



# 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

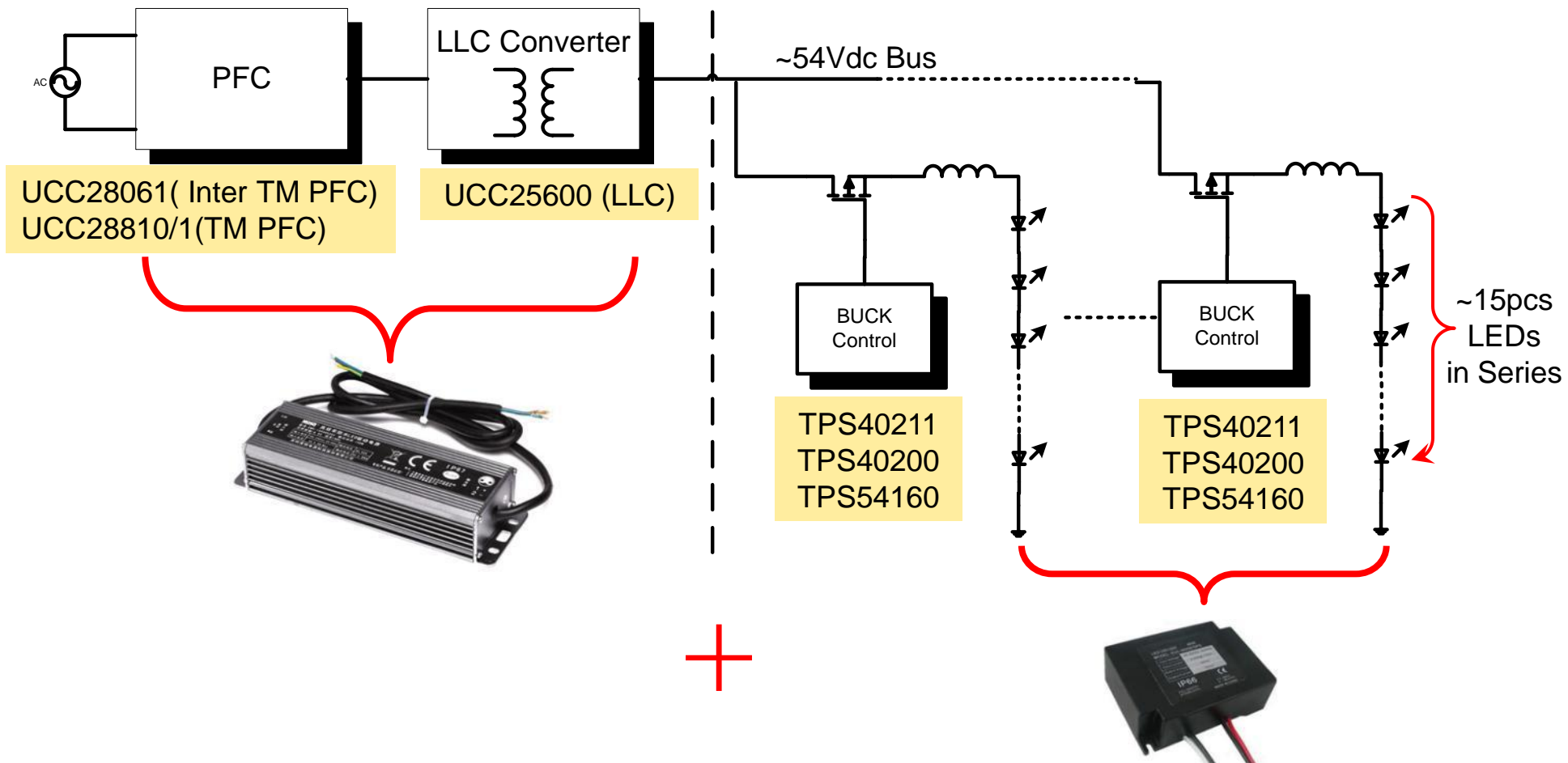
# LED 通用照明



# 典型高瓦特（高于 100W）LED 照明驱动器拓扑

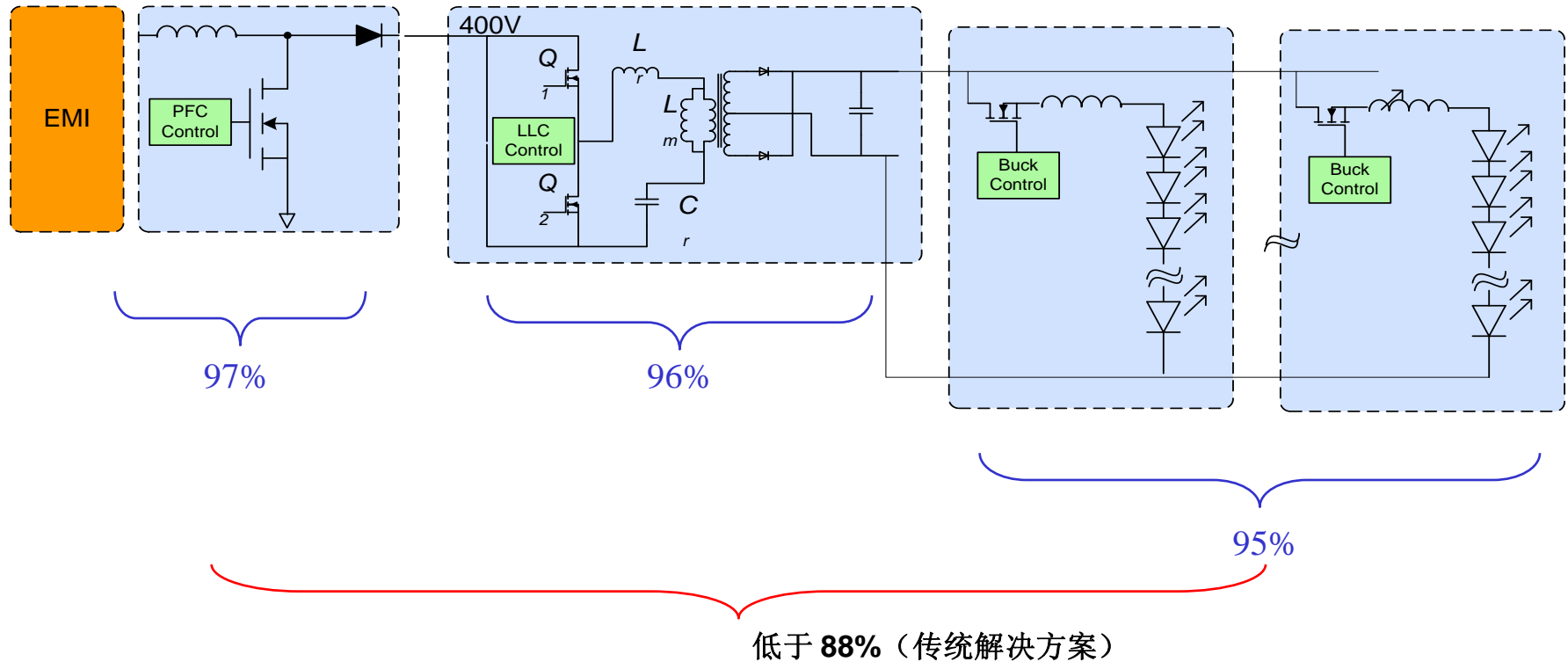
## 1. AC/DC 功率级

## 2. 恒定电流驱动器级



# 高瓦（高于 100W）LED 照明效率预算

Outdoor and Industrial >100W



传统拓扑问题:

- ☹️ 高成本: PFC+LLC+CC BUCK (多芯片!!)
- ☹️ 低效率 (<~88%)
- ☹️ 低可靠性 (许多组件数量)

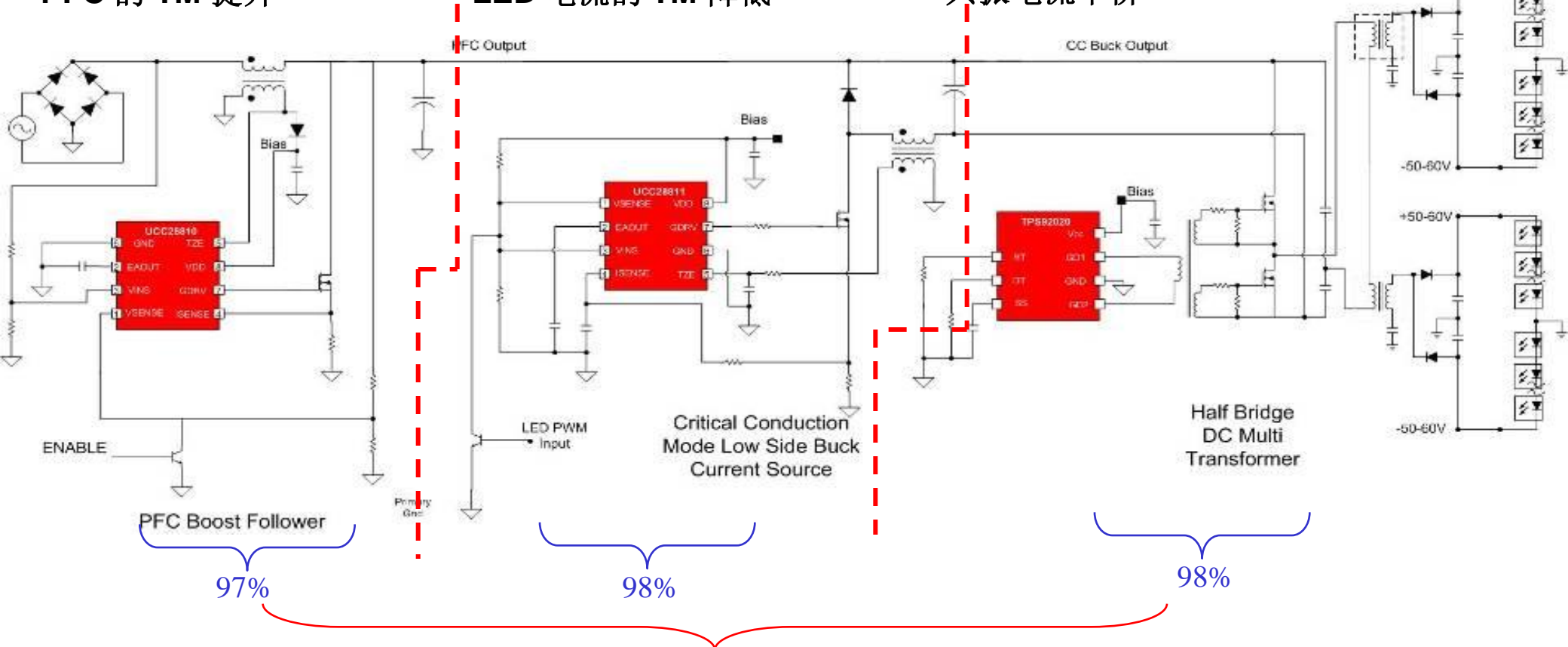
# TI UCC28810EVM-003 - SIMPLERdrive™

串行输入、多并行等价 LED 驱动器 (SIMPLERdrive)

