

# 基于ICL5101软开关拓扑高效简洁的 恒压及恒流LED驱动电源方案

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英飞凌科技应用中心

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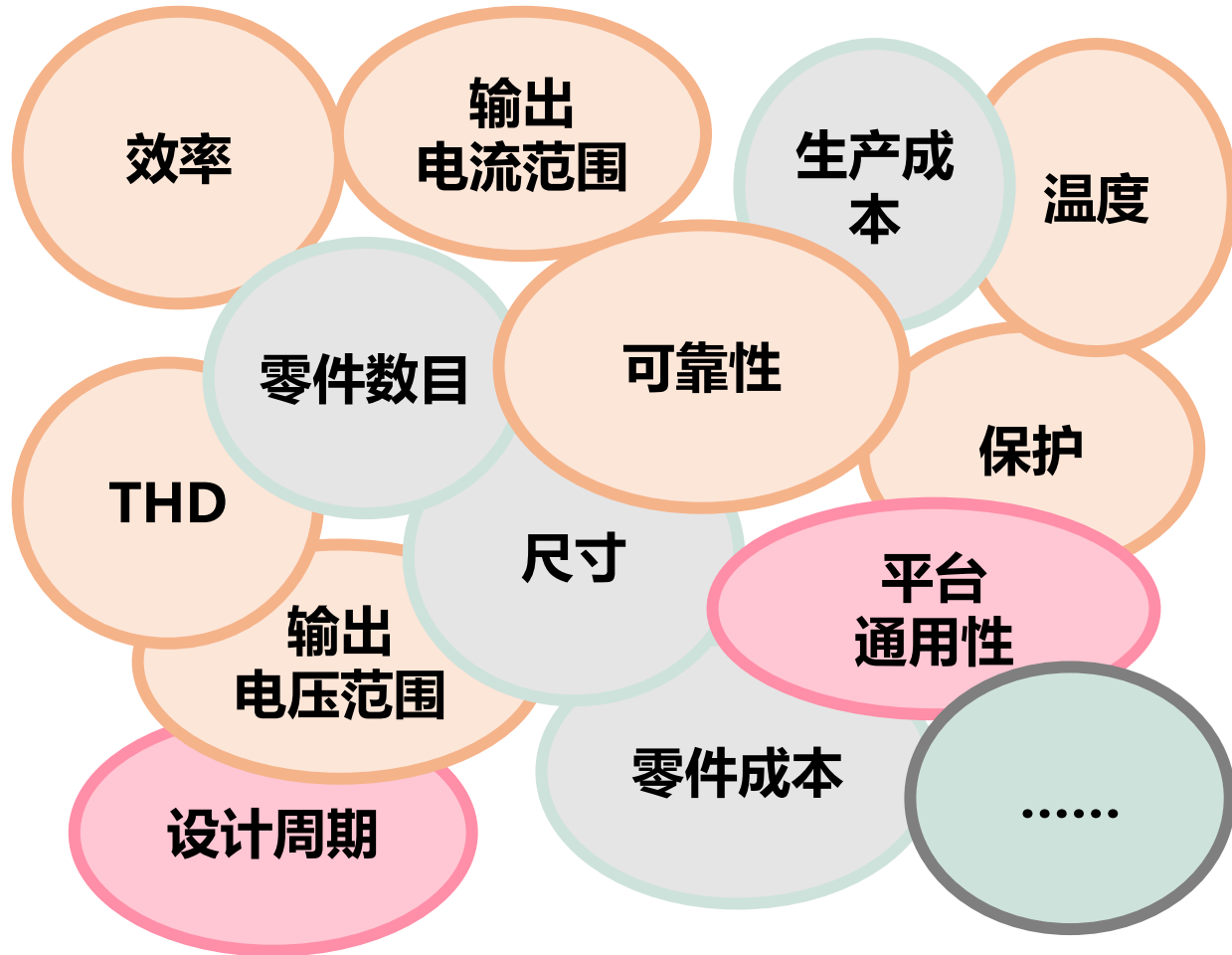
- **概述**
- **PFC+ LLC恒压方案**
- **PFC+ LCC恒流方案**
- **创新的CoolMOS™**
- **结论**
- **设计支持**

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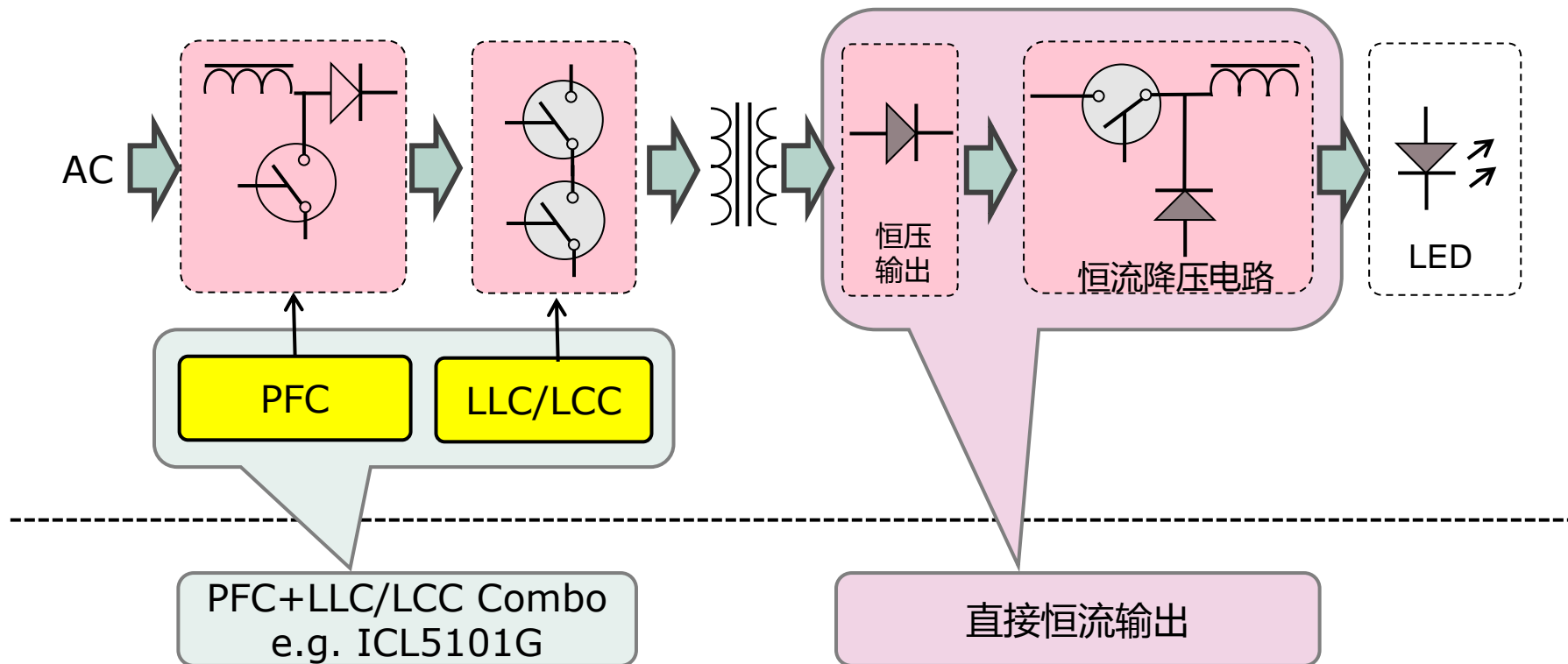
性能

