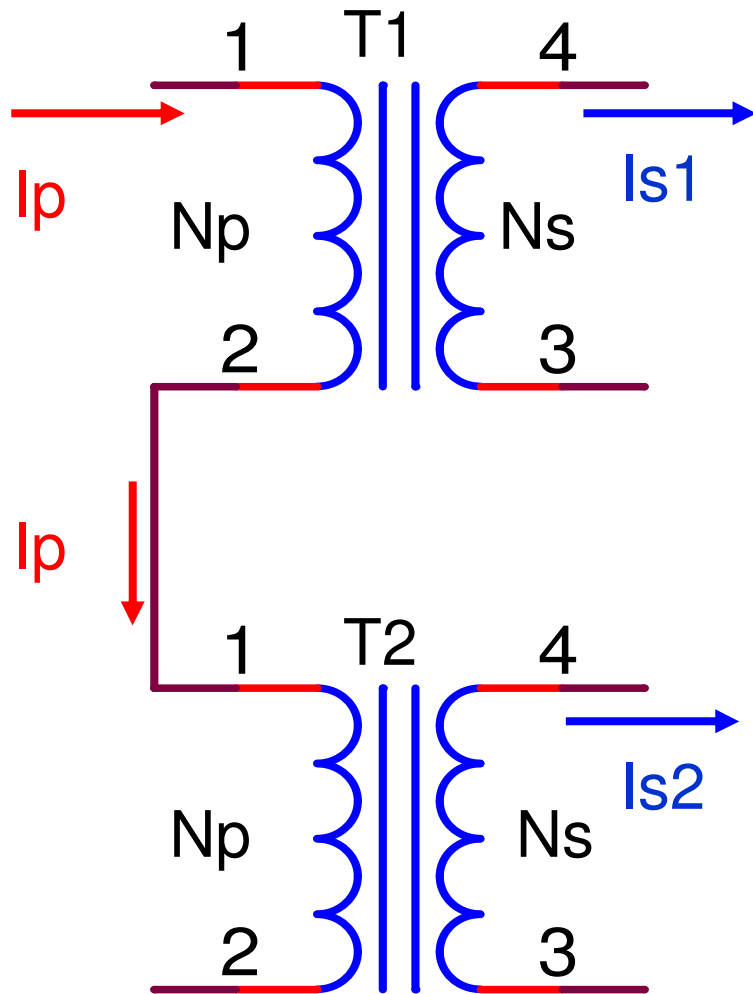
Resonant Current Half Bridge



Innovative two stages multi-string LLC topology for LED lighting

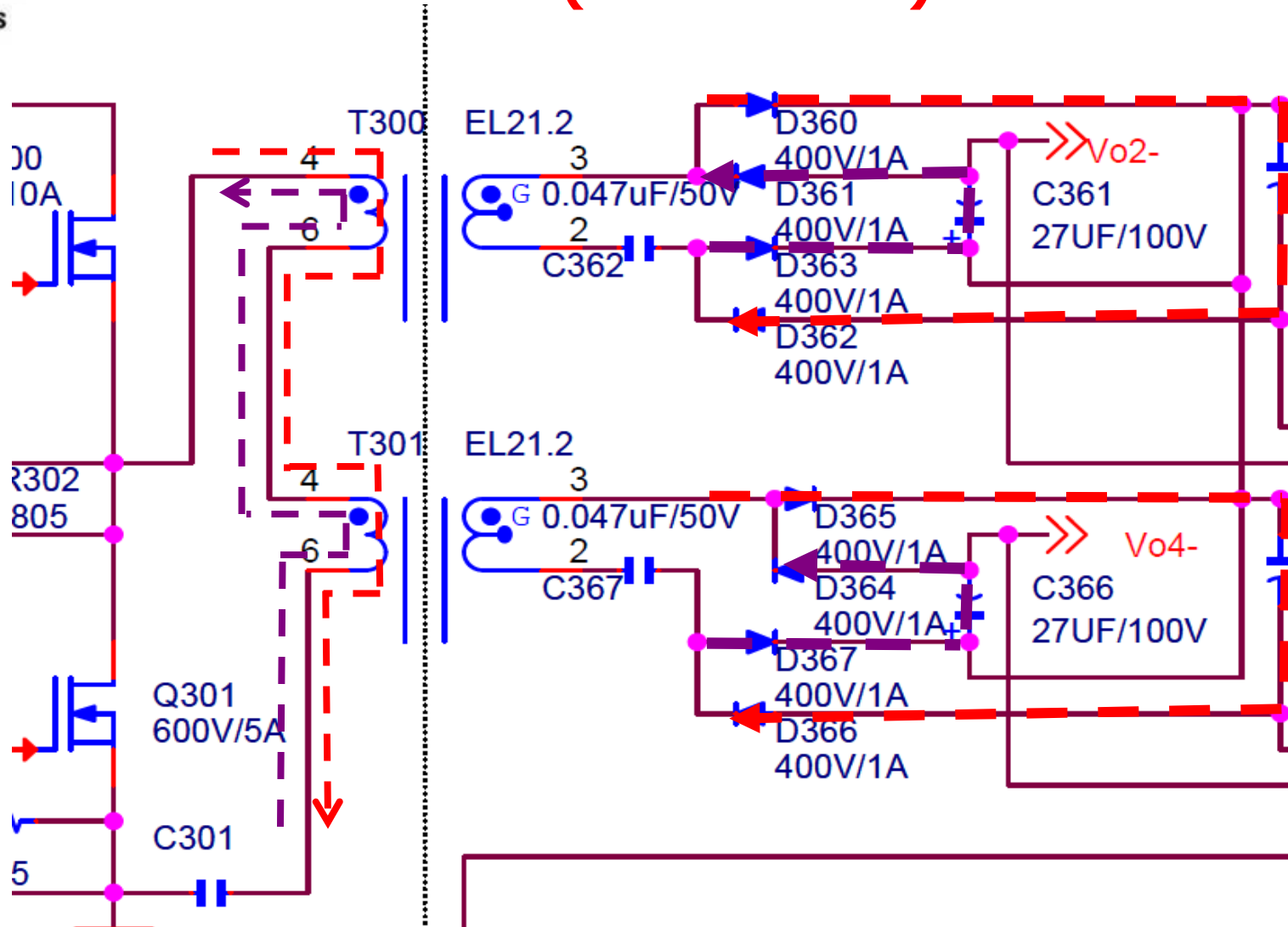


Why Transformer Can Balance Current



- Transformer current is in reverse proportion to turn ratio
- $I_p/N_p = I_s/N_s$; $I_s = N_s * I_p/N_p$
- When transformer primary is connected together, their primary current must be the same
- When T1 is the same as T2 because of transformer operation principle their secondary current is the same
- $I_{s1} = N_s * I_p/N_p = I_{s2}$

Multi-Transformer Architecture (TI Patented)



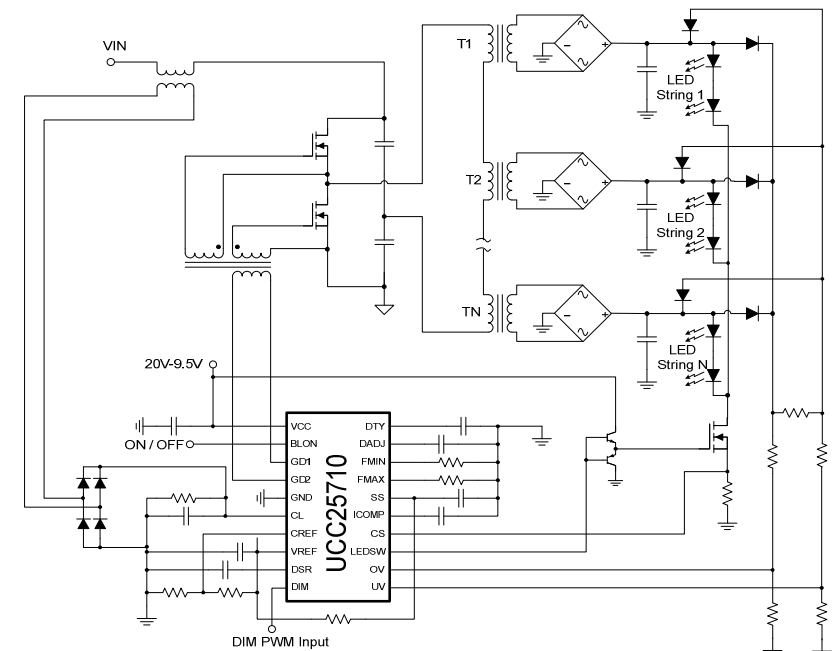
UCC25710: LED driver Controller IC

Features

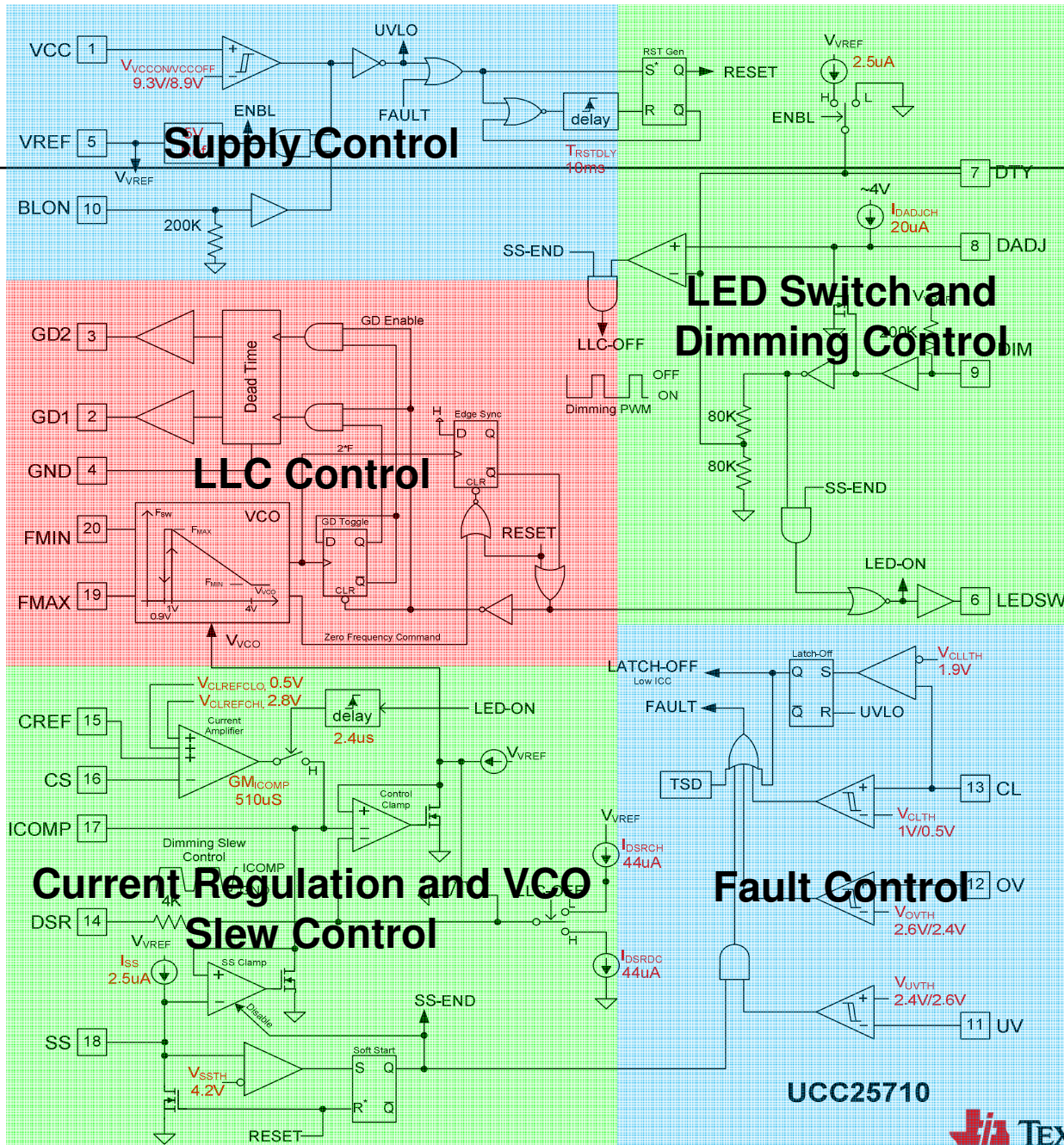
- Industry first single chip LLC controller for driving multiple LED strings directly from PFC output
- Adjustable Fmin (3% accuracy), and Fmax 6% (accuracy)
- Closed Loop LED String Current Control
- PWM Dimming Input
- LLC and Series LED Switch Control for Dimming
- Programmable Dimming LLC ON/OFF Ramp for Elimination of Audible Noise
- Closed Loop Current Control at Low Dimming Duty-Cycles
- Programmable Soft Start
- Accurate VREF for Tight Output Regulation
- Over-voltage and Under-voltage and Input Over-current Protection with Auto-restart Response
- Second Over-current threshold with Latch-off Response
- +400-mA/-800mA Gate Drive Current
- Low Start-Up and Operating Currents
- 20 pin SO Lead (Pb)-Free Package