1 级:  
PFC 的 TM 提升

2 级:  
LED 电流的 TM 降低

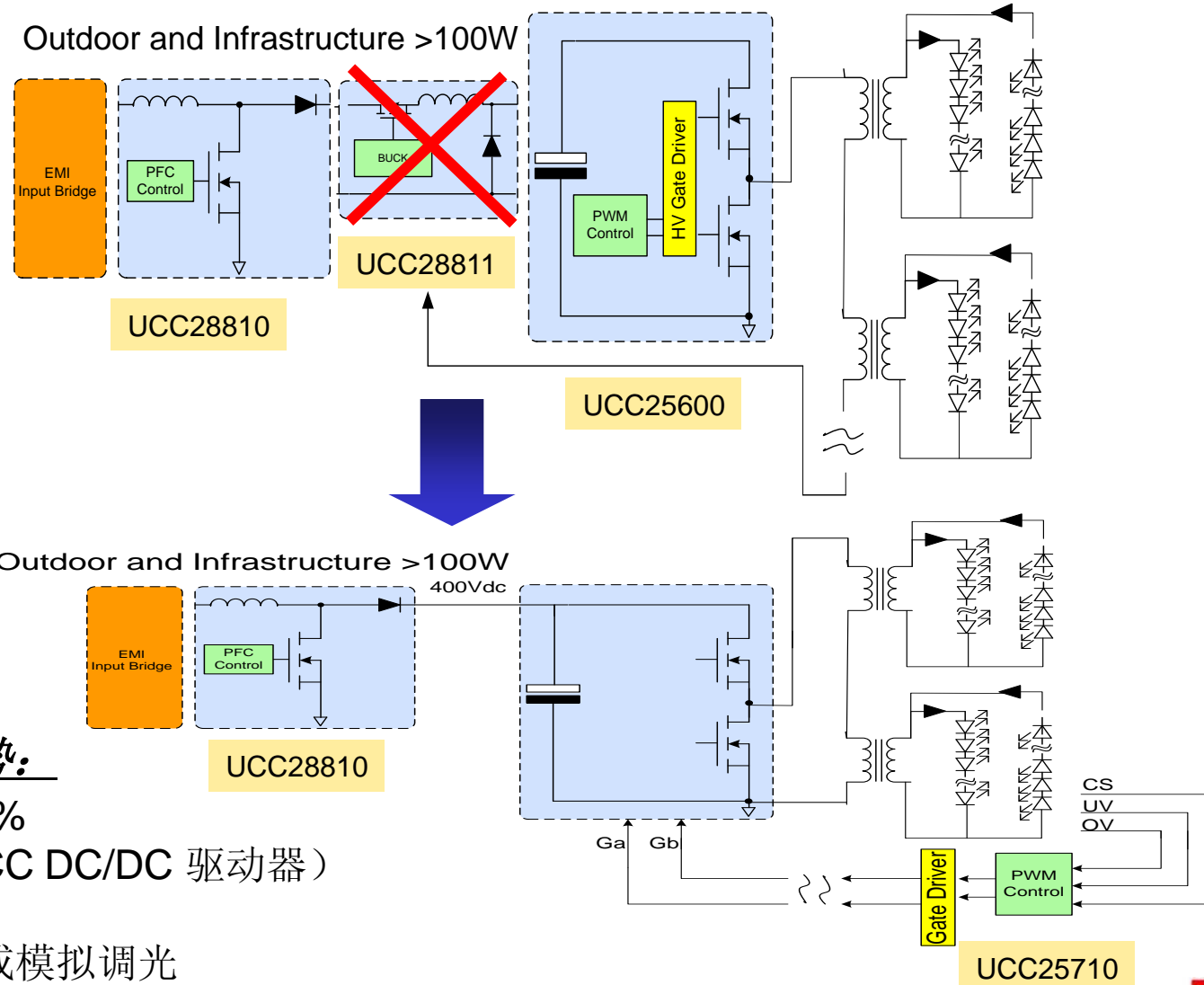
3 级:  
共振电流半桥



大于 93% (三级多串变压器解决方案)



# LED 照明的创新型双级多串 LLC 拓扑

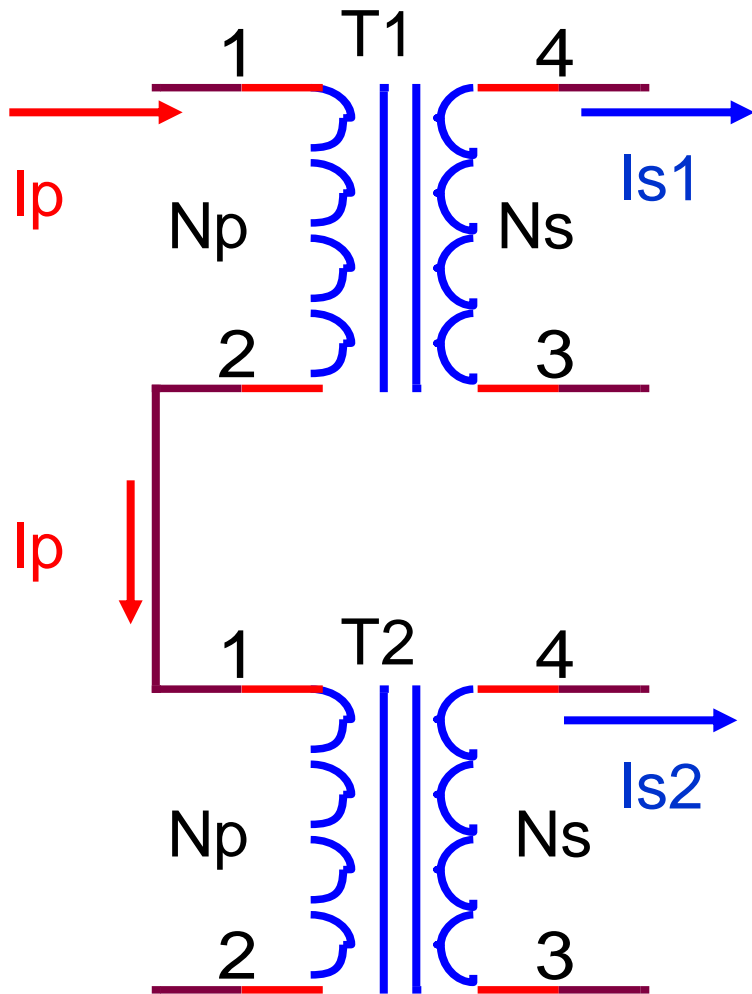


新品

## 推荐拓扑的优势:

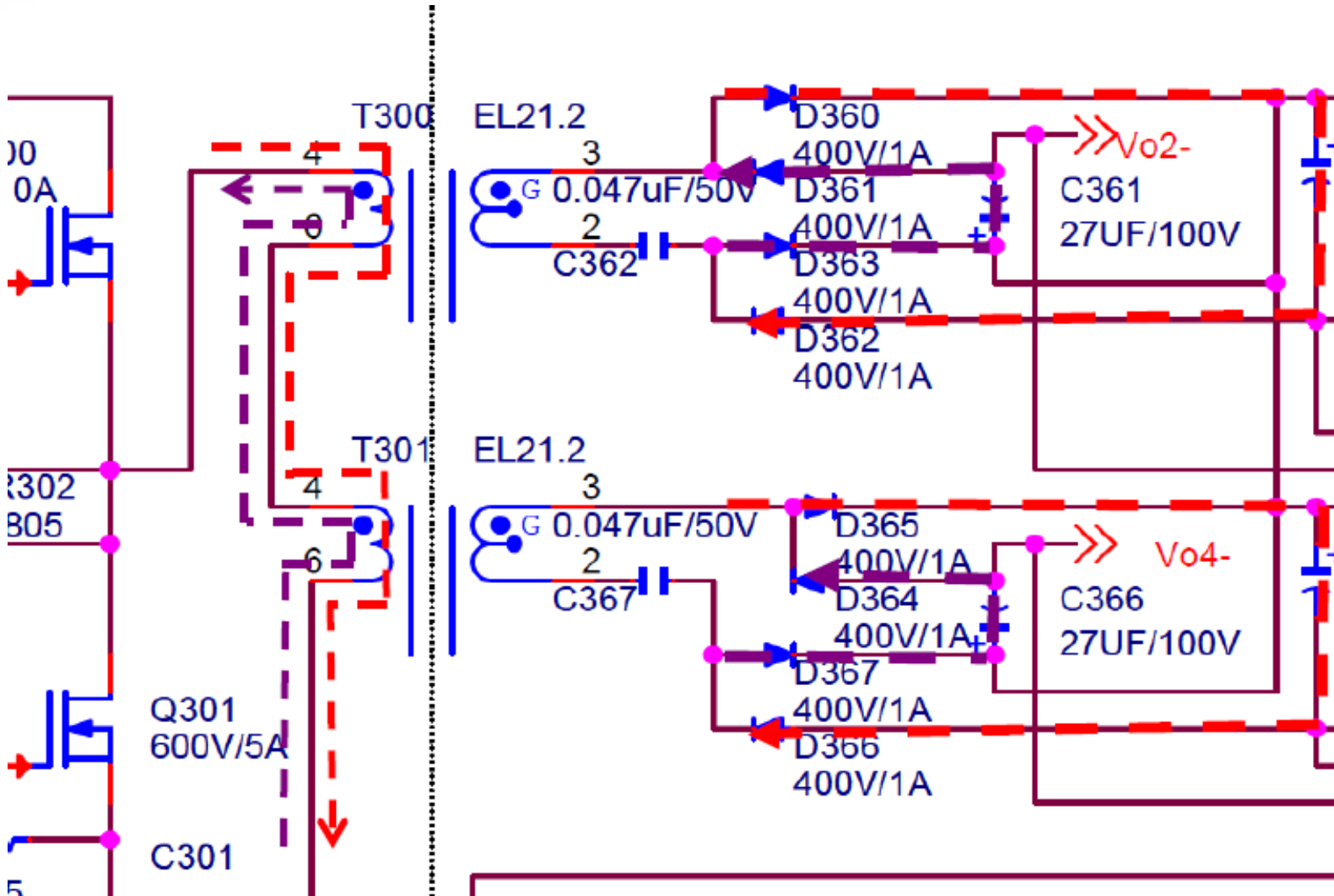
- ☺ 高效率: 约 92%
- ☺ 低成本 (无需CC DC/DC 驱动器)
- ☺ 高可靠性
- ☺ 兼容于 PWM 或模拟调光