成本

速度

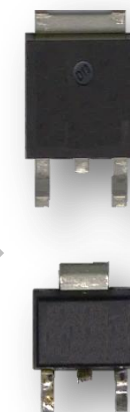
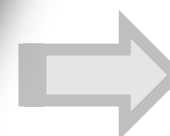
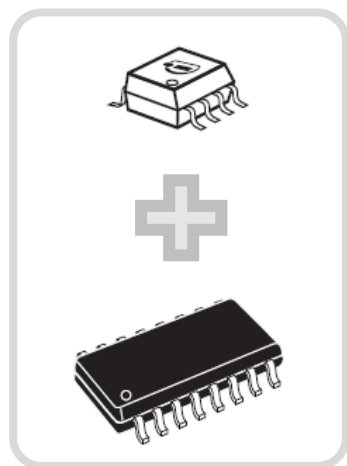
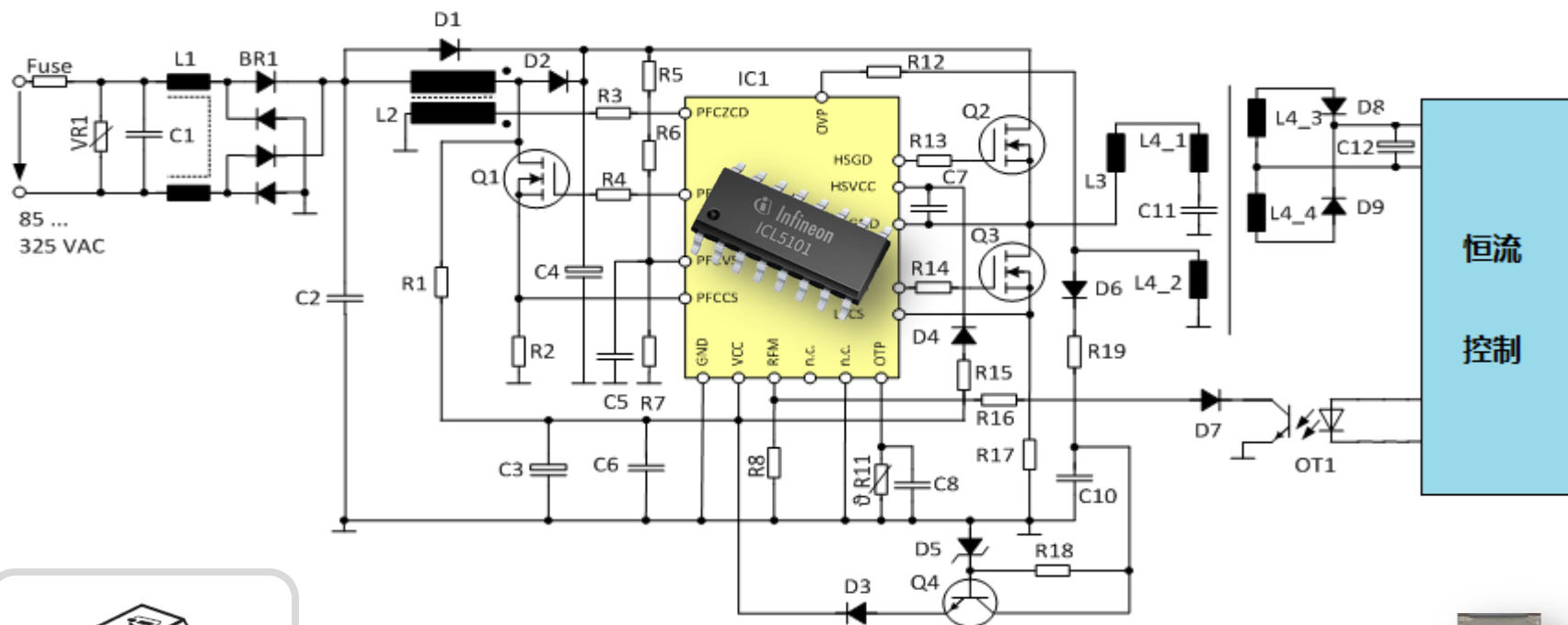


# 解决挑战的一些思路\_精简电路



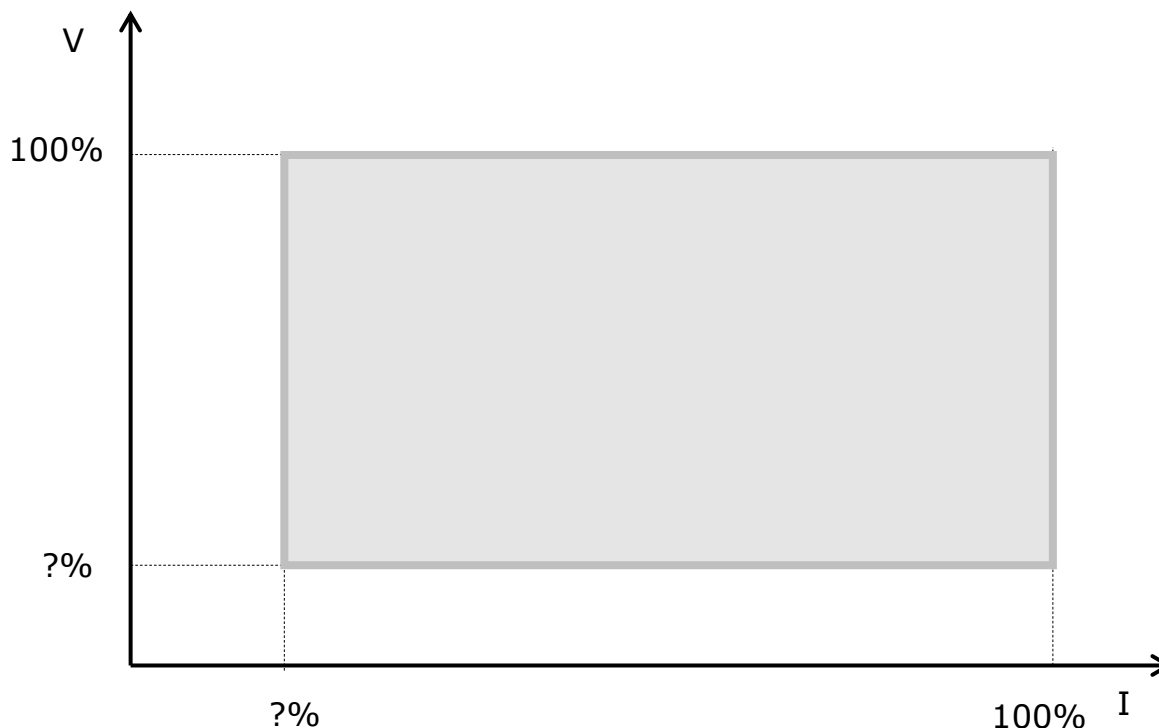
- › 设计宽范围输出电压电流，去掉后级变换器
- › 满足深度调光输出电压降低时的输出恒流（低输出电压+低输出电流）
- › 不同电压LED模块共用同一个LED驱动器