Applications

- General LED Lighting
- LED TV Backlighting



UCC25710 Block Diagram

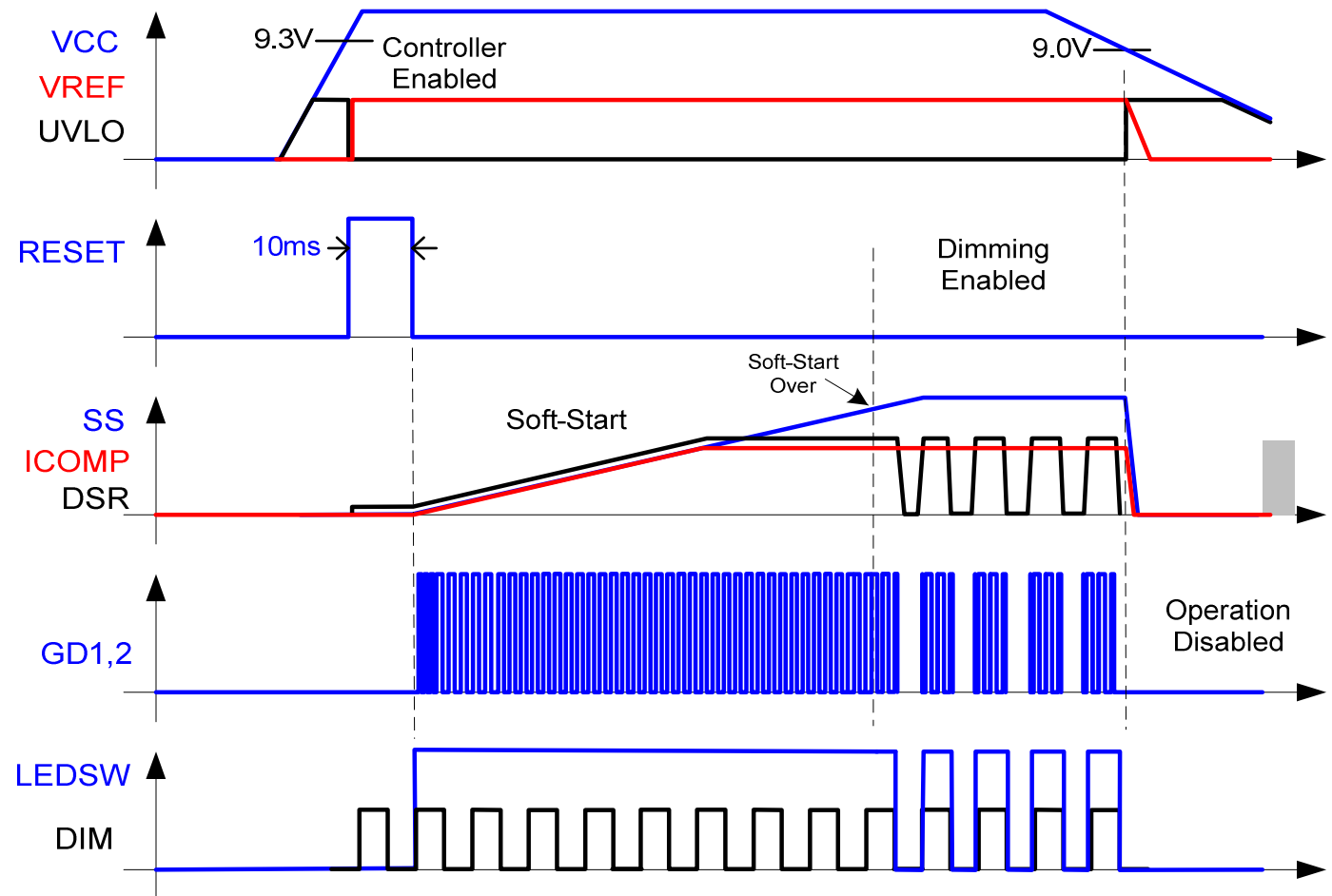


UCC25710

UCC25710: START-UP & DIM WAVEFORMS

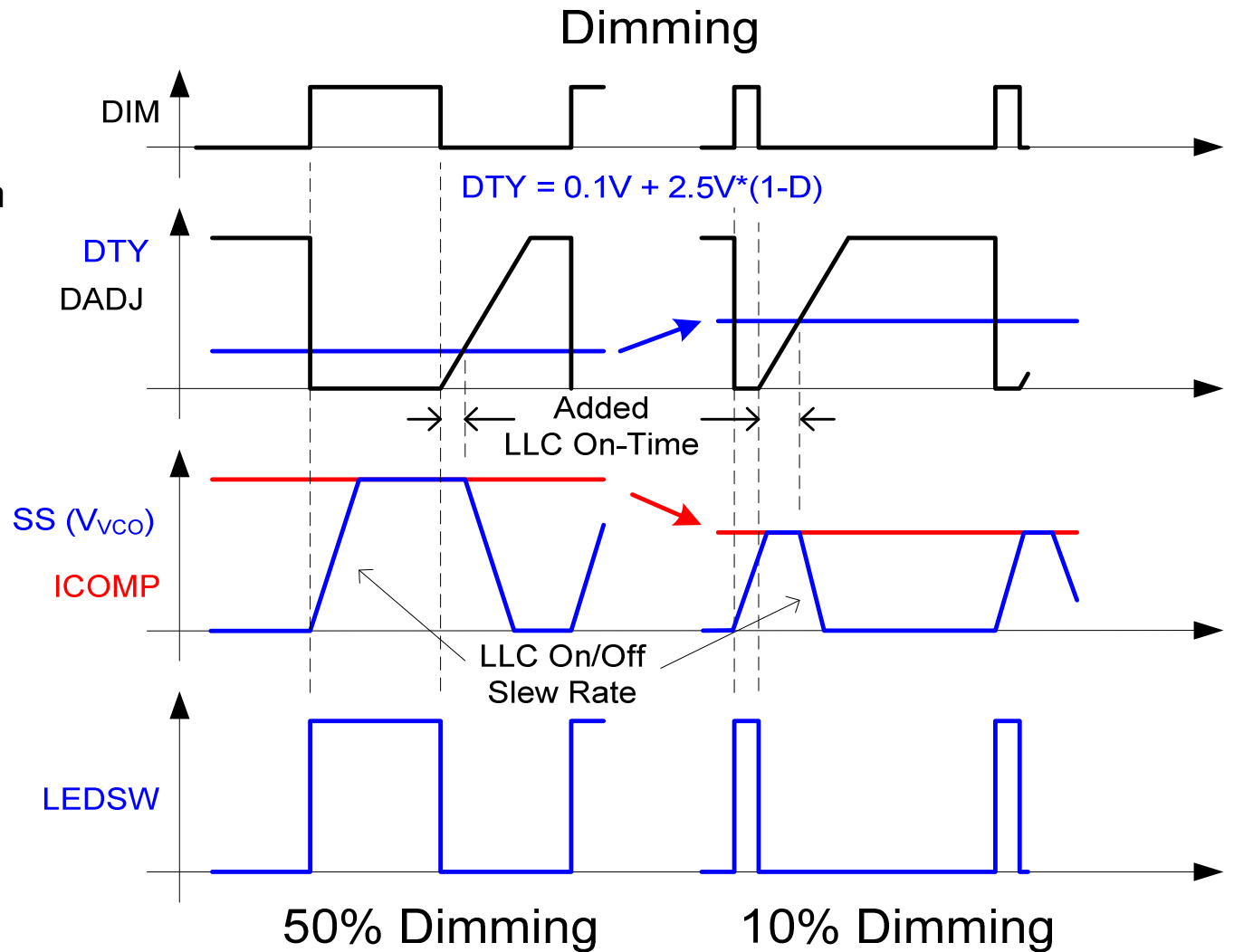
- 10ms RESET initiates Soft-Start (SS)
- LLC Soft-Start, VCO control is clamped to SS until $SS > I_{COMP}$
- Dimming is disabled during SS
- DSR cap is used to limit LLC control slew rate during dimming
- I_{COMP} voltage is maintained during dimming

Start-up and UVLO Shutdown



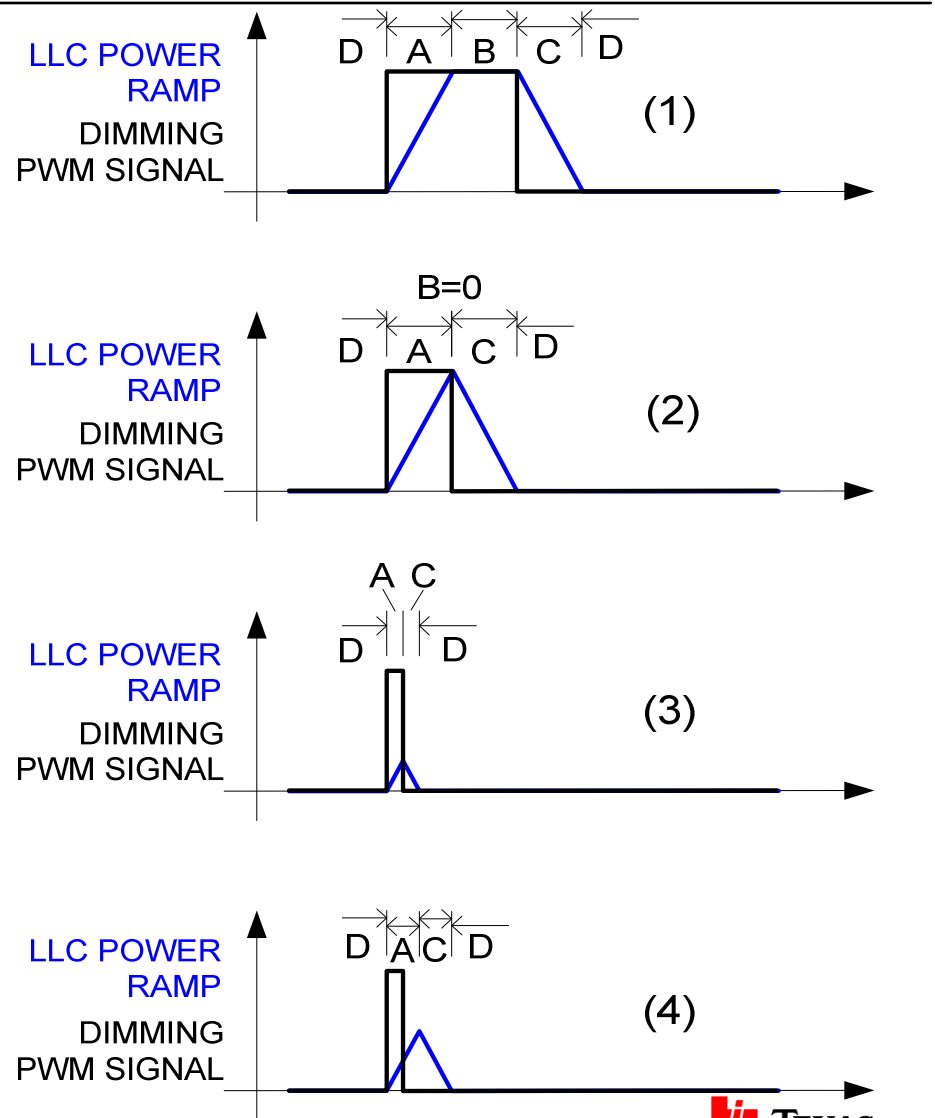
UCC25710: DIMMING – WAVEFORMS

- DIM input controls LEDSW
- DIM input triggers soft turn-on and turn-off of LLC converter
- LLC on-time is extended
- On-time extension is proportional to 1-D, D is dimming duty-cycle
- Extended on-time allows ICOMP to maintain current regulation at low D