# 变压器为何能平衡电流



- 变压器电流与转换率成反比
- $I_p/N_p = I_s/N_s$ ;  $I_s = N_s * I_p / N_p$
- 基本变压器连接在一起时，其基本电流必须相同
- T1 与 T2 相同，因为变压器工作原理要求二级电流相同
- $I_{s1} = N_s * I_p / N_p = I_{s2}$

# 多变压器架构 (TI 专利)





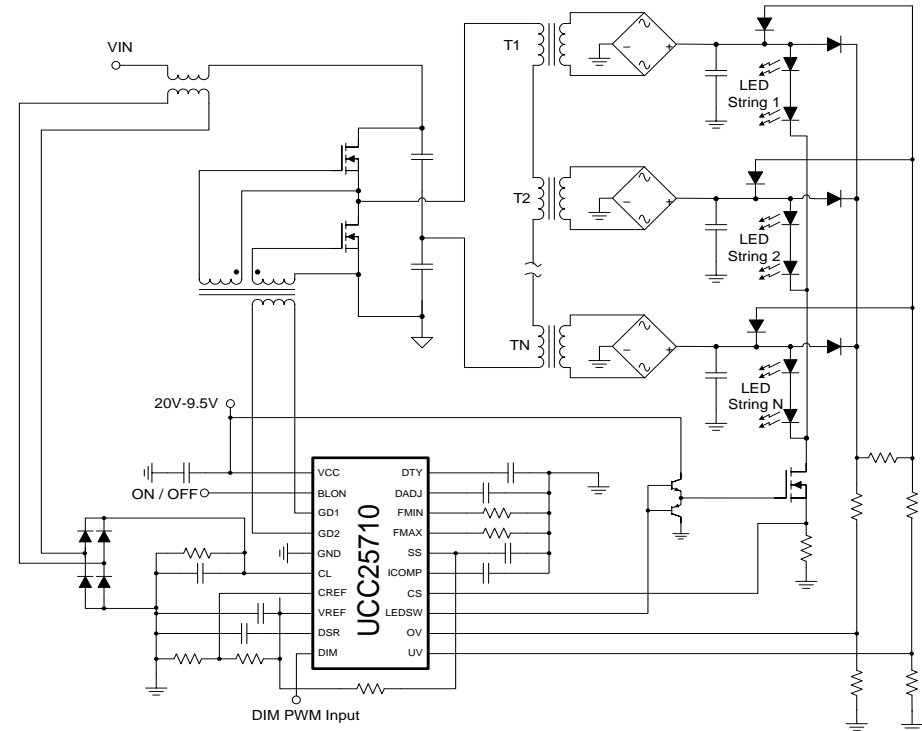
# UCC25710: LED 驱动器控制器 IC

## Features

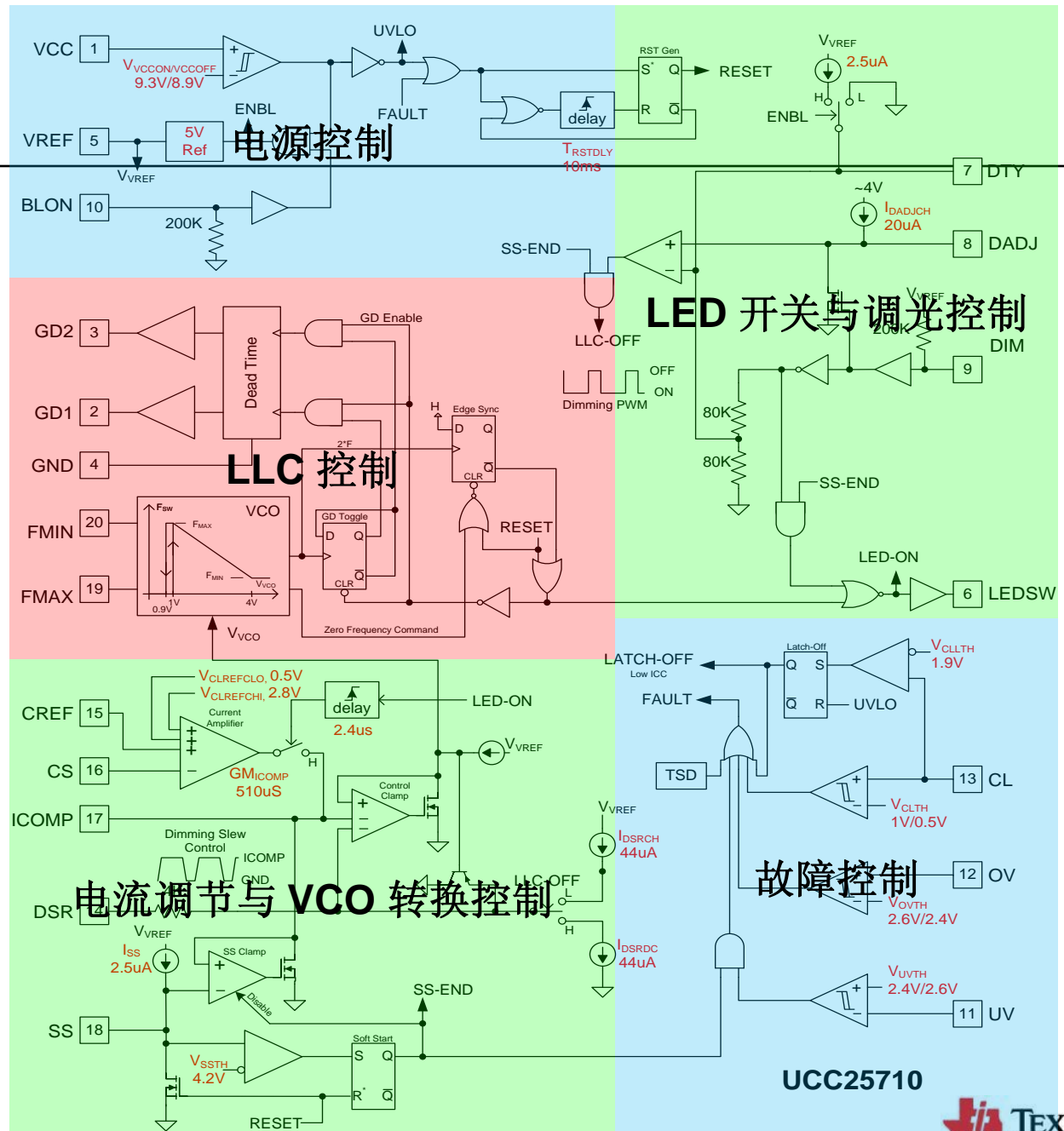
- 业界首款直接通过 PFC 输出驱动多个 LED 串的单芯片 LLC 控制器
- 可调节  $F_{min}$  (3% 准确度) 和  $F_{max}$  6% (准确度)
- 闭环 LED 串电流控制
- PWM 调光输入
- LLC 与串联 LED 开关控制支持调光
- 可编程调光 LLC 开关斜坡, 可消除噪声
- 可在低调光占空比下支持闭环电流控制
- 可编程软启动
- 准确的  $V_{REF}$  可实现严格的调节输出
- 过压、欠压与输入过流保护, 支持自动重启响应
- 二级过流阈值支持锁定响应
- +400-mA/-800mA 门驱动电流
- 低启动电流与低工作电流
- 20 引脚 SO 无铅 (Pb) 封装