# 解决挑战的一些思路\_采用小封装器件

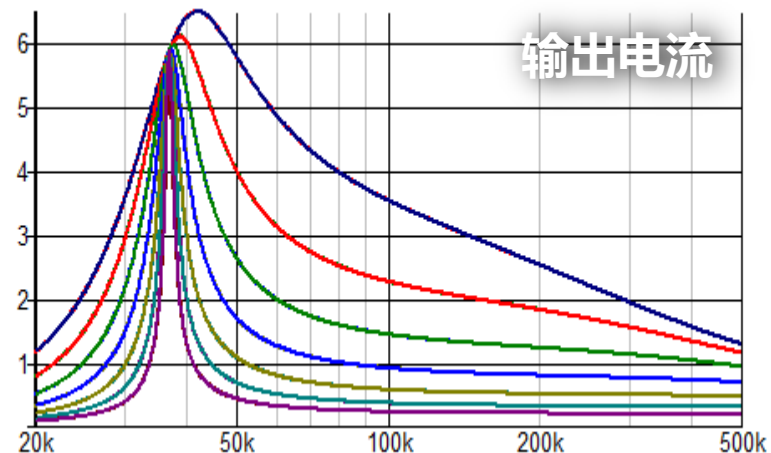
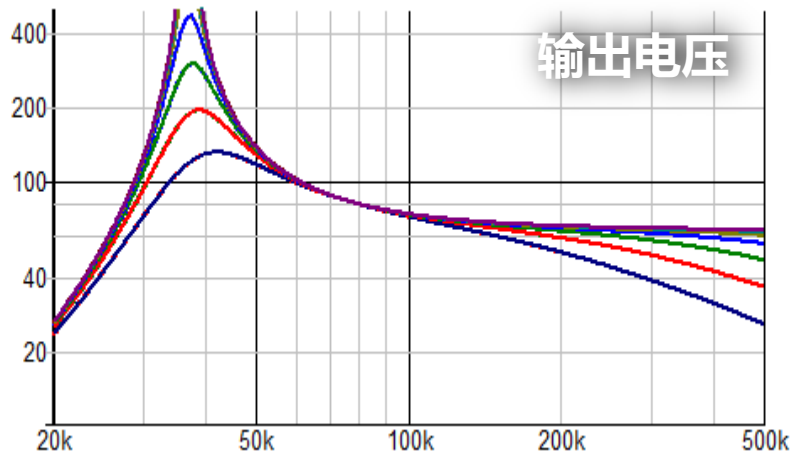
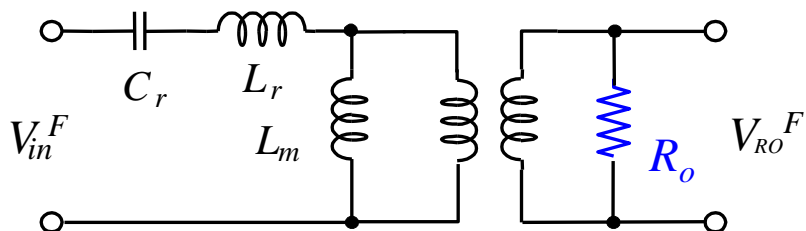


# 解决挑战的一些思路\_扩大输出范围

- 输出电流范围要求广 ( 10-100% ) , 部分应用要求深度调光
- 输出电压要求广 ( 10-100% ) , 以适应电流变化或不同的LED模组



## LLC

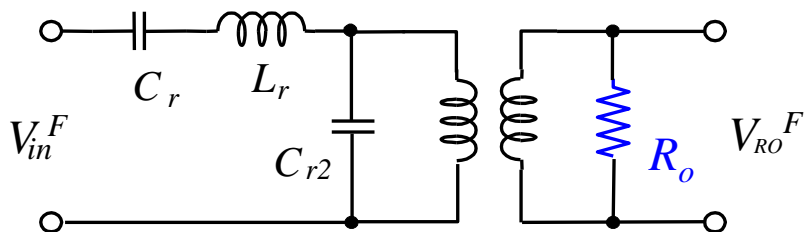


- 谐振点的输出电压恒定
- 恒压输出的表现更好
- 也可以用于恒流应用，对工作频率范围的设计需要更谨慎

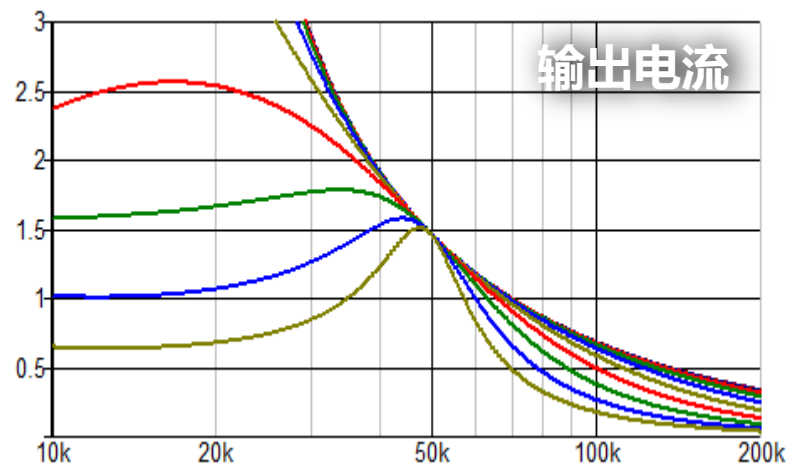
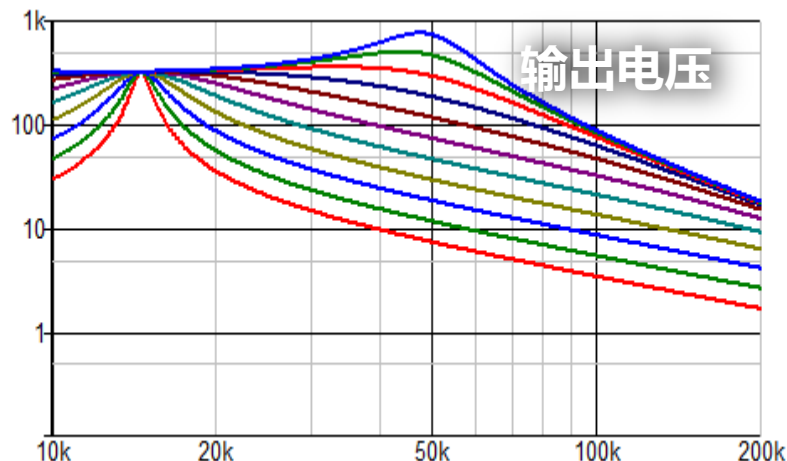