UCC25710: LOW DUTY-CYCLE ILLUSTRATION

1. LLC reaches power level equal to pedestal LED current in region B. Power is under delivered in region A, but is compensated for in region C
2. Region B is zero, but sum of A+C still deliveries correct energy.
3. Energy delivered in region A + C is too low, loop is open and realized peak LED current will drop
4. On-time is extended. A + C energy/pulse is correct to maintain same peak LED current

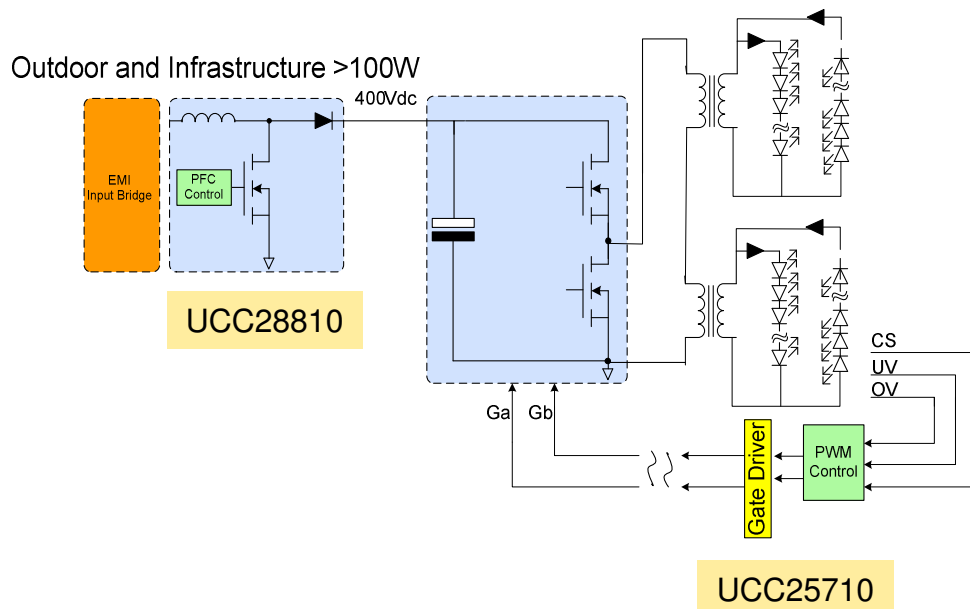


UCC25710: FAULT MANAGEMENT

- Faults
 - OV – highest LED string voltage
 - UV – lowest LED string voltage
 - CL(1V) – input current signal over-current
 - CL(2V) – input current signal latch-off
 - TSD – Chip thermal shutdown
- Response
 - OV, CL(1V) & TSD: The LLC converter and LEDSW are turned off. When the fault clears a RESET and SS are initiated.
 - UV: The LLC converter and LEDSW are turned off. A RESET and SS are immediately initiated, repeatedly, until fault clears.
 - CL(2V): The LLC and LEDSW are latched off until UVLO recycles.
 - During RESET the LLC converter and LEDSW are OFF
 - During SS the LLC converter and LEDSW are ON, i.e. no DIMMING

PMP4302: Multi-string LLC AC/DC Driver for general LED lighting

| Reference Design | TI Parts | V _{in} | Output | Topology | Eff. | Dimming |
|--|--|-----------------|----------------------------|-----------------------------------|------|-------------|
| PMP4302: AC input Multi-string LLC converter for general LED lighting | UCC28810 <i>(TM PFC)</i> UCC25710 <i>(Multi-string LLC)</i> UCC28610 <i>(Aux Flyback)</i> | 90V~ 264V | 54V@500mA with 4 string | TM PFC+Multi-string LLC converter | 92% | PWM dimming |

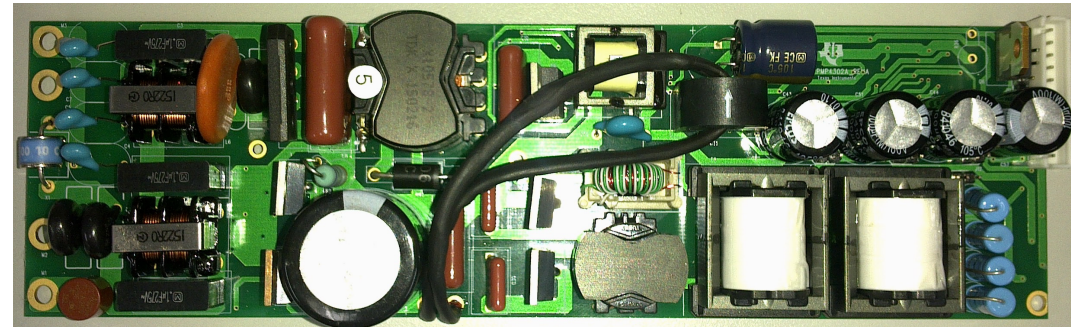


Features

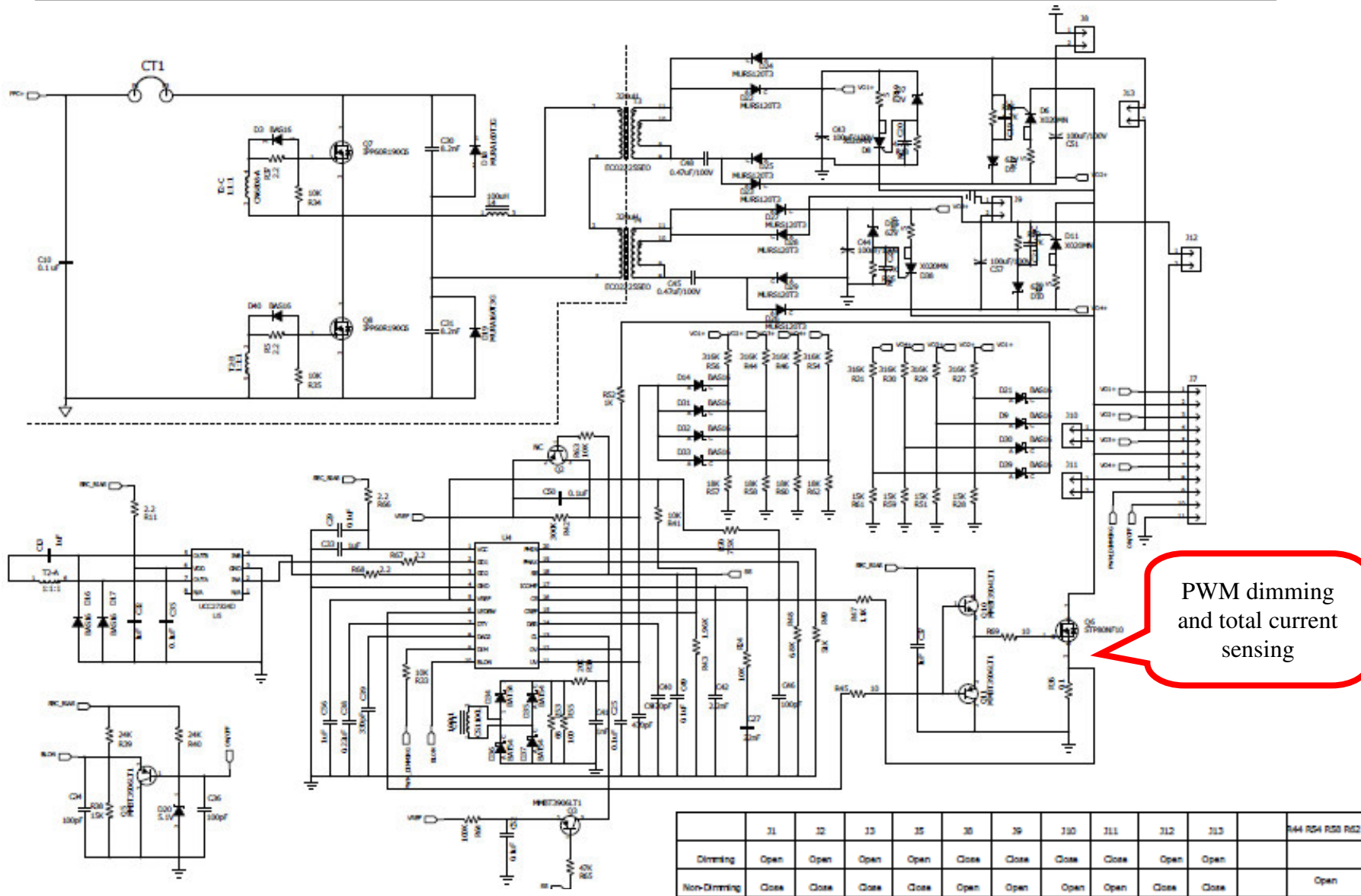
- Lowest cost than AC/DC + DC/DC
- Highest efficiency to 92%
- PWM dimming compatible
- Integrate LED open/short protection and over current protection

Applications

- General LED lighting and LED backlight TV



PMP4302: Schematics for UCC25700 after PFC stage

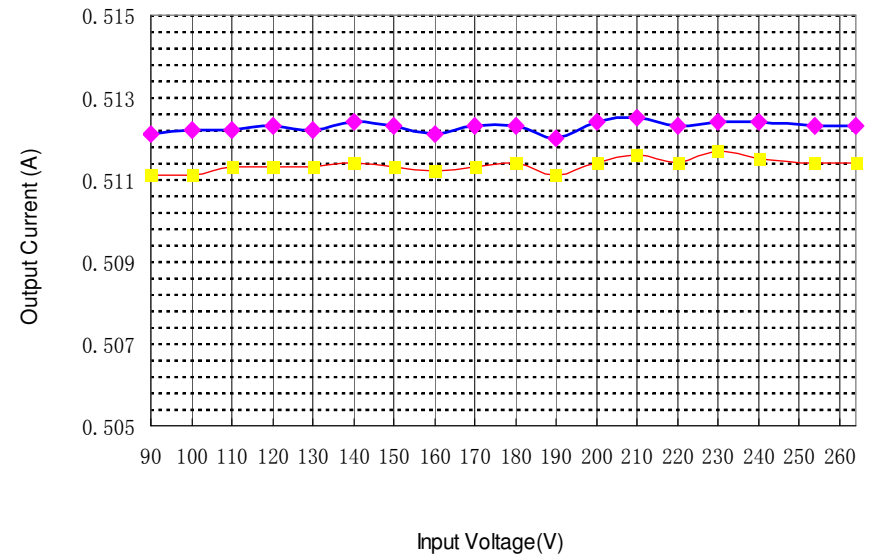


PMP4302: LED current output tolerance

230V ac input

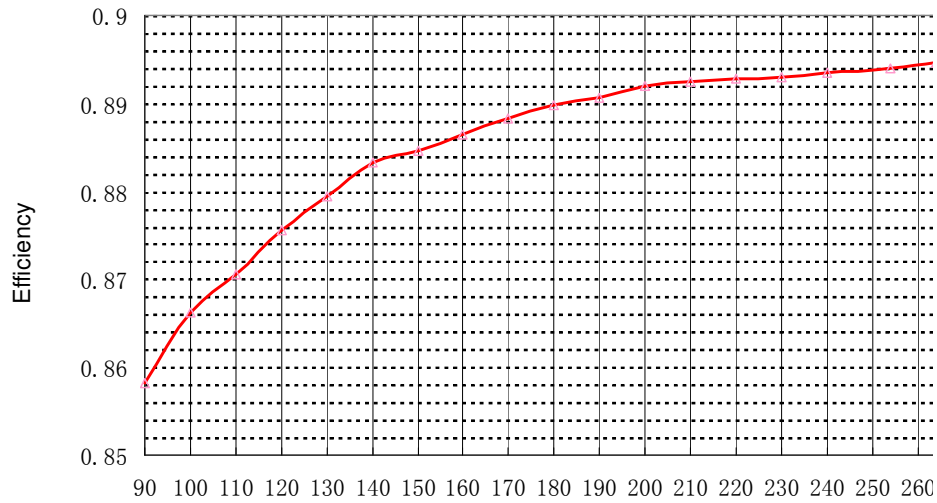
| PWM Dimming | Io1 | Io2 | Io3 | Io4 | % |
|-------------|-------|-------|-------|-------|-------|
| 1% | 4.9 | 4.8 | 5 | 5.1 | 3.030 |
| 2% | 10 | 9.8 | 10.4 | 10.3 | 2.962 |
| 5% | 25.2 | 24.1 | 25.2 | 25.1 | 2.208 |
| 10% | 50.4 | 49.7 | 51.5 | 51.3 | 1.774 |
| 20% | 100.9 | 100.1 | 102.7 | 102.5 | 1.280 |
| 30% | 151.4 | 150.4 | 154.1 | 153.6 | 1.214 |
| 40% | 201.9 | 200.9 | 205.1 | 204.9 | 1.033 |
| 50% | 252.4 | 251.1 | 256.4 | 255.8 | 1.043 |
| 60% | 302.9 | 301.4 | 307.7 | 307 | 1.033 |
| 70% | 353.5 | 351.8 | 358.6 | 357.8 | 0.956 |
| 80% | 403.9 | 402.2 | 409.7 | 408.8 | 0.923 |
| 90% | 454.3 | 452.2 | 461.1 | 460.1 | 0.973 |
| 99% | 499.3 | 496.7 | 507.2 | 506.2 | 1.045 |
| 100% | 503.9 | 501.4 | 512.4 | 511.7 | 1.084 |