## Applications

- 通用 LED 照明
- LED 电视背光



# UCC25710 方框图



# UCC25710: 调光 — LLC 开关转换与电流控制

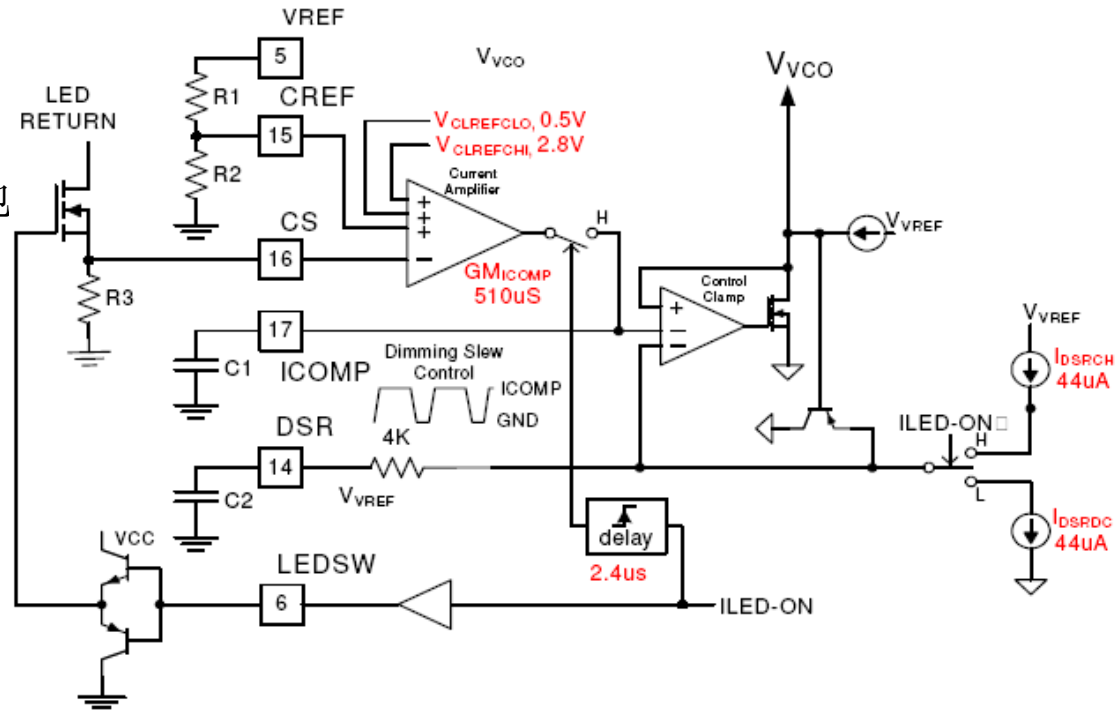
- DIM 输入可控制 ILED-ON 信号 ILED-ON

- DSR 电容器 C2 与内部 44uA 电流 可在调光开关转换时控制  $V_{VCO}$  的压摆率
  - 断开: DSR 由 44uA 电流放电至接地
  - 开启: DSR 由 44uA 电流充电至 ICOMP。充电标准可钳位至高于 ICOMP 的  $1V_{be}$

- 控制钳位输出  $V_{VCO}$  可跟踪更低的 ICOMP 与 DSR

- 在 LED-ON 时, ICOMP 仅由 GM 放大器驱动

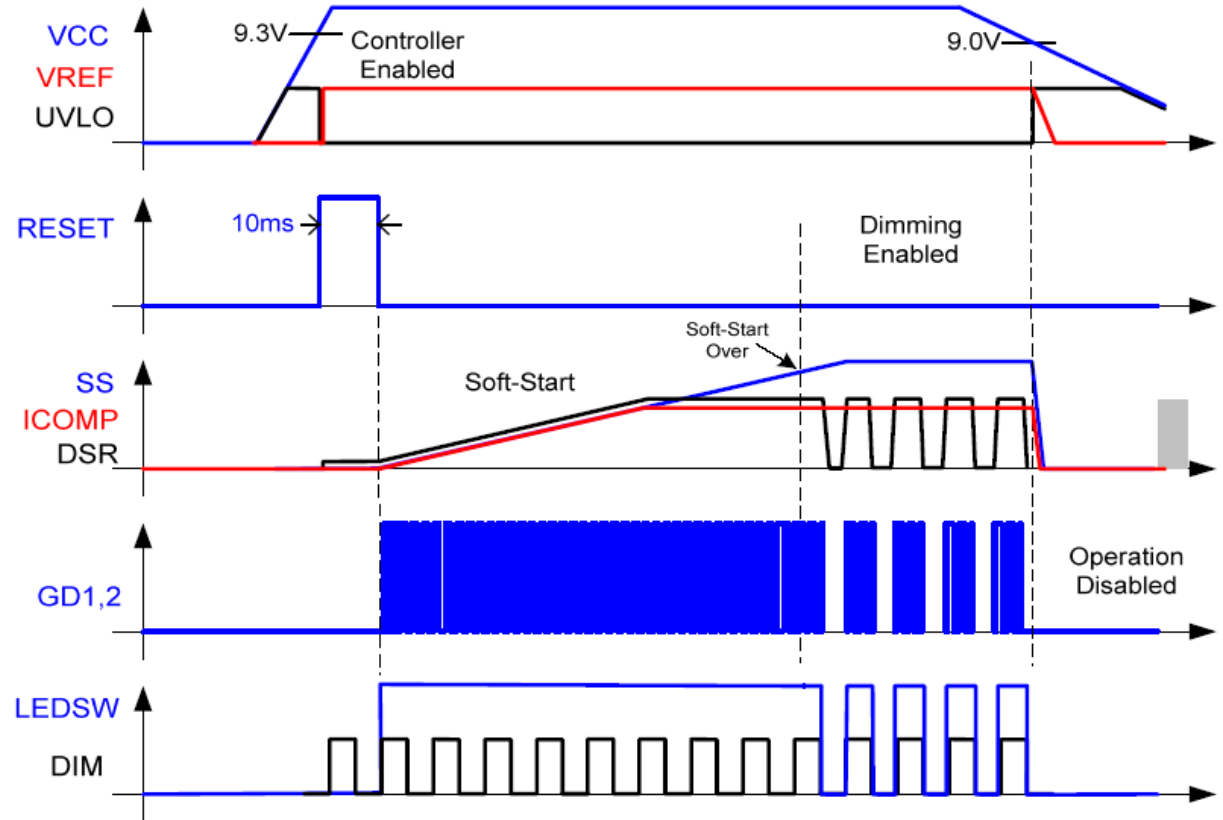
- 在 LED-OFF 时, ICOMP 电压由 C1 控制



# UCC25710: 启动与 DIM 波形

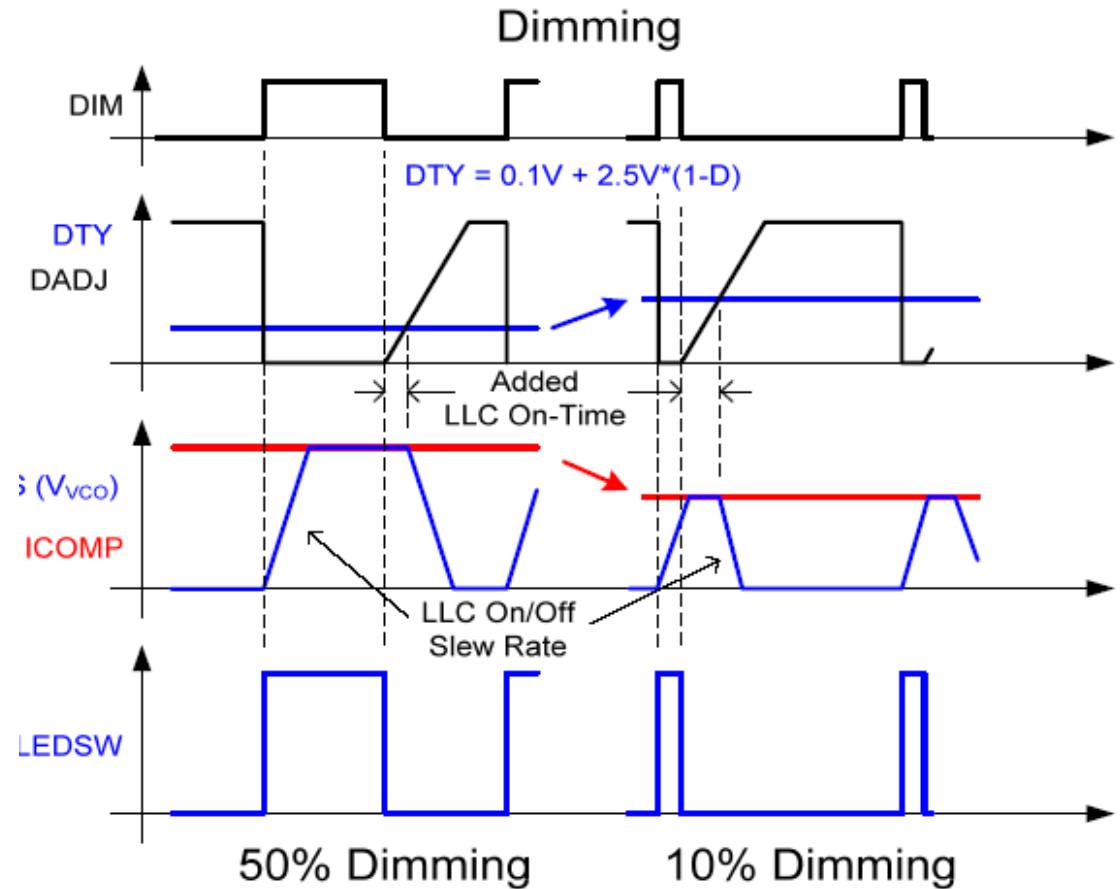
- 10ms RESET 可启动软启动 (SS)
- LLC 软启动, VCO 控制可错位至 SS, 直到  $SS > ICOMP$
- 在 SS 过程中可禁用调光
- 在调光过程中, DSR 电容可用于限制 LLC 控制压摆率
- 在调光过程中可保持 ICOMP 电压