# 解决挑战的一些思路\_重新考虑拓扑

## LCC

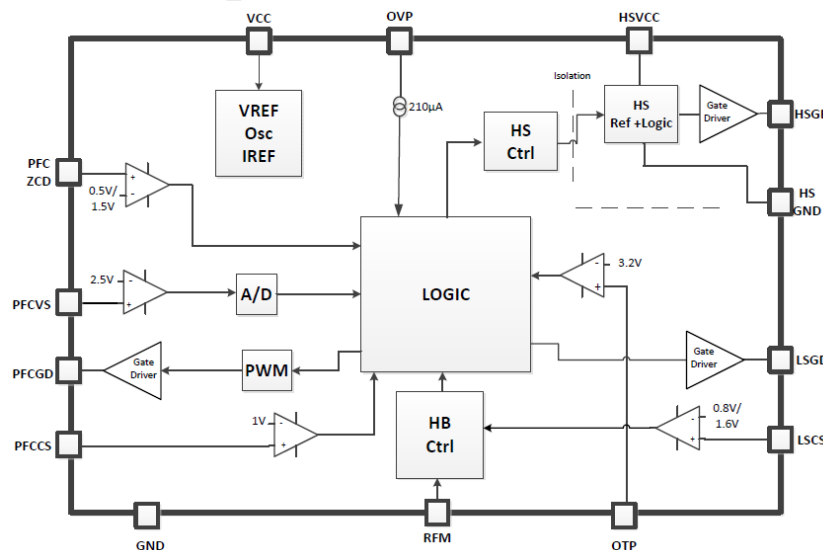
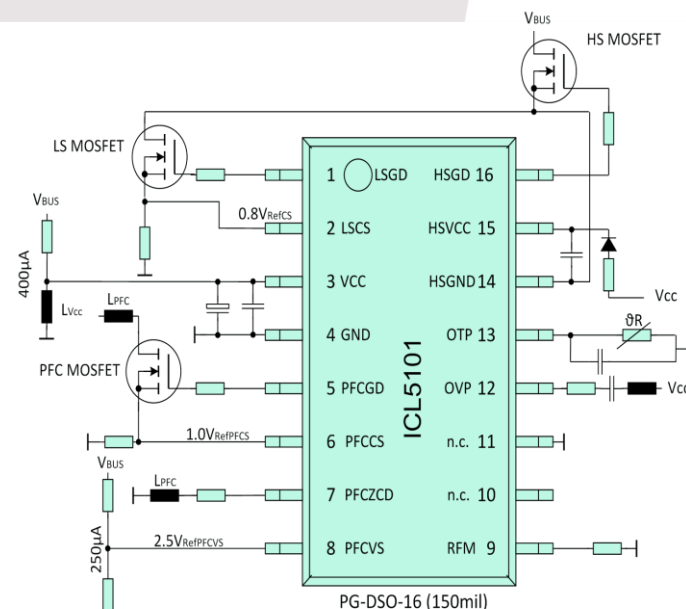


- 谐振点的输出电流恒定
- 无次级反馈情况下可以实现恒流，只需要设置工作频率在谐振频率附近
- 调光应用时可以在较窄的频率范围内实现很宽的输出电压范围
- 具有较好的短路特性



# ICL5101G 集成PFC 和半桥谐振控制

- 集成CRM PFC+半桥谐振控制
- 16脚封装
- 集成650V耐压高压驱动
- 全保护功能，包括外置过温保护等
- 所有参数均由电阻设置
- 支持户外使用，结温范围： $-40^{\circ}\text{C}\sim 125^{\circ}\text{C}$
- 轻载不会进入间歇模式，不会有音频噪声
- 功率因素 $>95\%$ ，总谐波失真 $<10\%$

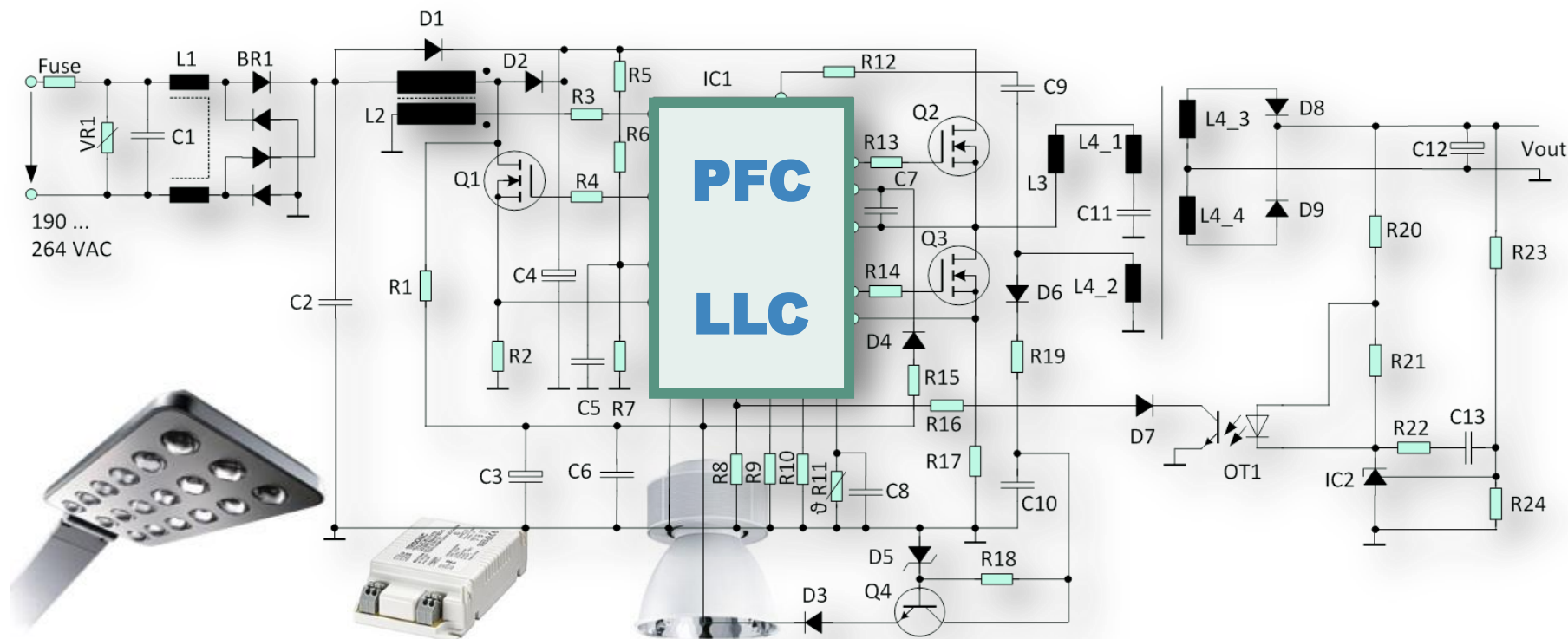


# ICL5101G应用



应用：

- PFC+LLC 恒压输出，效率高达94%
- PFC+LCC 恒流输出，极宽输出电压范围



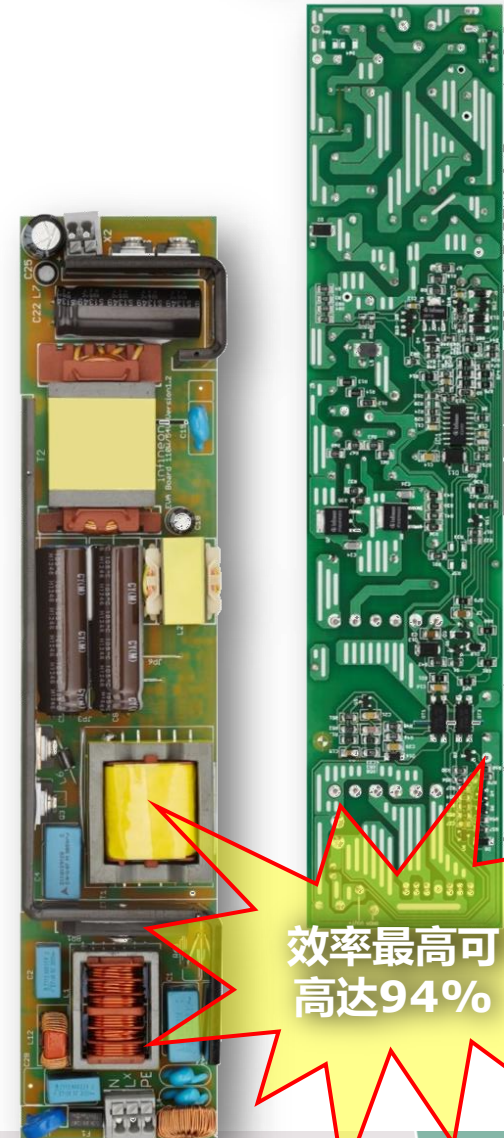
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# LLC 恒压方案 \_\_54V110W