LED output current Vs Input voltage w/ 100% dimming



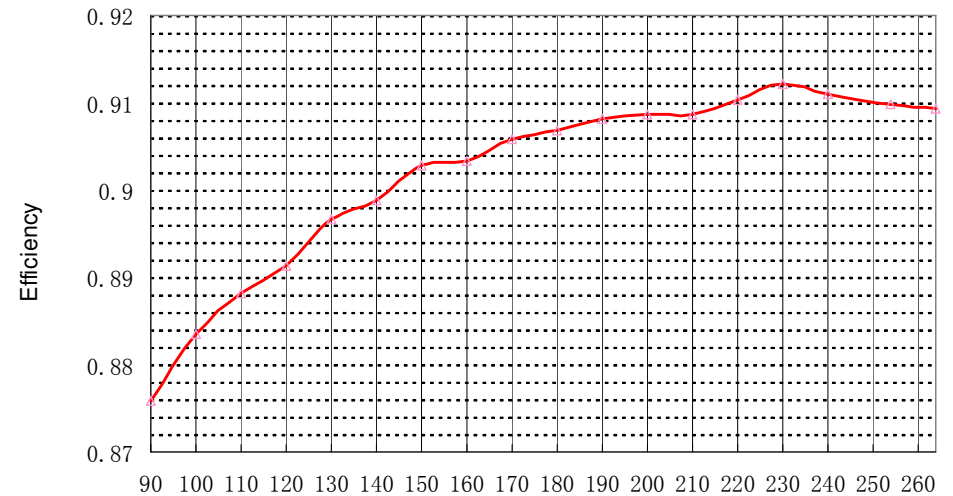
Current tolerance can achieve $\pm 3\%$ with dimming range from 1% to 100%

PMP4302: Efficiency (TM PFC + Multi-string LLC + Aux power)



Input Voltage(V)

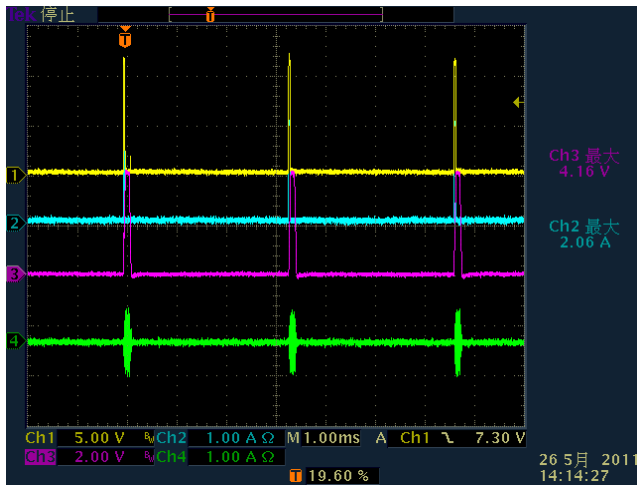
Dimming version



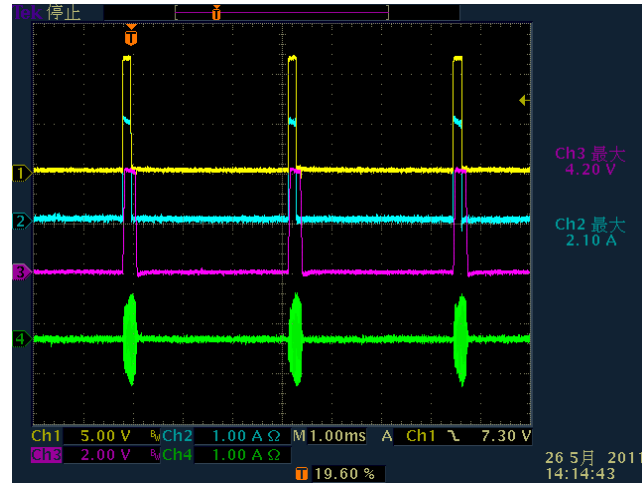
Input Voltage(V)

Non-Dimming version

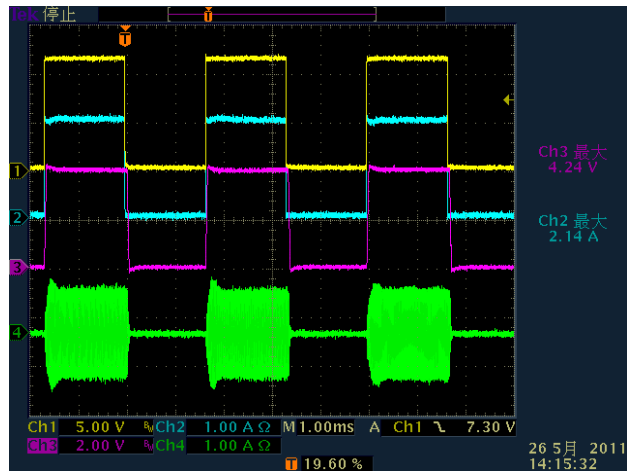
PMP4302: waveforms



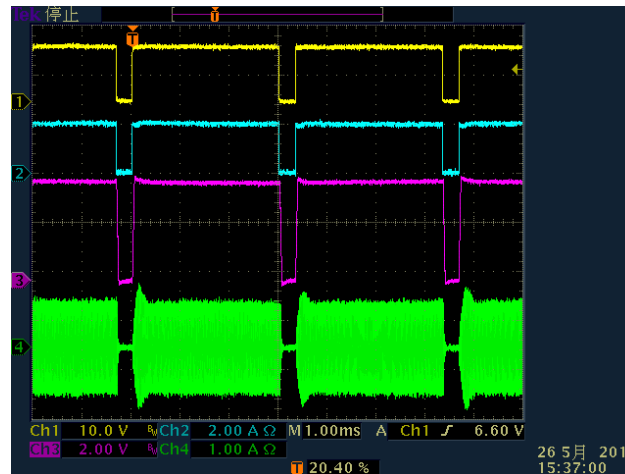
1% dimming



5% dimming



50% dimming



90% dimming

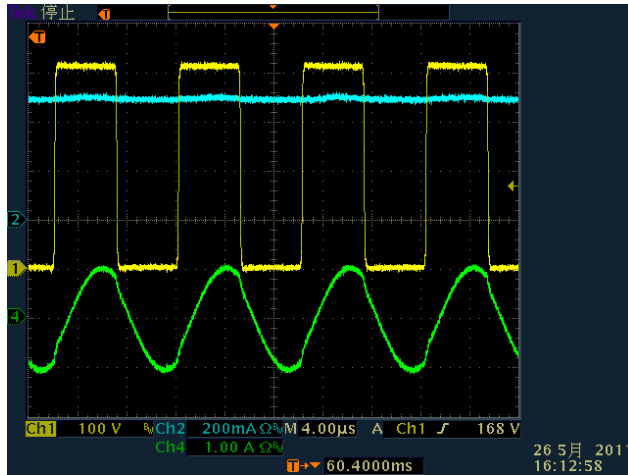
CH1: LEDSW
MOSFET V_{gs}
5V/Div

CH2: LED Output
Current 1A/Div

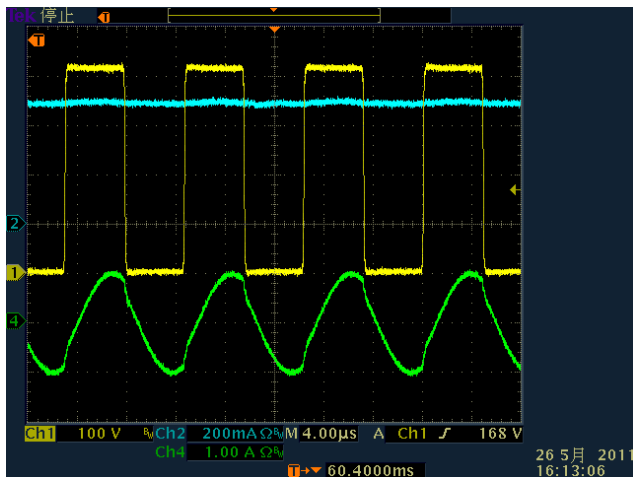
CH3: DSR 2V/Div

CH4: Primary
Current 1A/Div

PMP4302: waveforms



90Vac input



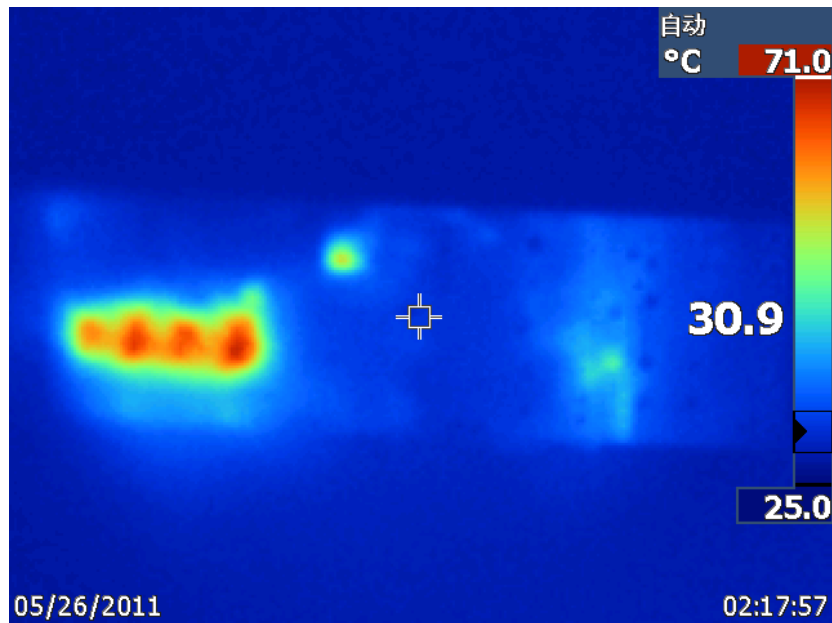
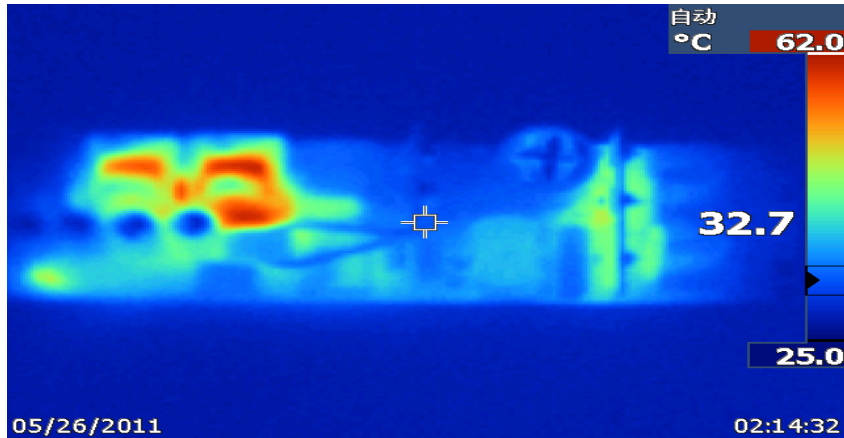
230Vac input