启动与 UVLO 关断



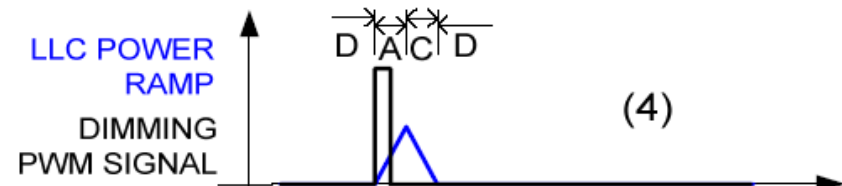
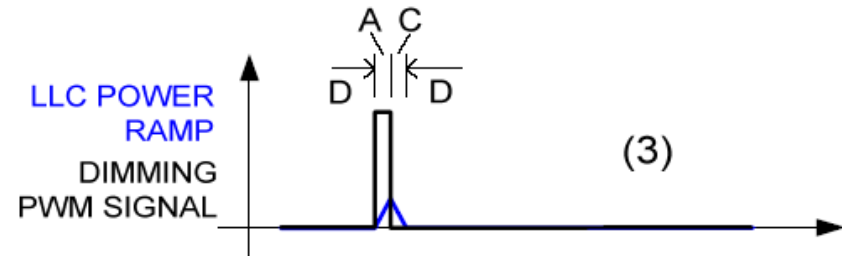
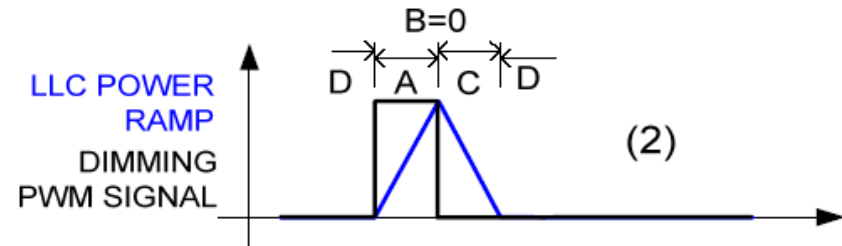
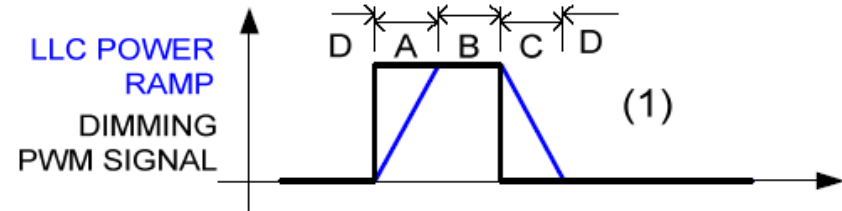
# UCC25710: 调光 — 波形

- DIM 输入可控制 LEDSW
- DIM 输入可触发 LLC 转换器的软开关
- LLC 接通时间可延长
- 接通时间的延长和  $1-D$  成比例， $D$  为调光占空比
- 延长的接通时间使 ICOMP 能够在低  $D$  下保持稳定的电流



# UCC25710: 低占空比说明

1. 在 B 区域，LLC 可达到的功率水平与基架 LED 电流相等。在 A 区域，功率低于所提供的功率，但可在 C 区域得到补充
2. B 区域为零时，A+C 的总数仍可提供适当的能源
3. A + C 区域所提供的能源太低时，环路打开，所实现的峰值 LED 电流将会降低
4. 接通时间延长时，可调整 A + C 能源 / 脉冲，使其保持与峰值 LED 相同的电流



# UCC25710: 故障管理

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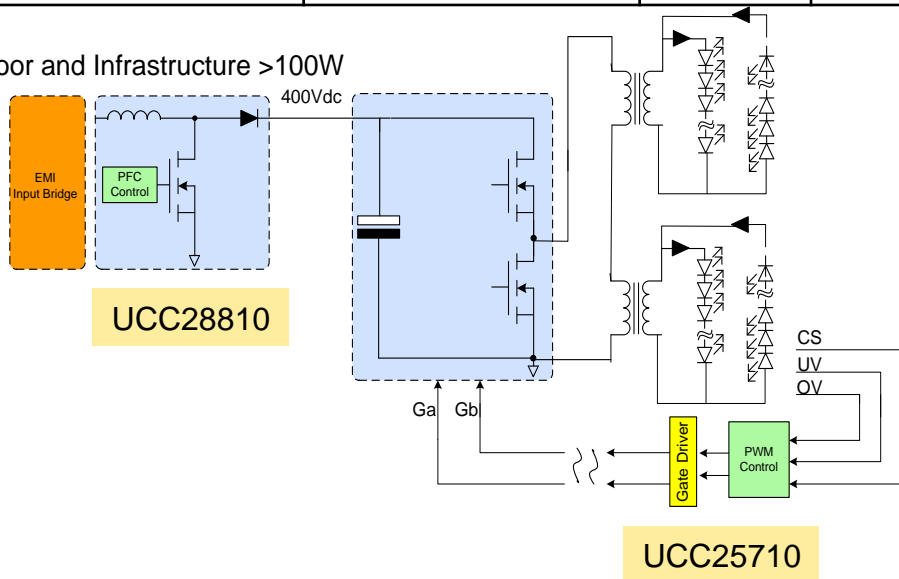
- 故障
  - OV — 最高 LED 串电压
  - UV — 最低 LED 串电压
  - CL(1V) — 输入电流信号过流
  - CL(2V) — 输入信号锁定
  - TSD — 芯片热关断
- 响应
  - OV、CL (1V) 与 TSD: LLC 转换器与 LEDSW 关闭。故障清除后将启动 RESET 与 SS
  - UV: LLC 转换器与 LEDSW 关闭。RESET 与 SS 立即启动, 并在故障清除前不断重复
  - CL (2V): LLC 与 LEDSW 锁定, 直到 UVLO 循环恢复
  - 在 RESET 期间, LLC 转换器和 LEDSW 为 OFF
  - 在 SS 期间, LLC 转换器与 LEDSW 为 ON, 如无调光。

# PMP4302:

## 通用 LED 照明的多串 LLC AC/DC 驱动器

参考设计	TI 部件	Vin	输出	拓扑	效率	调光
<b>PMP4302:</b> <u>AC 输入多串 LLC 转换器适用于通用 LED 照明</u>	UCC28810 ( <i>TM PFC</i> ) UCC25710 ( <i>多串 LLC</i> ) UCC28610 ( <i>辅助反激</i> )	90V~264V	500mA 时为 54 V，支持 4 个串	TM PFC+多串 LLC 转换器	92%	PWM 调光

Outdoor and Infrastructure >100W



### 特性

- 最低成本，低于 AC/DC + DC/DC
- 最高效率，达 92%
- PWM 调光兼容性
- 集成 LED 开路 / 短路保护和过流保护

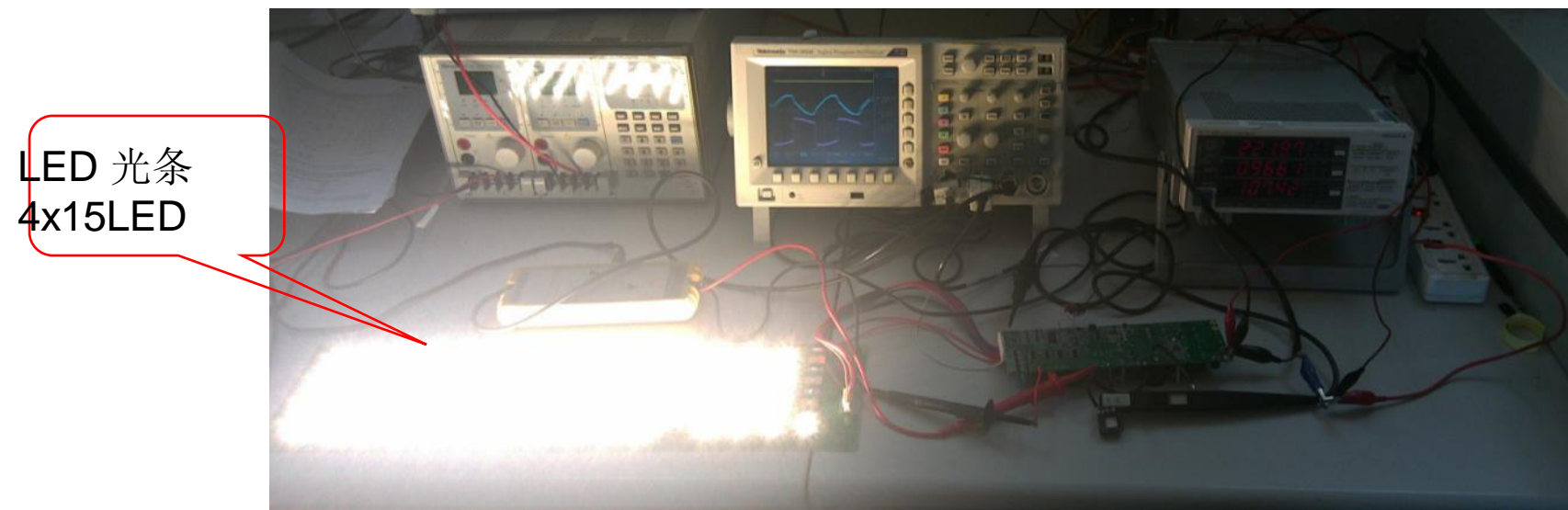
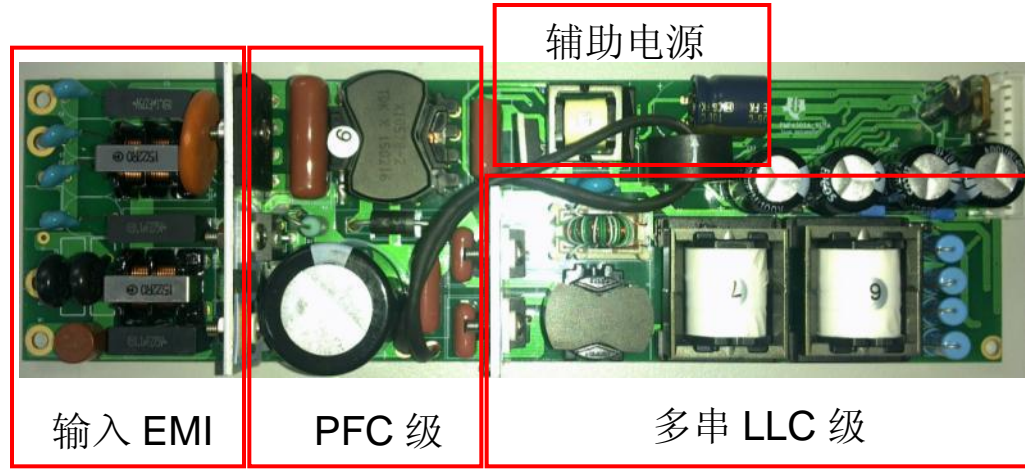
### 应用