- 采用低导通电阻CoolMOS™，无散热器
- 尺寸：247.3mm(L) x 48.25mm(W) x 34.2mm(H)

Vin(AC)	85-305Vac
Vout (DC)	54V
Iout (A)	2.06A
output Power (W)	110W
Efficiency @ Max Load	>93.5% min @ 230Vac
THD	< 10% @ > 35%Load at 230 VAC

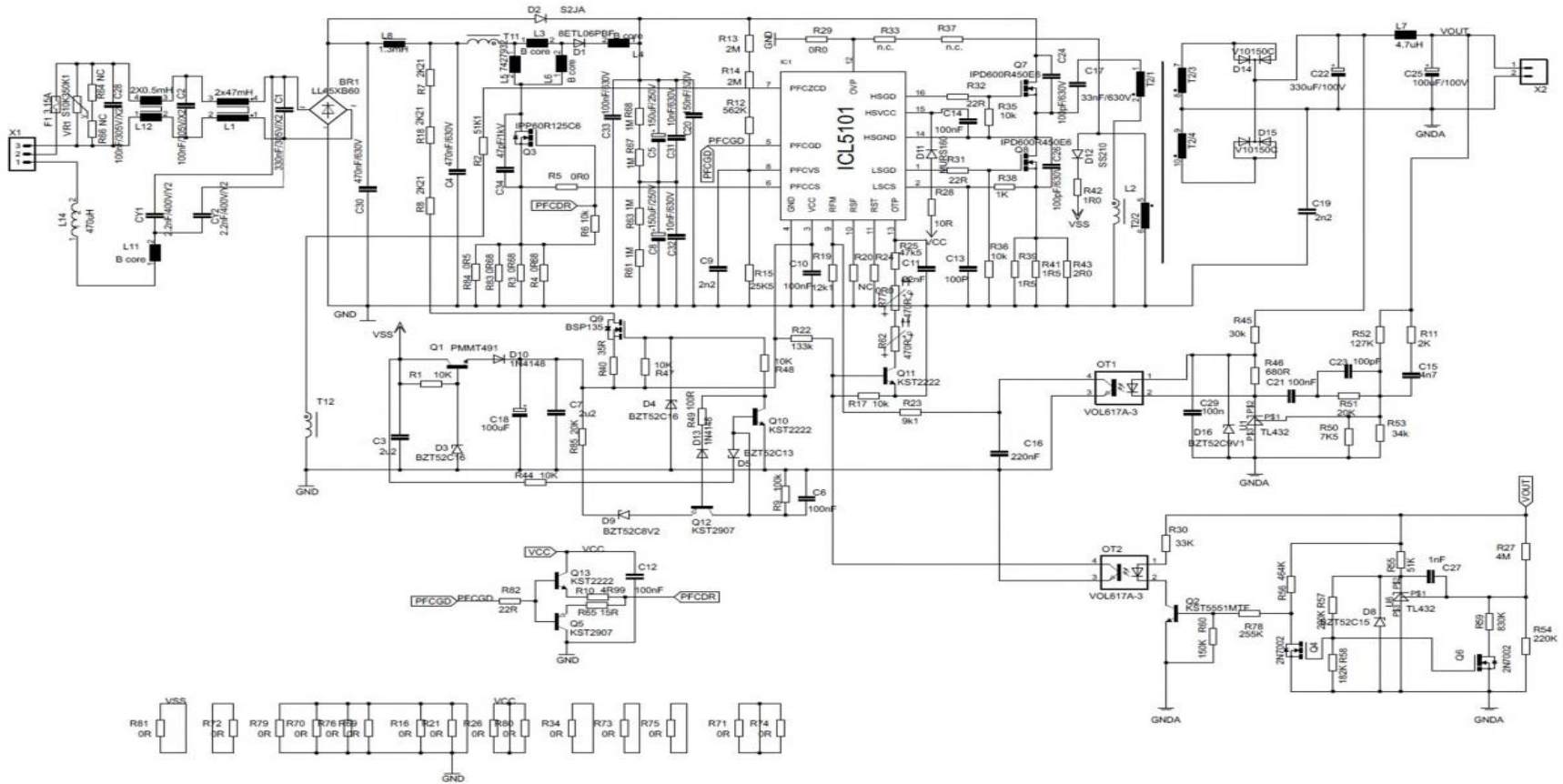


效率最高可  
高达94%

# LLC 恒压方案电路 \_\_ 54V110W



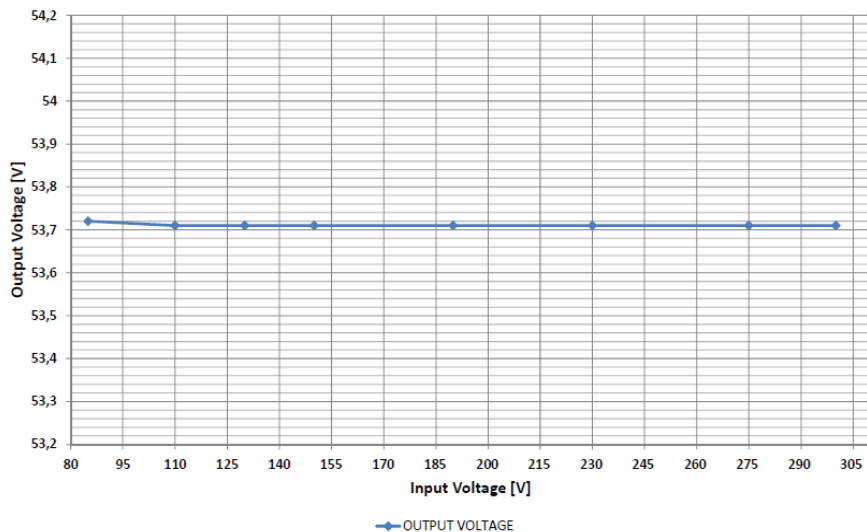
- 控制 IC：ICL5101
- MOSFET：CooIMOS™系列
  - PFC：IPD60R400CE\*2pcs
  - LLC：IPD60R400CE\*2pcs