CH1: Primary MOSFET V_{ds} 100V/Div

CH2: LED Output Current 200mA/Div

CH4: Primary Current 1A/Div

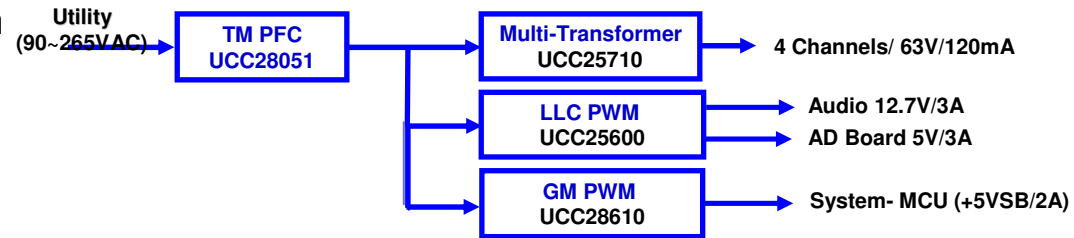
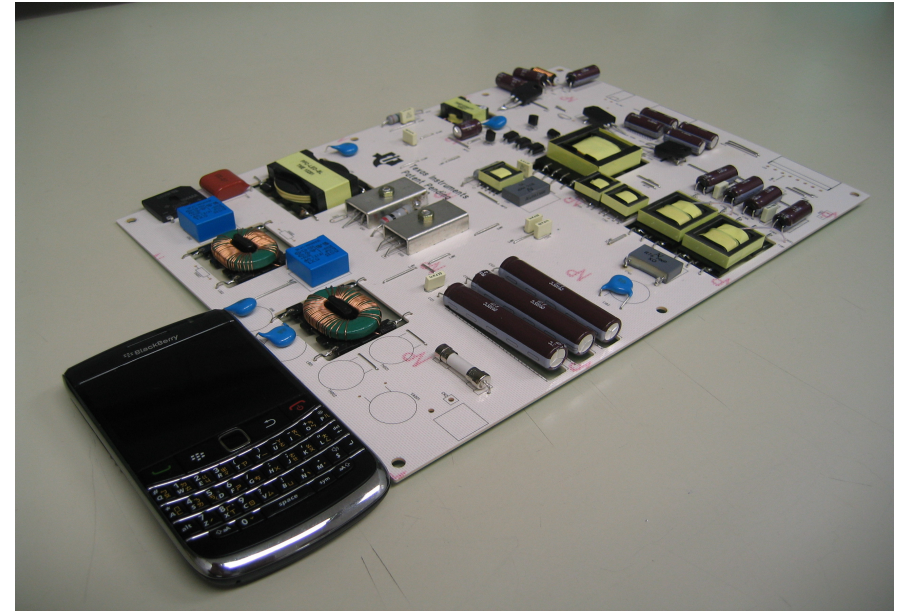
PMP4302: Thermal and Bode Plot



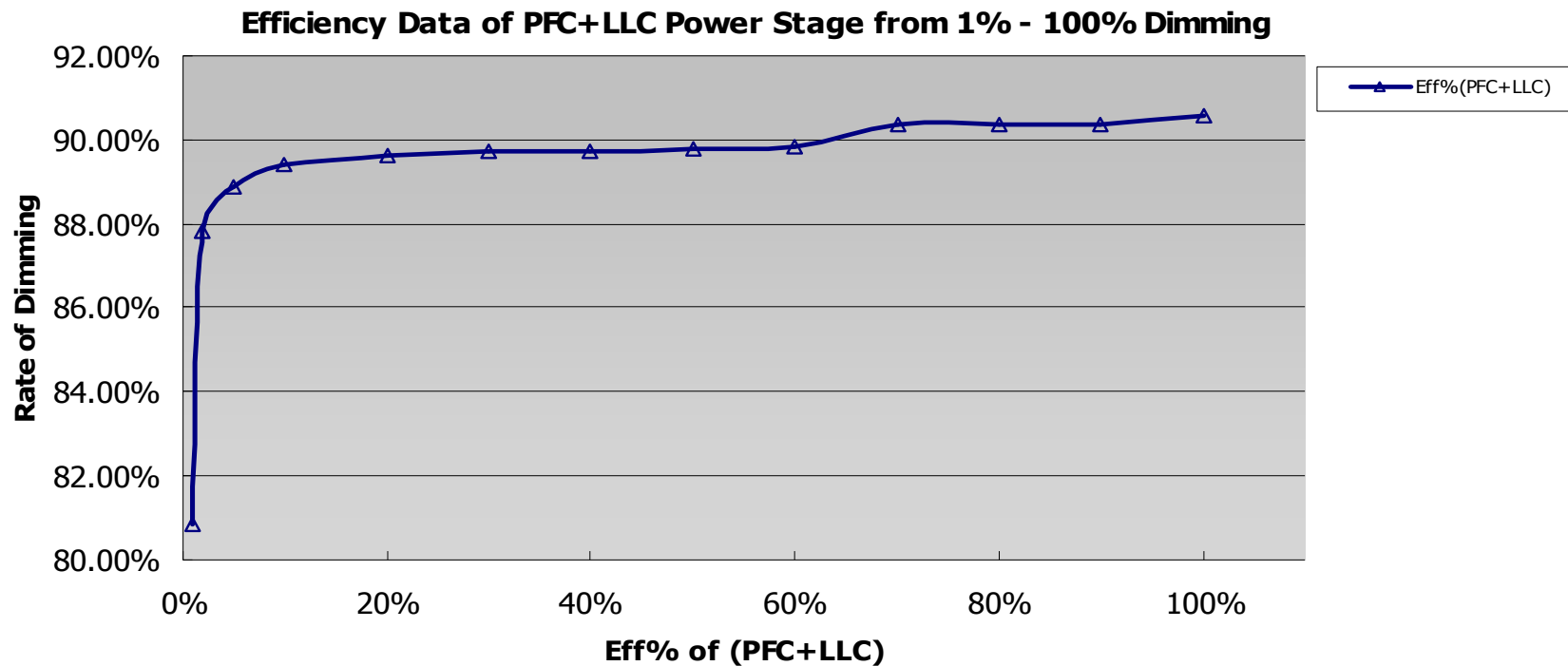
PMP6251: LED Backlighting for Edge-Lite/ Group Dimming Digital TV Application

Reference design Features

- Support to universal 90~264Vac range
- LED 4 outputs @120mA, 63V, 5Vsb@1A, 5V@3A, 13V@3A
- Eff 83.7%@110Vac, 85.2%@240Vac
- Secondary side 120Hz blanking control for dimming
- 8mm height and 6mm height for LED magnetic component
- Board dimension 300mm(L) * 200mm(W) * 8mm(H)
- LED output common + and LED OVP and UVP
- Integrated the protection ckt to reduce the solution part count.
- Dedicated controller for edge-lit/ group dimming base on the LLC topology – **UCC25710**
- Providing design package – Schematic, Gerbo file, PCB file, Magnetic components...



PMP6251: PFC+ Multi-string LLC Efficiency

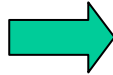


Efficiency exclude standby Power Converter at full load condition ~ 90%

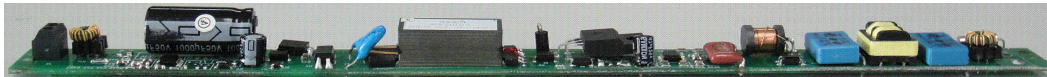
TI LED Driver Reference Design Solution

| Reference Design | TI Parts | Application | P _{out} | V _{in} | Output |
|--|----------------------|---------------------------------|------------------|------------------------|-------------------|
| PMP5541 : 12Vac input MR-16 LED (SEPIC) Reference Design | TPS40211 | MR16 | 3W | 12Vac | 11V 350mA |
| PMP4301 : AC input, T10/T8 LED Driver for Fluorescent Lamp | UCC28810 TL103 | Commercial Tube Lighting | 19 W | 90-264 V _{ac} | 40V 450 mA |
| PMP4304A : AC input, 7W TRIAC dimming LED lighting Driver | TPS92210 | PAR lighting w/ TRIAC | 7 W | 90-264 V _{ac} | 16V~25V 350 mA |
| PMP4288 : AC Input 200W AC/DC Power supply for Street LED lighting | UCC28061 UCC25600 | Street LED lighting for outdoor | 200 W | 90-264 V _{ac} | 54V 3.7A |
| PMP4302 : AC Input 110W AC/DC Power supply for Street LED lighting with multistring LLC | UCC28810 UCC25710 | Street LED lighting | 110W | 90-264 V _{ac} | 54V 700mAx4 |

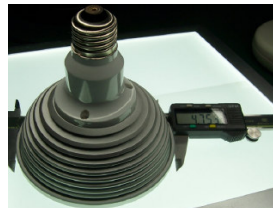
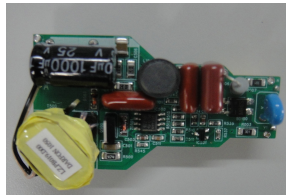
**MR16:
PMP5541**



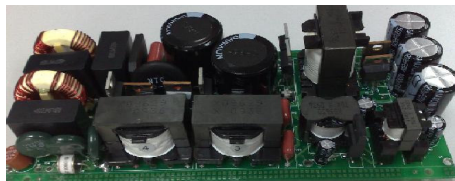
**Commercial:
PMP4301**



**Residential:
PMP4304**



**Outdoor:
PMP4288**



Visit www.ti.com/led for more LED driver reference designs

PMP4301: T10/T8 AC/DC LED Driver for Fluorescent Lamp

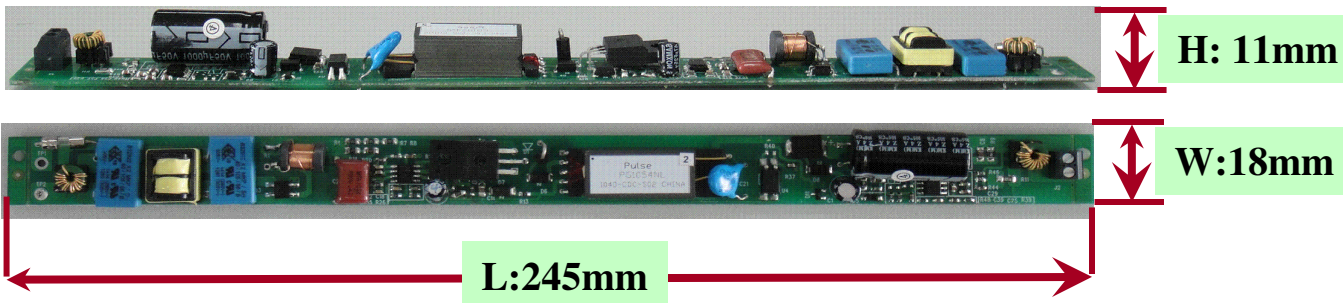
| Reference Design | TI Parts | V_{in} | P_o | V_o I_o | Topology | Dimming | Eff. | PF |
|---|----------|------------|-------|------------------|--|-------------|------|-------|
| <u>AC Input T8 AC/DC LED Lighting Driver for fluorescent lamp</u> | UCC28810 | 90~264 Vac | 20W | 30V~42V 450mA | Isolated single Stage high PF Flyback with Transition Mode | PWM dimming | >87% | >0.97 |