- 通用 LED 照明与 LED 背光电视



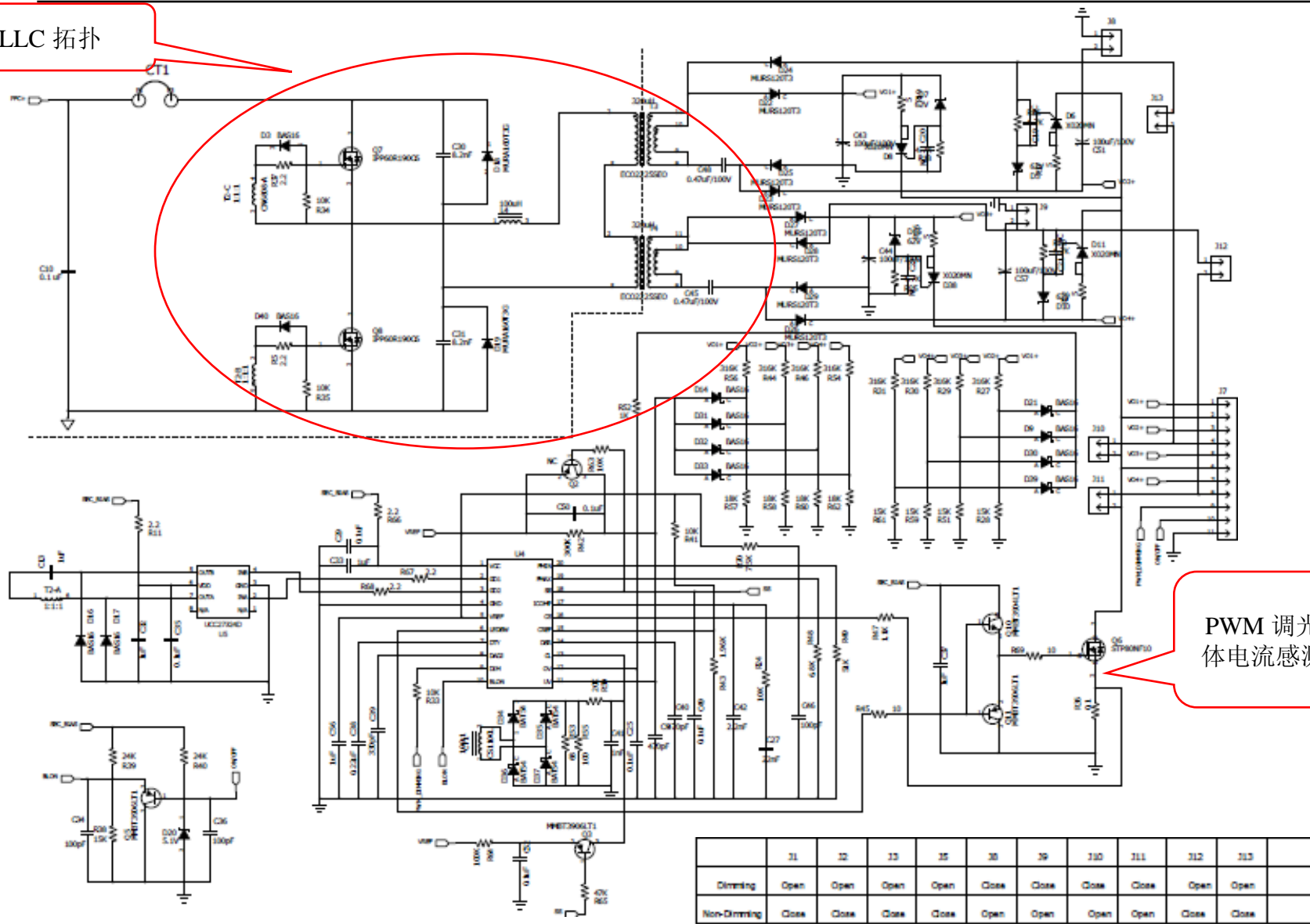


# PMP4302 演示板



# PMP4302: PFC 级后的 UCC25710 原理图

多串变压器 LLC 拓扑



PWM 调光与总体电流感测反馈

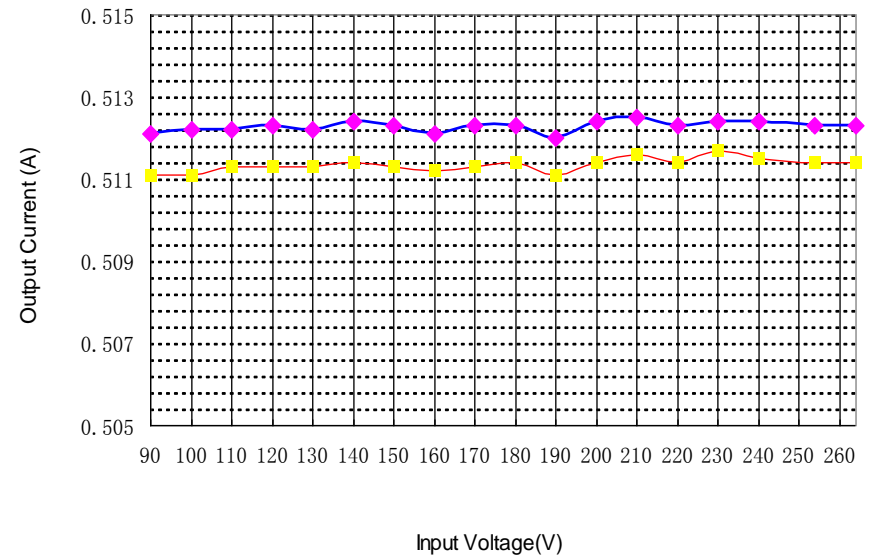
	21	22	23	25	26	29	310	311	312	313		R44	R54	R55	R52
Dimming	Open	Open	Open	Open	Close	Close	Close	Close	Open	Open					
Non-Dimming	Close	Close	Close	Close	Open	Open	Open	Open	Close	Close					Open

# PMP4302: LED 电流输出容限

230V ac 输入

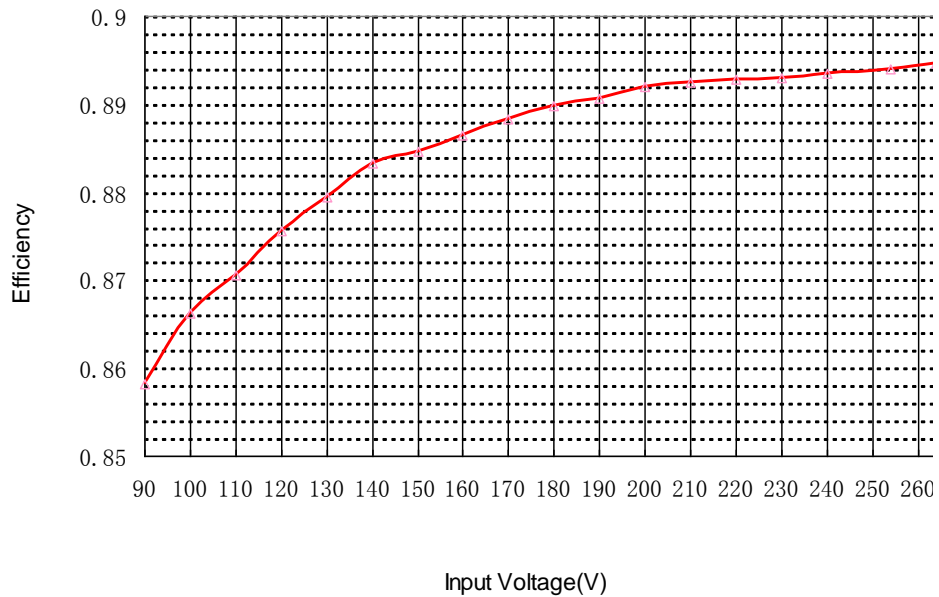
PWM Dimming	Io1	Io2	Io3	Io4	%
1%	4.9	4.8	5	5.1	3.030
2%	10	9.8	10.4	10.3	2.962
5%	25.2	24.1	25.2	25.1	2.208
10%	50.4	49.7	51.5	51.3	1.774
20%	100.9	100.1	102.7	102.5	1.280
30%	151.4	150.4	154.1	153.6	1.214
40%	201.9	200.9	205.1	204.9	1.033
50%	252.4	251.1	256.4	255.8	1.043
60%	302.9	301.4	307.7	307	1.033
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 输出电流与输入电压  
可 100% 调光