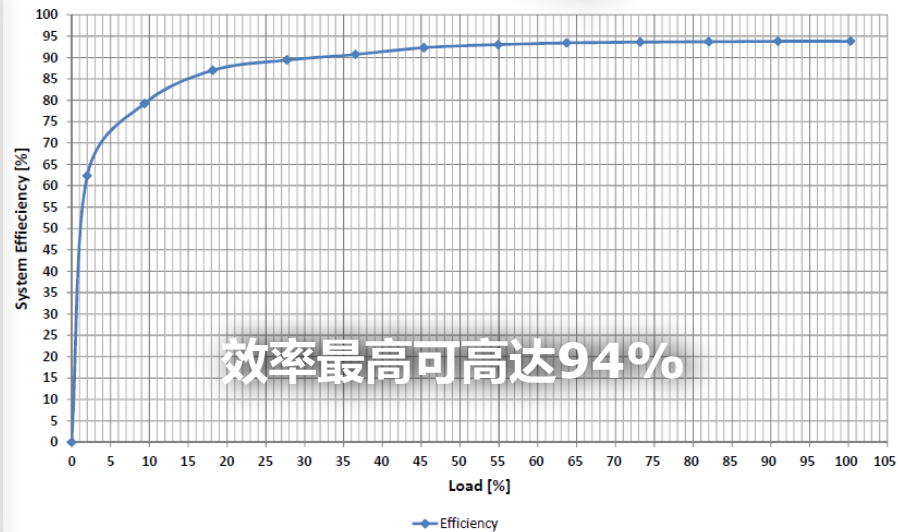
# 调整率, 效率, PF和THD



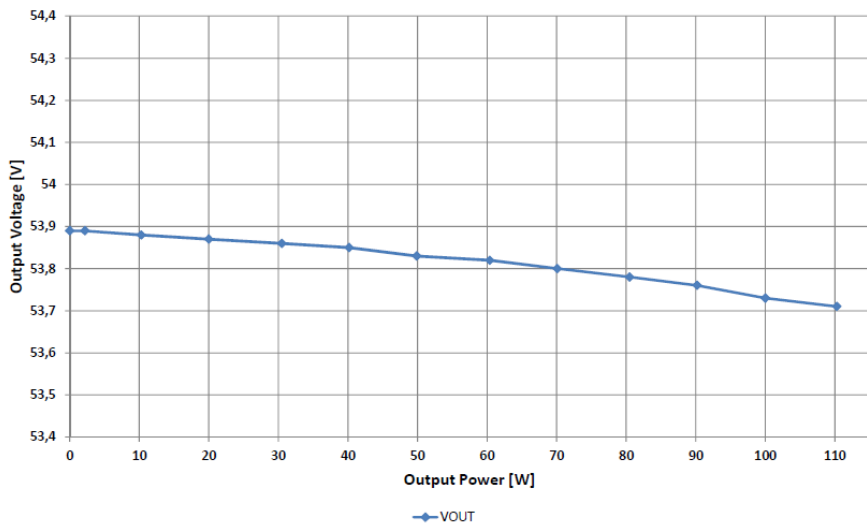
$V_{OUT}$  versus  $V_{IN}$  at Nominal Load



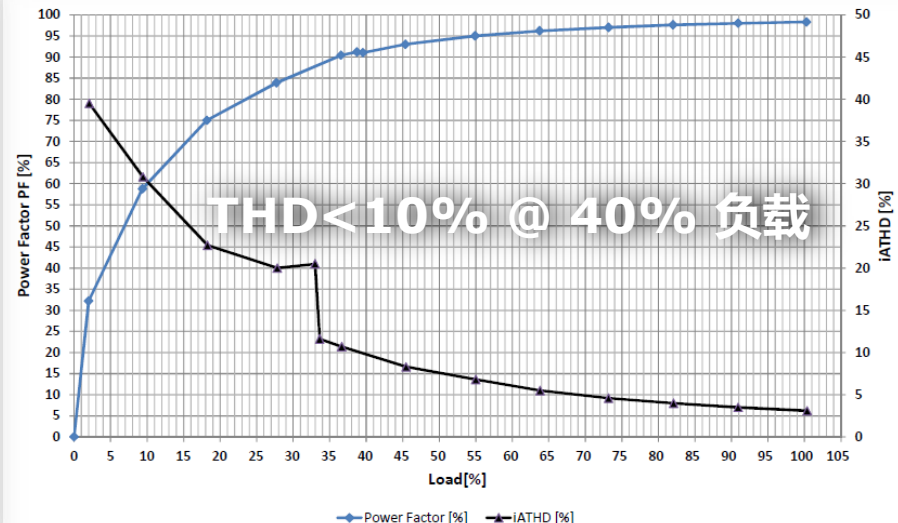
System -  $\eta$  versus Load @  $V_{ACIN} = 230V$



$V_{OUT}$  versus  $P_{OUT}$  @  $V_{ACIN} = 230V$



Power Factor /  $iATHD$  versus Load @  $V_{ACIN} = 230V$



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# 120W LCC 极宽输出电压 恒流 照明方案\_1 非调光，无反馈



- PFC+LCC拓扑
- 无次级反馈
- 宽输出电压范围
- 高效率达**92.5%**，50%负载条件下,THD<**10%**
- 采用低导通电阻CoolMOS™，无散热器
- 外围零件极少
- 尺寸：178mm\*52mm\*22mm

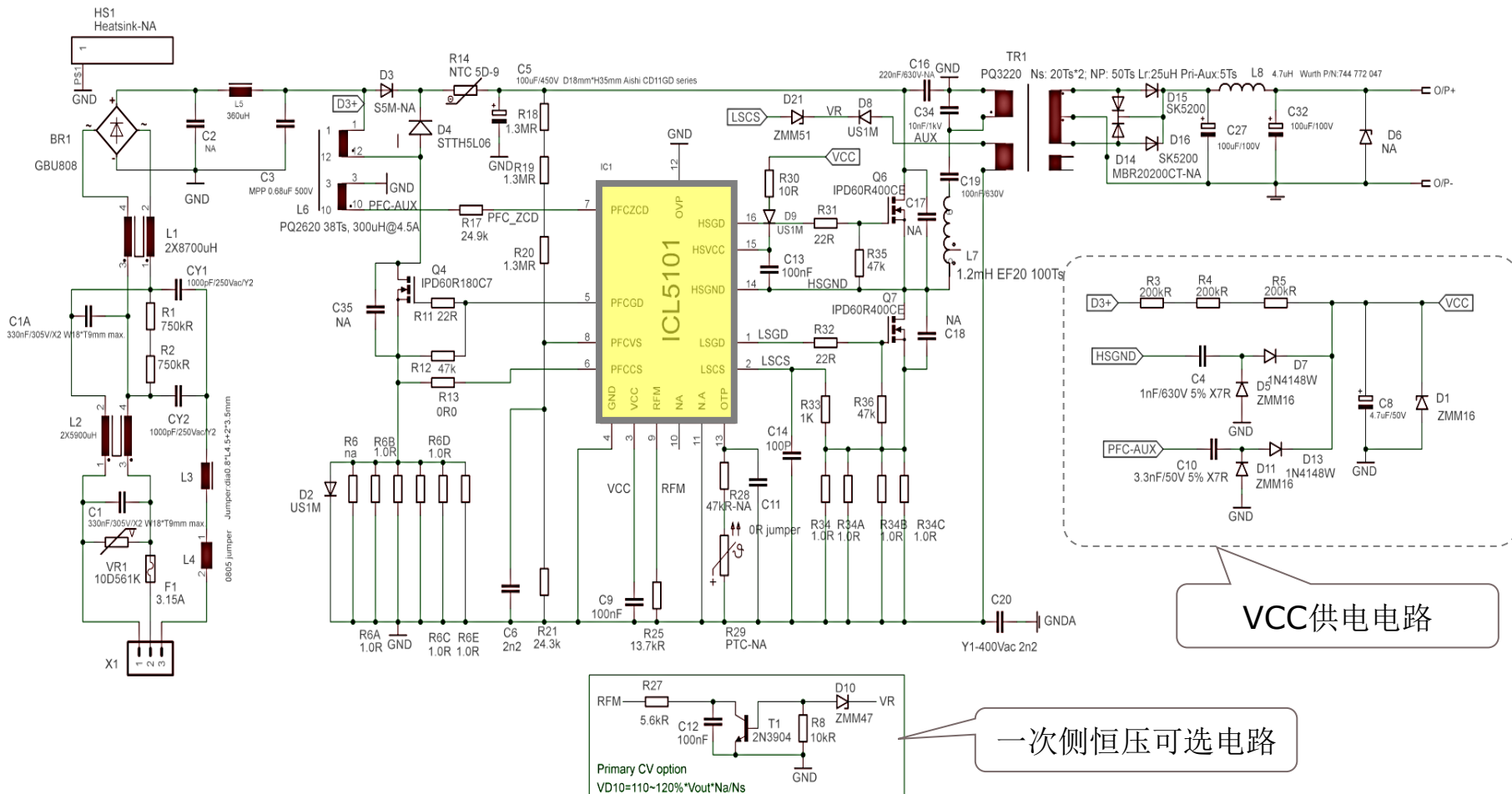
Vin(AC)	90-277Vac
Vout (DC)	10-80V
Iout (A)	1.5A
output Power (W)	120W
Efficiency @ Max Load	90% min @90Vac 92.5% min @ 230Vac