Features

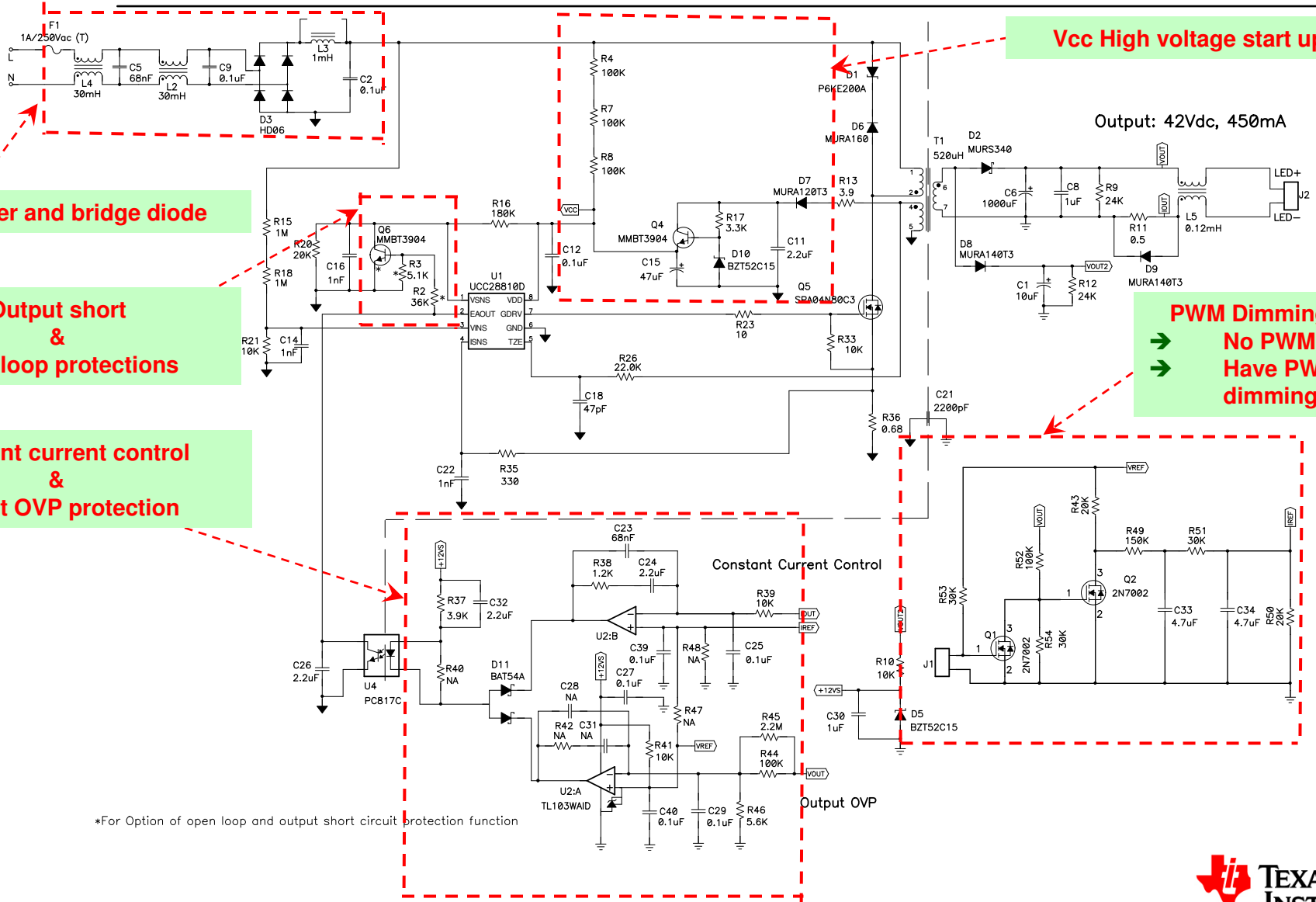
- Specific transformer for T8 lighting form factor
- PWM dimming compatible
- Low BOM cost
- Efficiency >87% at 230Vac input
- Isolated single stage w/ PF>0.97 at 230Vac input
- Output over voltage protection: 45Vdc
- Output ripple current: <30% of output current
- Size: 245mmX18mmx11mm (ultra-slim)

Applications

- T8 and T10 tube LED lighting
- Wall-wash LED lighting
- Commercial LED lighting with PWM dimming

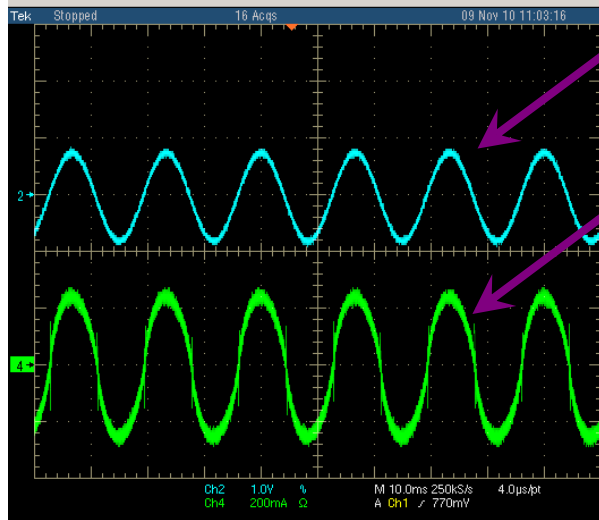


PMP4301: Schematics of Single Stage PFC with UCC28810

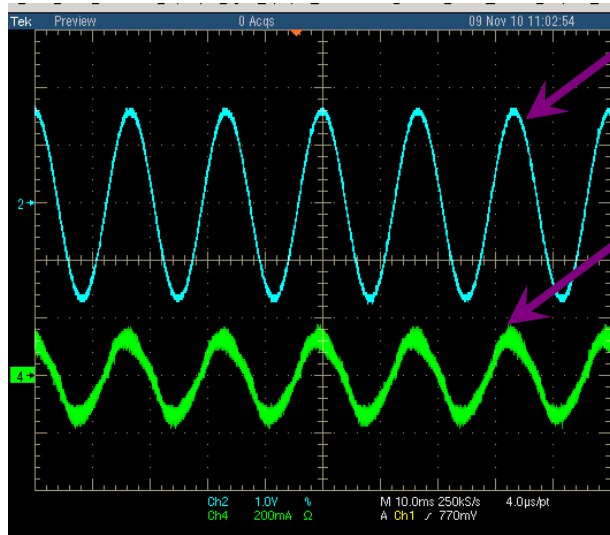


*For Option of open loop and output short circuit protection function

PMP4301: PFC & THD



Input with 110VAC



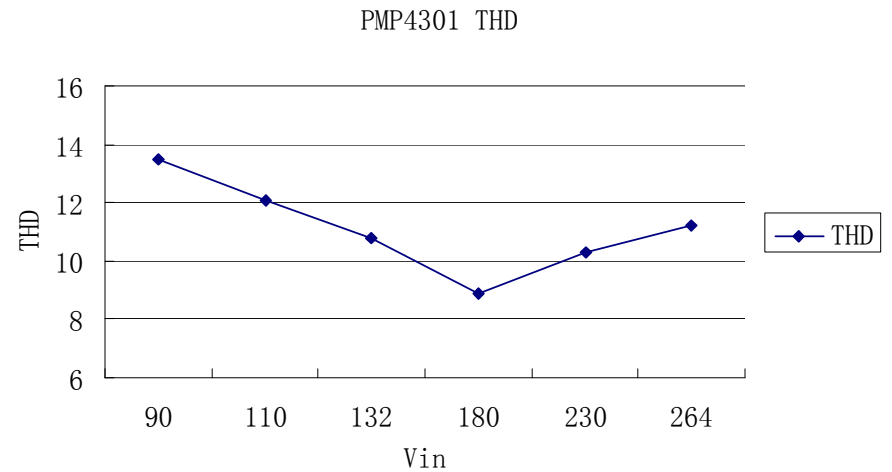
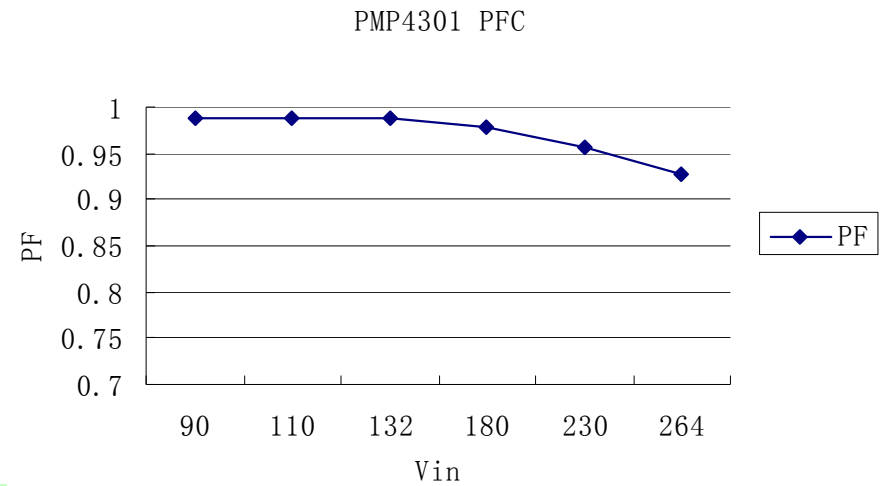
Input with 230VAC

Input Voltage
200V/div

Input Current
200mA/div

Input Voltage
200V/div

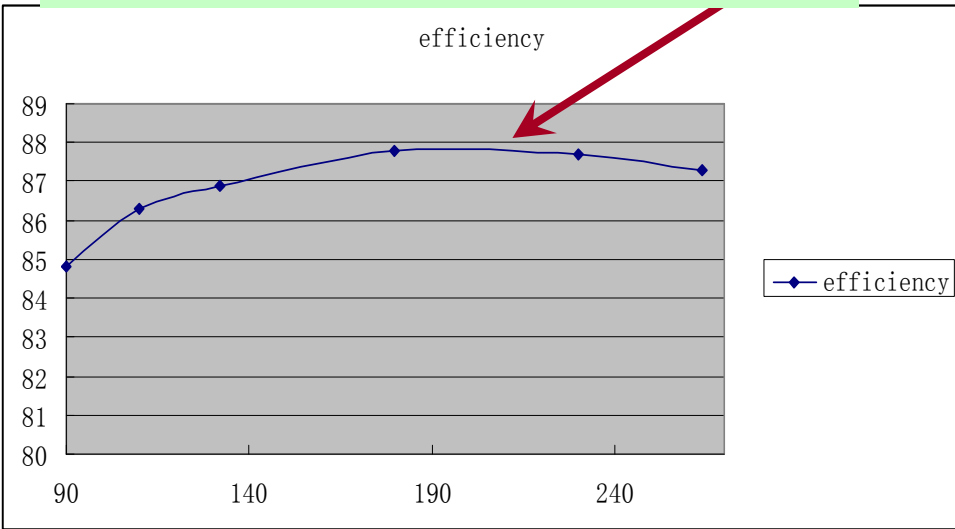
Input Current
200mA/div



PF > 0.92 w/ wide range input

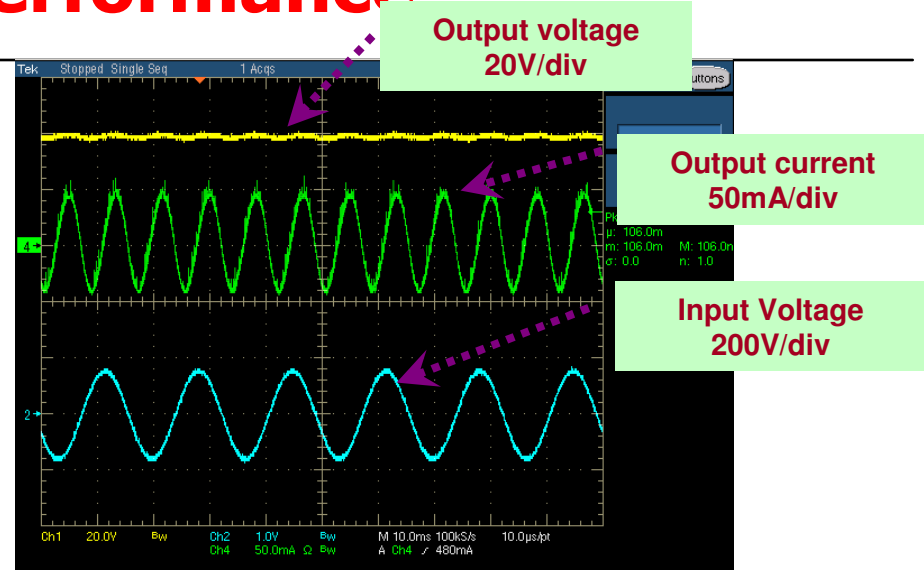
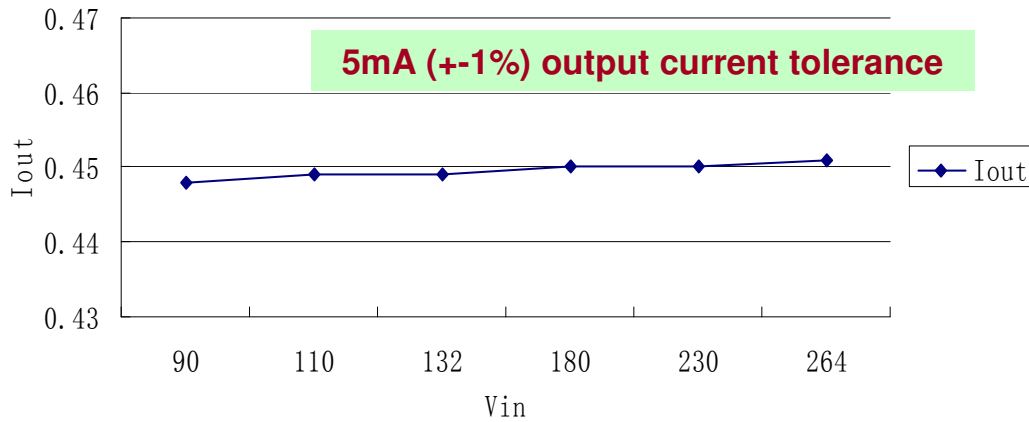
PMP4301: Performance