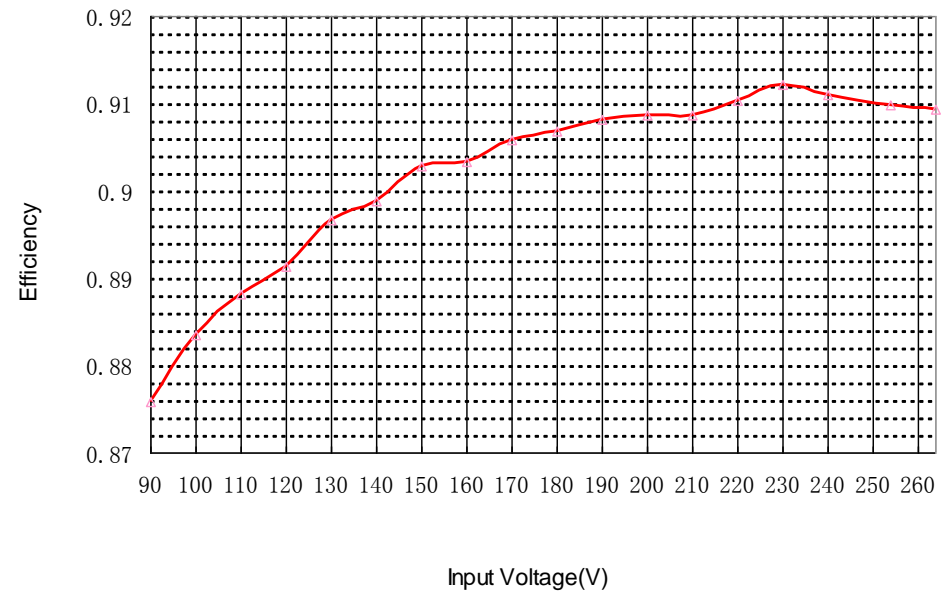


电流公差 <math>\pm 3\%</math>, 调光范围从  
1% 到 100%

# PMP4302: 效率 (TM PFC + 多串 LLC + 辅助电源)

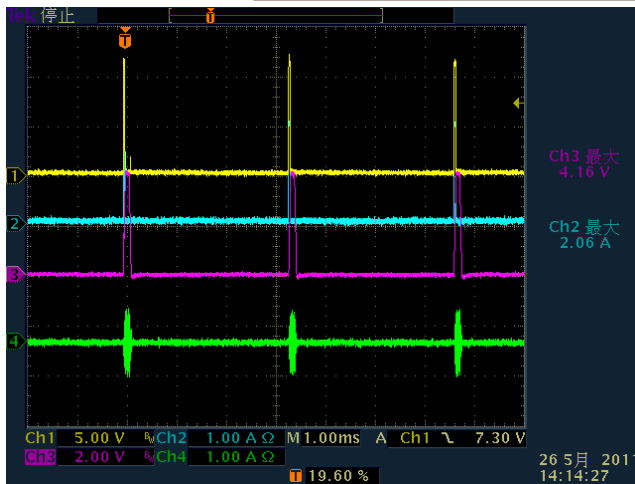


调光版本

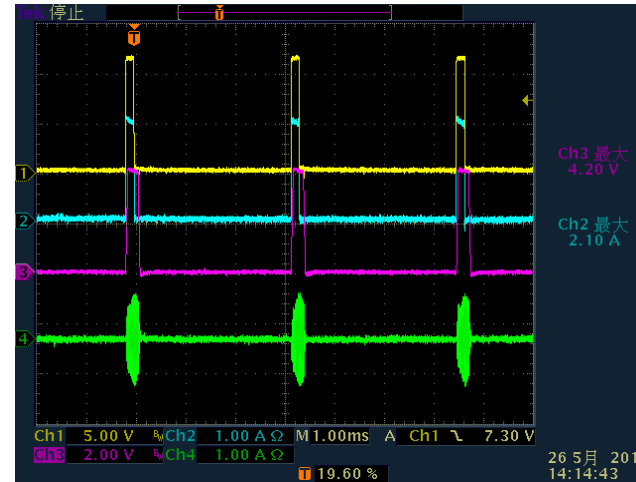


非调光版本

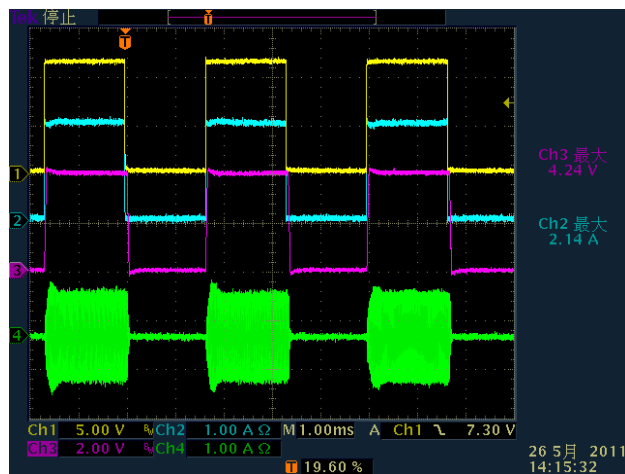
# PMP4302: 波形



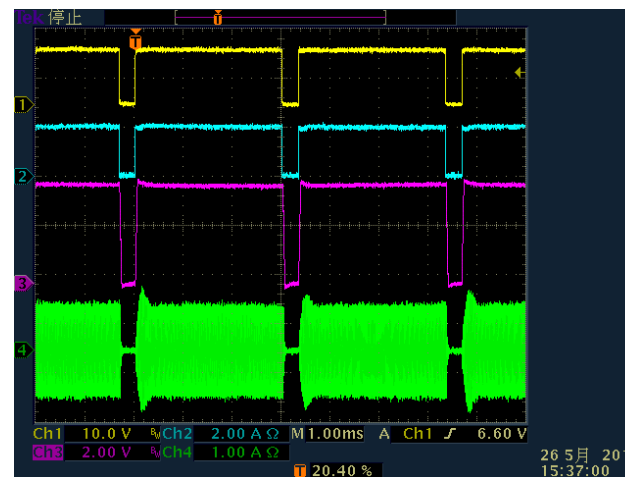
1% 调光



5% 调光



50% 调光



90% 调光

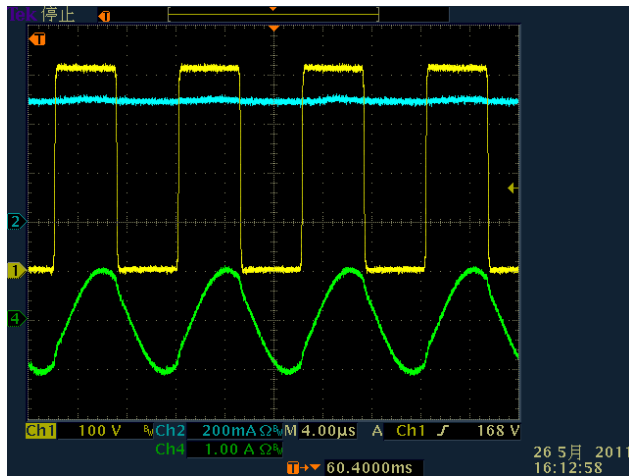
CH1: LEDSW  
MOSFET Vgs  
5V/Div

CH2: LED 输出电  
流 1A/Div

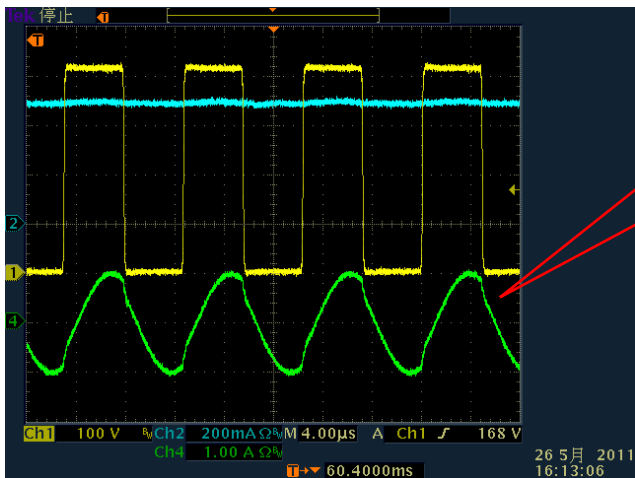
CH3: DSR 2V/Div

CH4: 基本  
电流 1A/Div

# PMP4302: 波形

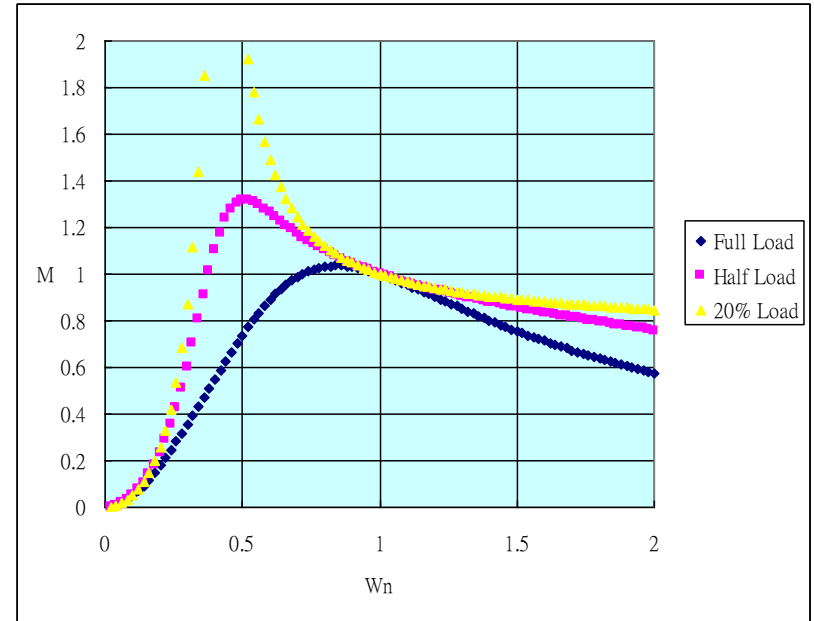


90Vac 输入



230Vac 输入

CCM 可获得  
更优异的电  
流容限



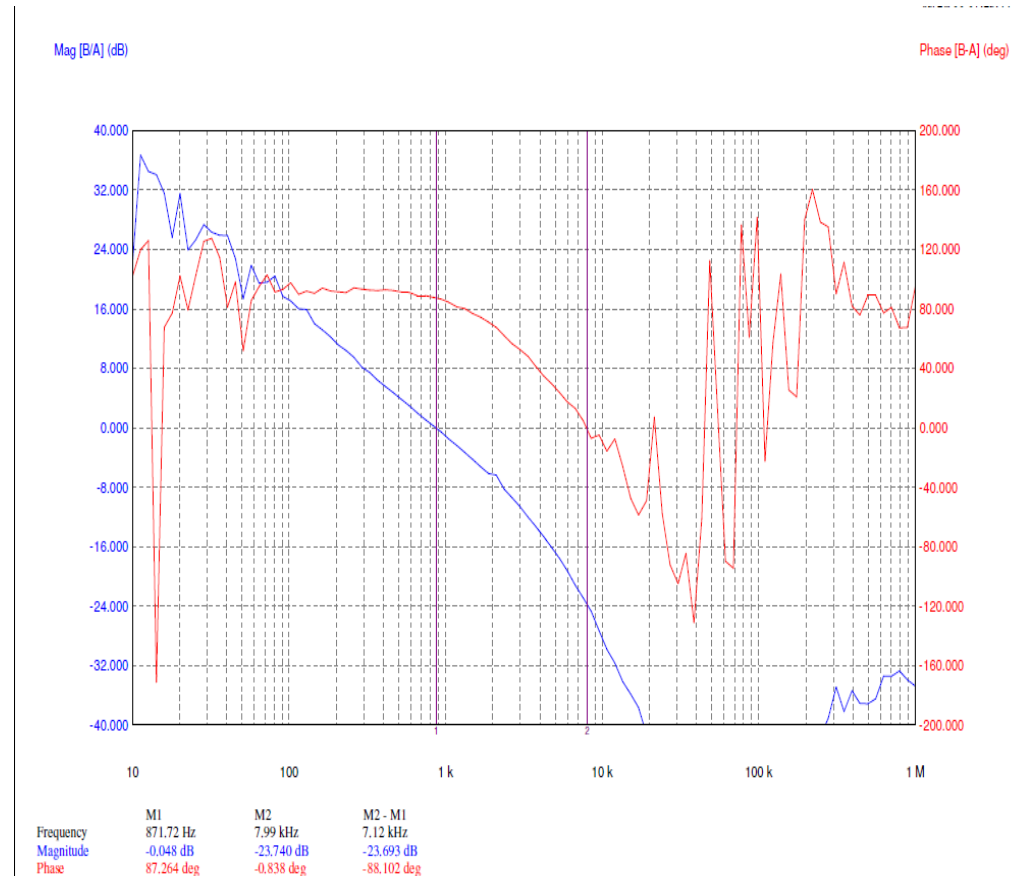
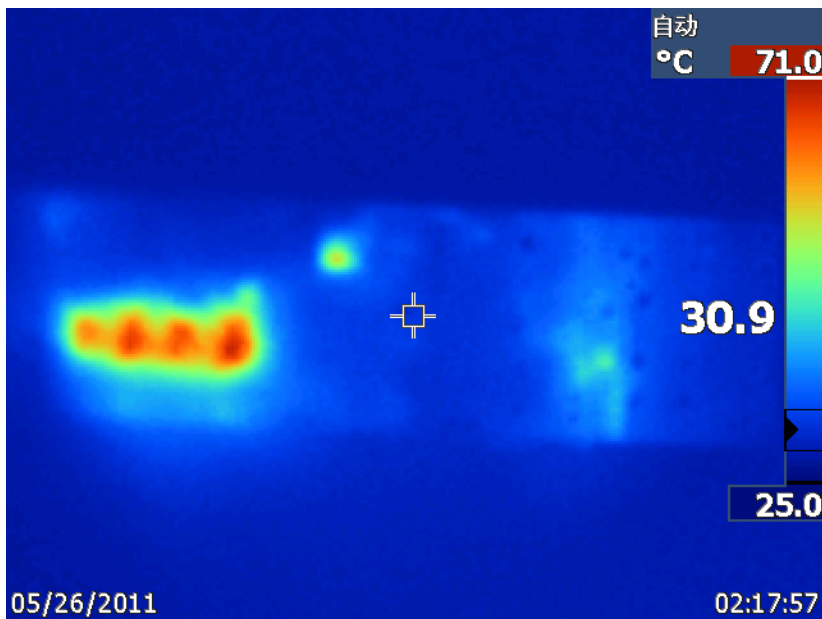
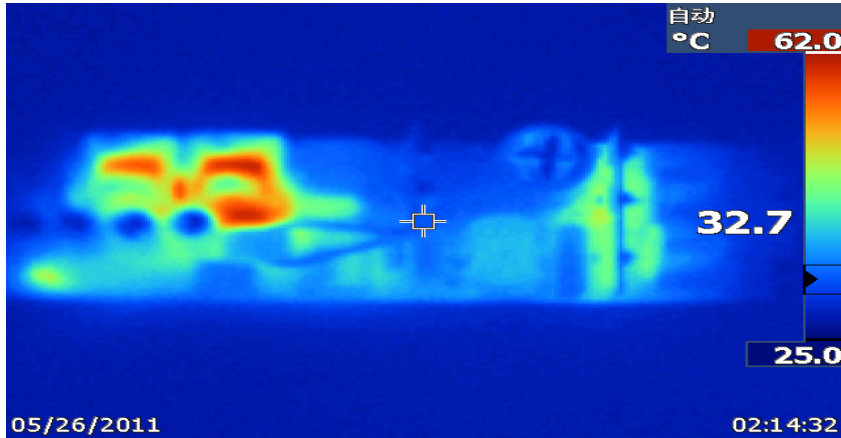
$Lm/Lk=6$   
 $Fs=100KHz$   
 $Q=0.7$



$Lm1+Lm2=640uH$   
 $Lr=100uH$   
 $Cr=30nF$

- CH1: 基本 MOSFET  $V_{ds}$  100V/Div
- CH2: LED 输出电流 200mA/Div
- CH4: 基本电流 1A/Div

# PMP4302: 散热和波德图



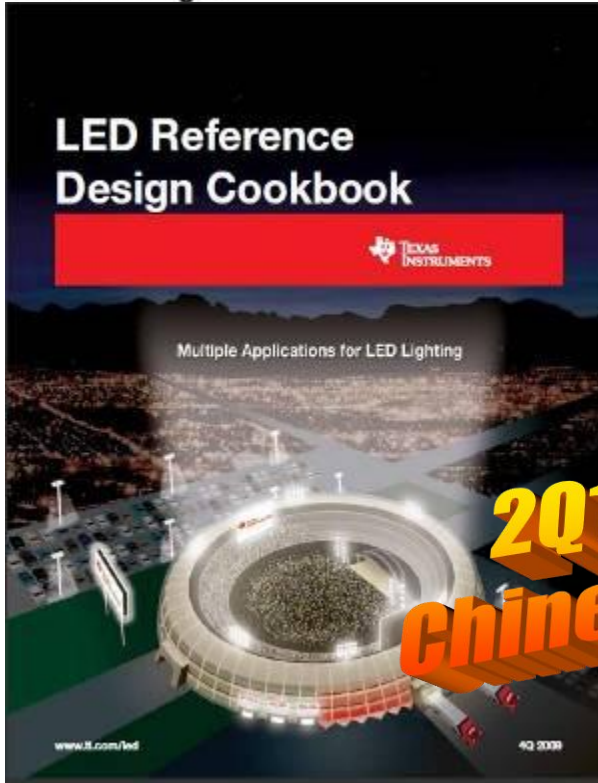
## 总结

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- 采用多变压器 LLC 拓扑的 UCC25710 可实现:
  - ☺ 高效率
  - ☺ 低总体材料清单成本与高可靠性
  - ☺ 兼容于 PWM 或模拟调光
  - ☺ 输出 LED 串开路 / 短路保护
  - ☺ 输入过流保护
  - ☺ 支持 1%~100% 调光范围



# LED 参考设计手册



Reference Design Cookbook  
Table of Contents

LED Configuration	Driving Option	$V_{in}$	$V_{out}$ (Peak)	Typ. Power	Device	Page
10 series	Digital PFM	5 to 14 $V_{DC}$	20 to 30 maximum	700 maximum	TP501001	4
4 parallel (2 series PFC)	—	2.3 to 5.5 $V_{DC}$	2 typical	20 per LED	TP501006	6