# 120W LCC 无反馈非调光恒流方案原理图



- 控制 IC: ICL5101
- PFC MOSFET: IPD60R190C7
- HB MOSFET: IPD60R650CE





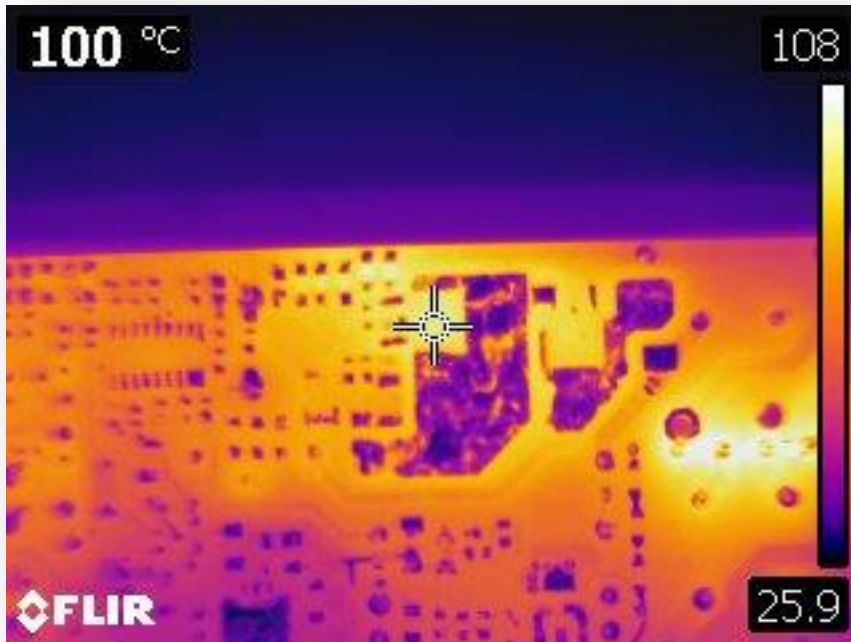
无反馈，工作频率设定在36.5kHz：

- THD<6% @ 负载>30%条件下
- 效率可达92.8%

Vac	Pin	Vout	Iout	Pout	THD	Efficiency	Half Bridge Freq (kHz)
90	137.1	80.2	1.545	123.8	3.00%	90.29%	36.5
90	149.7	89.8	1.504	135.1	3.00%	90.24%	36.5
230	145.4	89.8	1.503	134.9	2.40%	92.82%	36.5
230	133.8	80.2	1.546	123.9	2.40%	92.63%	36.5
230	116.6	65.5	1.594	104.4	3.20%	89.52%	36.5
230	91.6	50.5	1.614	81.5	3.20%	89.03%	36.5
230	66.1	35.5	1.628	57.9	2.60%	87.59%	36.5
230	40.5	20.6	1.639	33.7	2.70%	83.32%	36.5
230	23.7	10.6	1.649	17.5	2.40%	74.11%	36.5
230	7.45	1.26	1.68	2.12	2.40%	28.41%	36.5



**测试条件:** Ta=25°C; Open frame; 90Vin\_ac, 80Vout/1.55A



PFC MOSFET:  
IPD65R190C7

max. temperature: 100°C

# 120W LCC 极宽输出电压 恒流 照明方案\_2 调光，有反馈



- PFC+LCC拓扑
- 宽输出电压范围
- 高效率达**92.5%**，50%负载条件下THD低于**10%**
- 采用低导通电阻CoolMOS™，无散热器
- 外围零件极少
- 尺寸：178mm\*52mm\*22mm

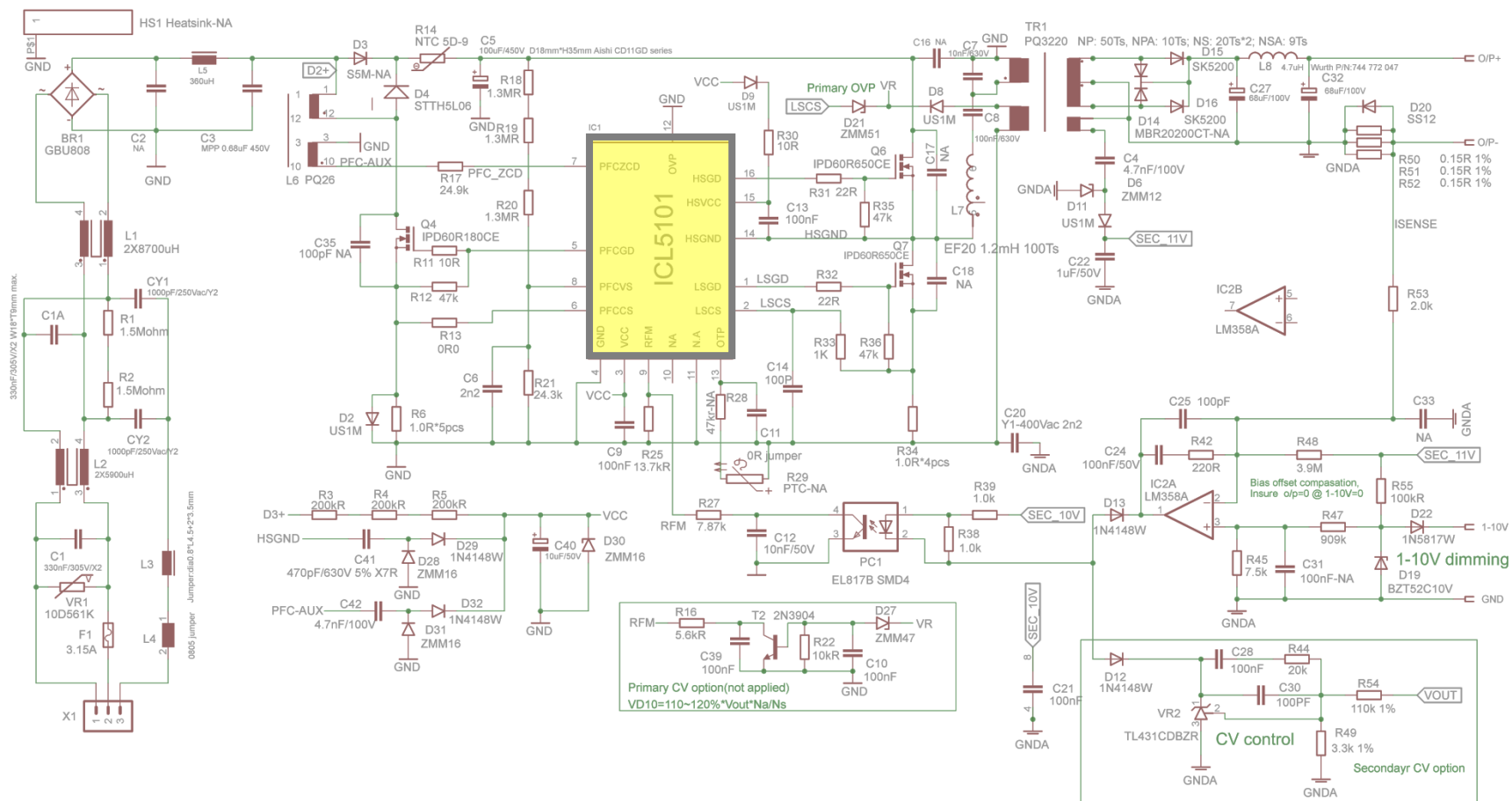
Vin(AC)	90-277Vac
Vout (DC)	30-80V
Iout (A)	0.05~1.5A
output Power (W)	120W
Efficiency @ Max Load	90% min @90Vac 92.5% min @ 230Vac