Peak efficiency is 87.7% at 110Vac & 220Vac

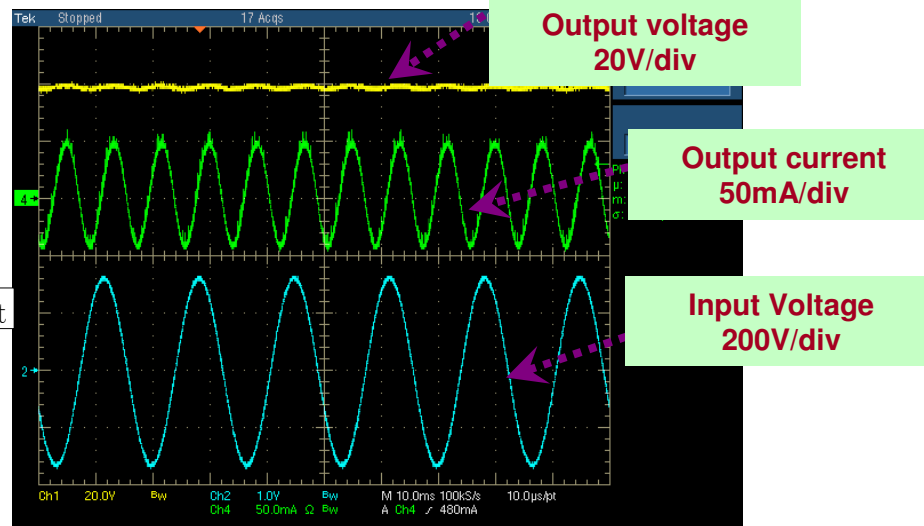


PMP4301 Iout

5mA (+-1%) output current tolerance



Output ripple current with 110VAC input



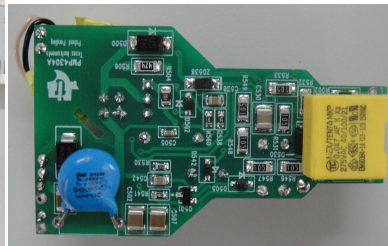
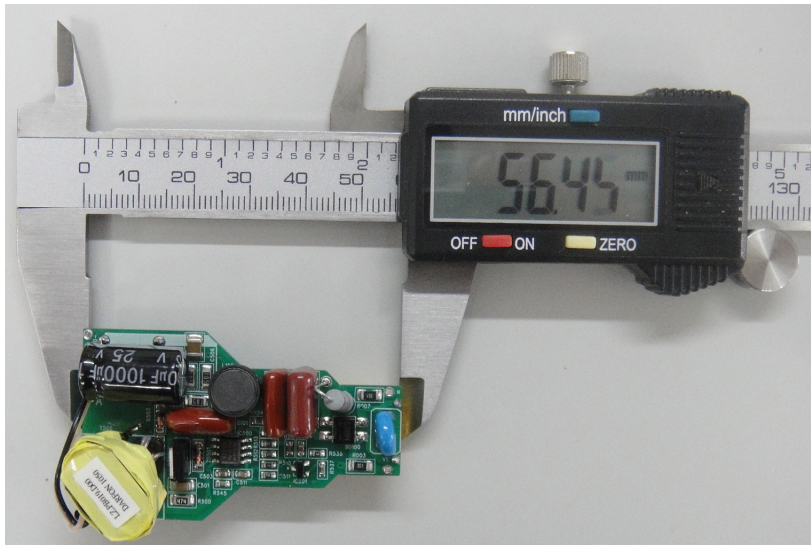
Output ripple current with 220VAC input

PMP4304: 7W TRIAC dimming LED lighting Driver

| Reference Design | TI Parts | V_{in} | P_o | V_o I_o | Topology | Eff. | PF |
|---|-------------------|----------------|-------|--------------------------------|--|------|-------|
| <u>AC Input 7W AC/DC LED Lighting Driver /w TRIAC dimming</u> | TPS92210 TL431 | 180-265 Vac | 7W | 16V~25V 350mA (5~7 LEDs) | Singe Stage high PF with TRIAC dimming | ~80% | >0.95 |

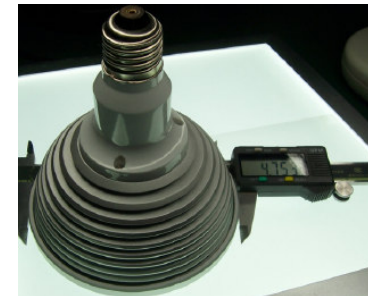
Features

- 50 components counts with low BOM cost
- TRIAC dimmable solutions without flicking
- Primary side controls without opto-coupler
- Constant On-time control with high power factor