3 series	Digital PFM	3 to 17 $V_{DC}$	1 typical	300	TP501005	8
3 series	Analog PFM	4 to 24 $V_{DC}$	10 to 40	300	TP501005	10
10 to 13 series	—	10 to 20 $V_{DC}$	10 to 40	300	UC120618	12
30 series	TRAC driver	120 to 204 $V_{DC}$	200 maximum	200	UC120618	14
7 to 8 series	TRAC driver	90 to 130 $V_{DC}$	24 to 32	400	TP500001	18
10 series	TRAC driver	85 to 205 $V_{DC}$	43 to 38	700	UC120618	20
10 to 30 series	PFM	90 to 205 $V_{DC}$	55 to 100	900	UC120618	22
7 to 10 series (4 to 6 strings)	Analog PFM	90 to 205 $V_{DC}$	23 to 30	300	UC120618	24
3 to 6 series	—	120 to 204 $V_{DC}$	24 typical	300	TP500010	30
2 parallel (stack)	—	4.5 to 5.5 $V_{DC}$	2 typical	100 per LED	—	34
1	Dual-Port	1.2 to 5 $V_{DC}$	—	—	—	34
4 to 6 series	Analog PFM	—	—	—	—	34

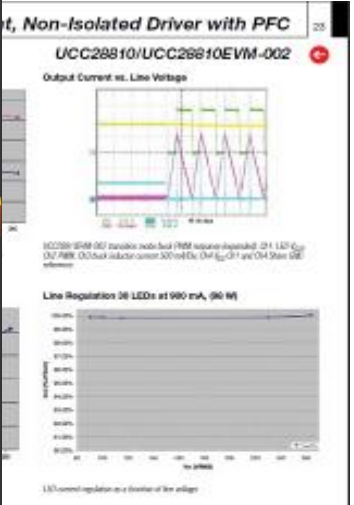
**2011 Fresh Off the Press  
Chinese Version ready now!**

**Current Driver with PFC**

**TP4501**

Prevents dangerous output voltages from occurring during open-string conditions. A current-sense amplifier reduces the sensing resistor's power dissipation, thus increasing overall efficiency. The internal reference voltage of the operational amplifier achieves excellent LED-current regulation versus output power and input voltage. The TP4501 achieves high efficiency (90% peak), high power density and a high power factor. This reference design protects the user's investment.

Web Links:  
Datasheet, user's guide, samples:  
[www.ti.com/lit/dsp/tiuc228100](http://www.ti.com/lit/dsp/tiuc228100)



<http://focus.ti.com.cn/cn/lit/sg/zhct063a/zhct063a.pdf>

谢谢