Applications

- PAR20/30/38 LED Lighting
- Small form factor indoor Lighting



PMP4304 Schematics with TPS92210

Hold up dummy load

Differential EMI filter

Cascade Flyback

Damp resistors

Peak voltage feed forward

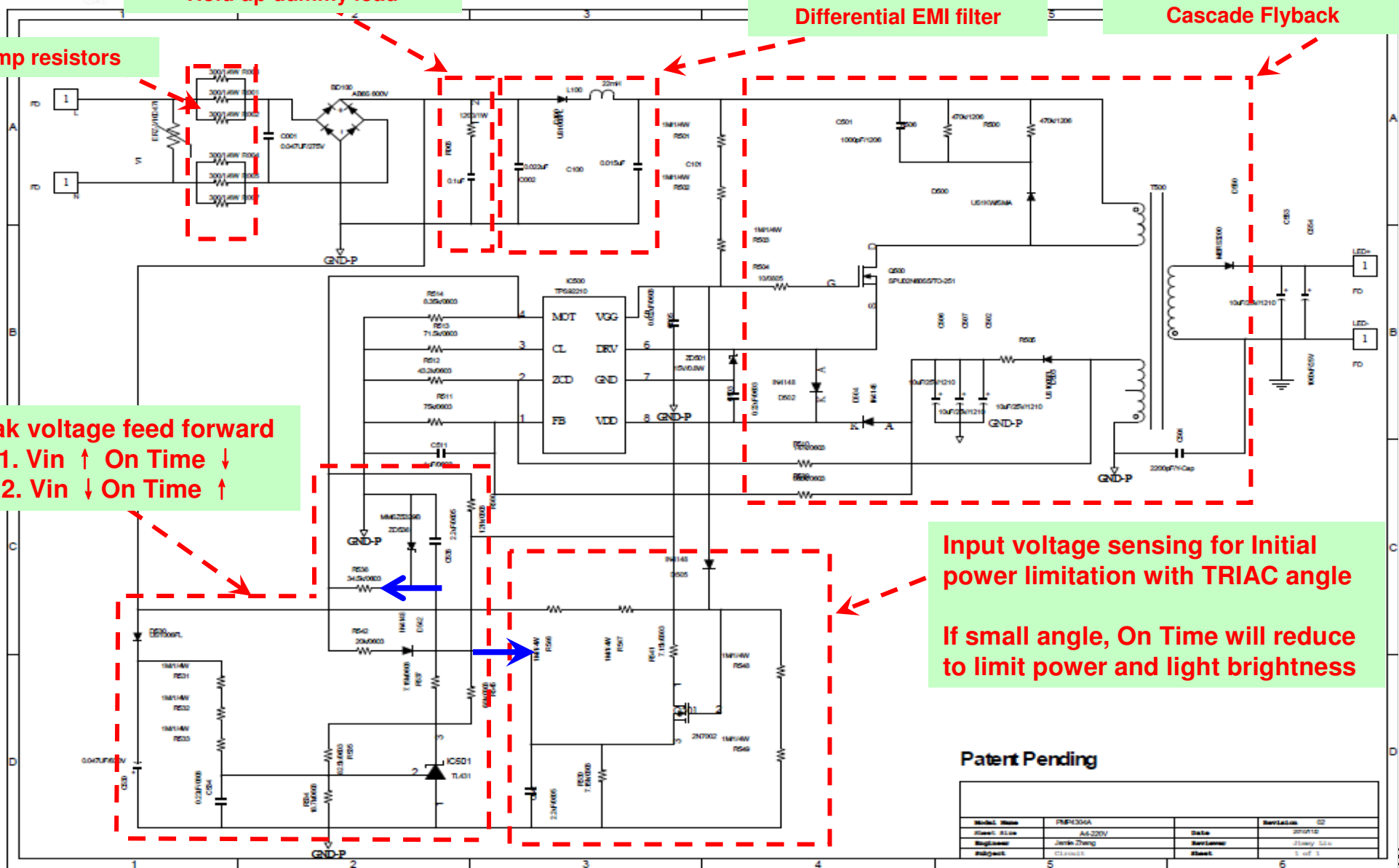
1. Vin ↑ On Time ↓
2. Vin ↓ On Time ↑

Input voltage sensing for Initial power limitation with TRIAC angle

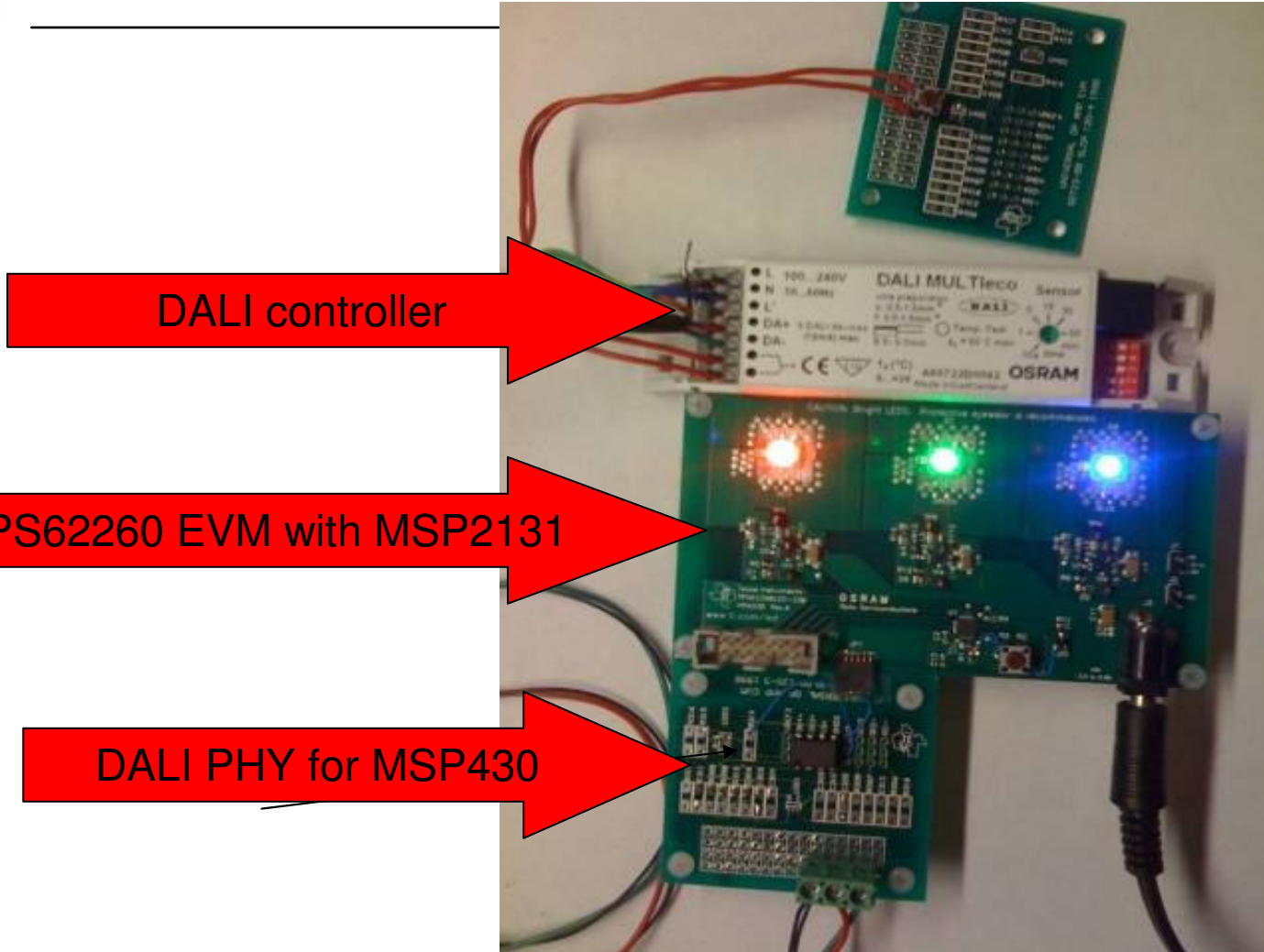
If small angle, On Time will reduce to limit power and light brightness

Patent Pending

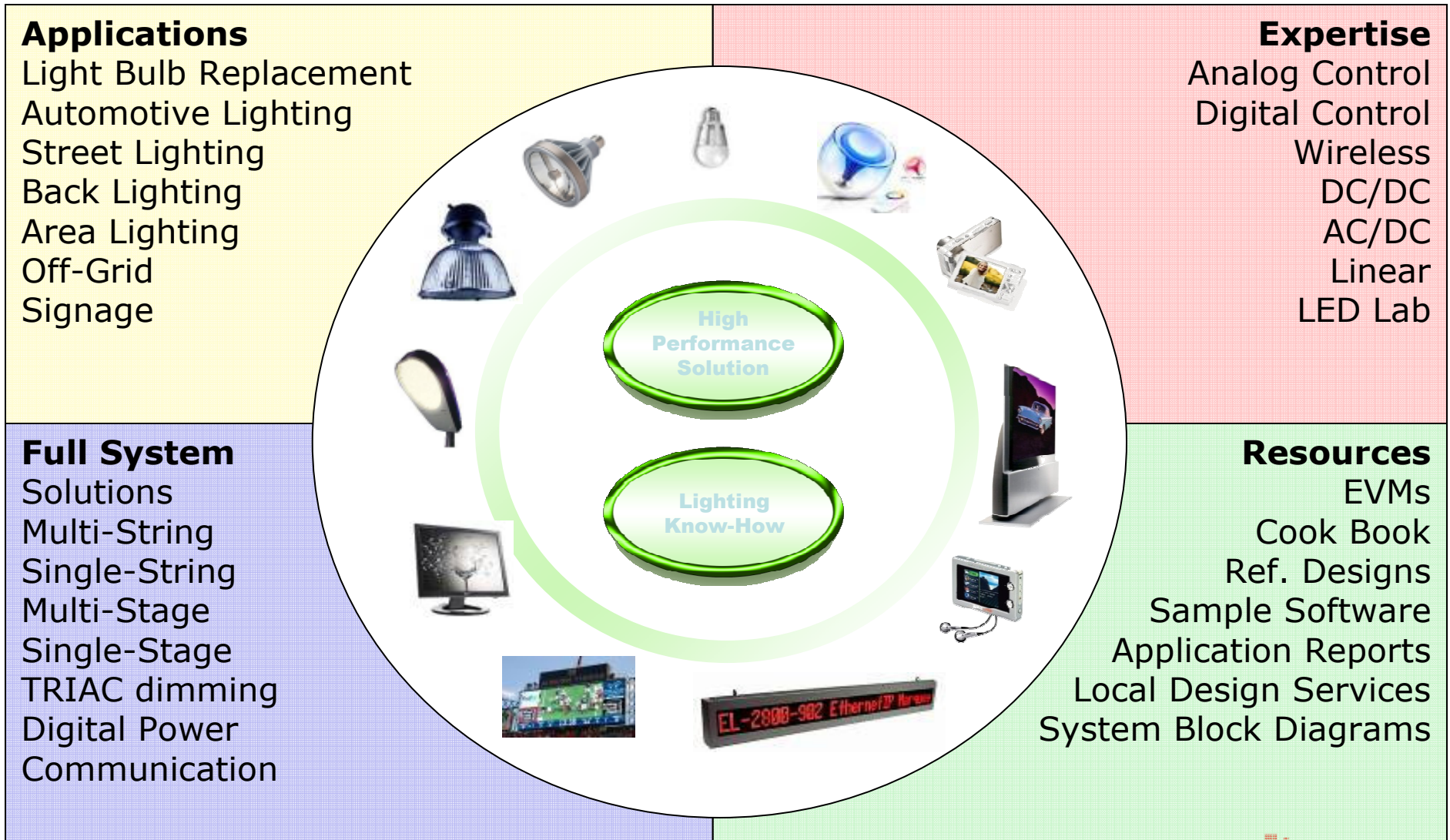
| | | | |
|--------------|------------|--------|------------|
| Michel Steen | PMP4304A | Date | Revision |
| David Allen | 24-220V | Date | 201210 |
| Engineer | Jian Zhang | Author | Jian Zhang |
| Subject | 03-00001 | Sheet | 1 of 1 |



DALI Demo and Evaluation Platform



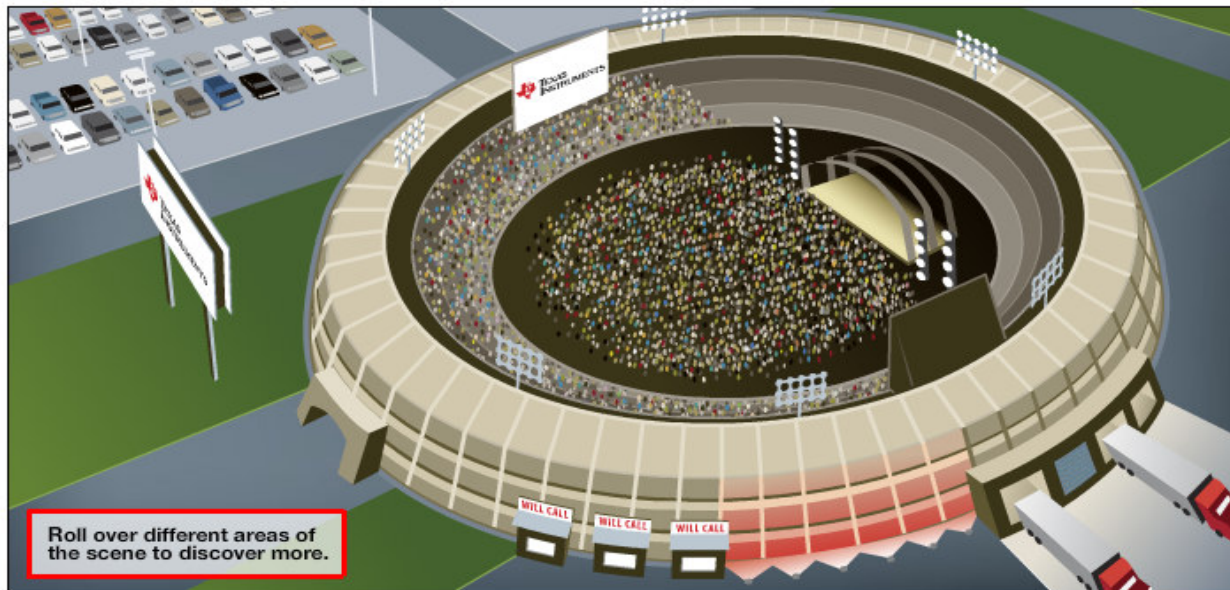
TI LED Lighting Solutions



LED Driver, Lighting & Display Solutions

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Complete solutions for LCD backlighting, signage, information displays, LCD HDTV, general LED lighting, automotive and more.



Texas Instruments provides a broad portfolio of high-performance products for your LED design needs. From RF and power management (including AC/DC, Power Factor

News Releases

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

Texas Instruments Piccolo™ 32-bit microcontrollers bring real-time control for greater energy efficiency to cost-sensitive applications

Contributed Articles

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

LED Reference Design Cookbook



LED Reference Design Cookbook

Contents

| Configuration | Driving Option | R_{LED} | R_{LED} (Typ) | Typ PWR | Device | Page |
|---------------|----------------|-----------------------------|------------------------|-------------|----------|------|
| 1 LED | Simple PWM | 1 to 11 R_{LED} | 20 to 20 maximum | 700 maximum | T50-H001 | 4 |
| 1 LED | — | 2.0 to 0.5 R_{LED} | 2 typical | 20 per LED | T50-H001 | 4 |
| 1 LED | Simple PWM | 1 to 11 R_{LED} | 1 typical | 300 | T50-H001 | 5 |
| 1 LED | Active PWM | 4 to 24 R_{LED} | 16 to 40 | 300 | T50-H001 | 10 |
| 1 to 12 LEDs | — | 100 to 200 R_{LED} | — | 700 | UC1201B | 12 |
| 20 LEDs | TRAC driver | 100 to 200 R_{LED} | 200 maximum | 200 | UC1201B | 14 |
| 7 to 8 LEDs | TRAC driver | 90 to 100 R_{LED} | 24 to 32 | 400 | T50-H001 | 18 |
| 10 LEDs | TRAC driver | 90 to 100 R_{LED} | 24 to 32 | 700 | UC1201B | 20 |
| 7 to 8 LEDs | PWM | 90 to 200 R_{LED} | 25 to 100 | 400 | UC1201B | 22 |
| 10 LEDs | Active PWM | 90 to 200 R_{LED} | 25 to 100 | 700 | UC1201B | 24 |
| 1 to 8 LEDs | — | 120 to 200 R_{LED} | 24 typical | 300 | T50-H001 | 30 |
| 1 LED (Shunt) | — | 4.0 to 0.5 R_{LED} | 2 typical | 100 per LED | — | — |
| 1 to 8 LEDs | Dual-Driver | 1.2 to 1/2 R_{LED} | 1 typical | — | — | — |

2011 Fresh Off the Press
Chinese Version ready now!

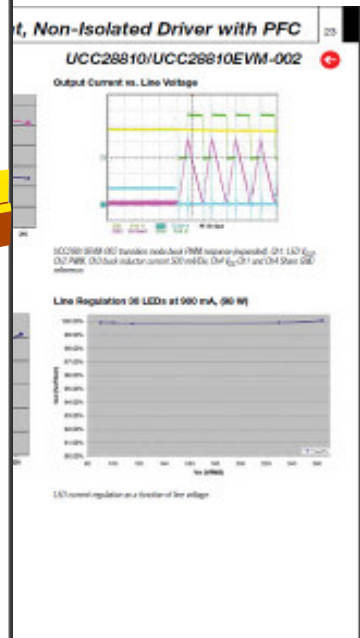
Current Driver with PFC

P4501

Prevents dangerous output voltages from occurring during open-circuit 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 covers:

- 100W to 1000W
- 100V to 400V
- 100mA to 10A
- 100kHz to 10kHz

Web Links:
Data sheets, user's guide, samples:
www.ti.com/lit/zip/TIUC22810



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

Thank you