# 120W LCC 有反馈调光恒流方案原理图



- **控制IC :** ICL5101
- **PFC MOSFET:** IDP60R190C7
- **HB MOSFETs:** IDP60R650CE



# 测试数据

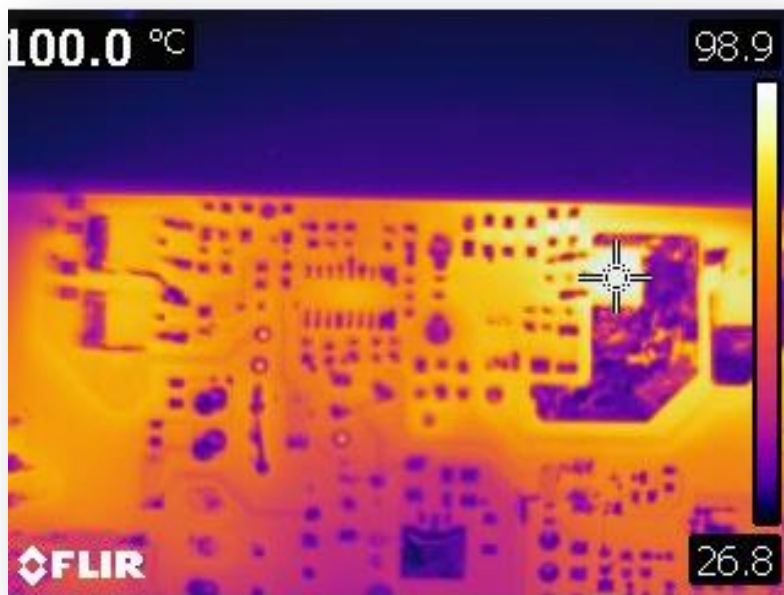


- THD<6% @ 负载>50%条件下
- 效率可达92%

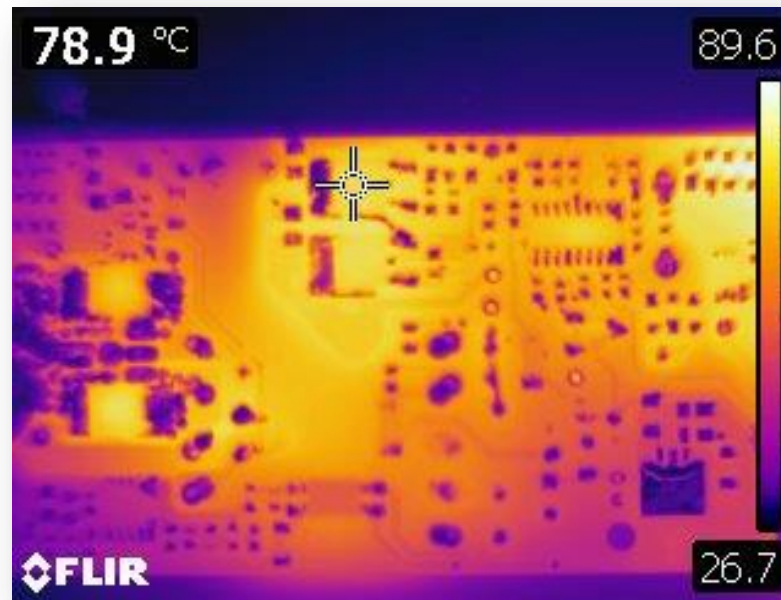
Vac	Pin	Vout	Iout	Pout	THD	Efficiency	Half Bridge Freq(kHz)
90	133.21	80.22	1.492	119.69	2.60%	89.85%	36.5
100	132.43	80.22	1.49	119.53	3.20%	90.26%	36.5
120	131.98	80.22	1.491	119.61	3.20%	90.63%	36.5
132	131.33	80.22	1.49	119.53	2.90%	91.01%	36.5
198	130.48	80.22	1.49	119.53	2.00%	91.61%	36.5
264	130.04	80.22	1.49	119.53	2.80%	91.92%	36.5
230	130.11	80.22	1.491	119.61	2.10%	92.01%	36.51
230	68.16	80.13	0.75	60.10	5.10%	88.15%	54.06
230	46.11	80.10	0.5	40.05	8.80%	86.84%	61.79
230	24.37	80.07	0.25	20.02	13.60%	82.14%	68.86
230	11.35	80.05	0.1	8.01	25.76%	70.53%	70.75
230	7.00	80.05	0.05	4.00	31.20%	57.18%	70.97
230	102.55	60.24	1.54	92.77		90.47%	36.53
230	102.45	60.25	1.54	92.78		90.52%	55.63
230	51.63	60.15	0.75	45.11		87.36%	55.63
230	35.09	60.12	0.5	30.06		85.64%	64.07
230	18.33	60.09	0.25	15.02		81.96%	73.57
230	8.54	60.07	0.1	6.01		70.34%	76.32
230	5.28	60.07	0.05	3.00		56.88%	76.61
230	54.45	30.21	1.563	47.22		86.73%	36.5
230	26.92	30.11	0.75	22.58		83.89%	59.25
230	18.55	30.08	0.5	15.04		81.08%	70.16
230	9.70	30.05	0.25	7.51		77.45%	89.32
230	4.61	30.03	0.1	3.00		65.15%	94.2
230	2.95	30.03	0.05	1.50		50.89%	94.9



**测试条件:**  $T_a=25^{\circ}\text{C}$ ; Open frame; 90Vin\_ac, 80Vout/1.50A



PFC MOSFET:  
IPD60R190C7  
 $T_c= 100^{\circ}\text{C}$

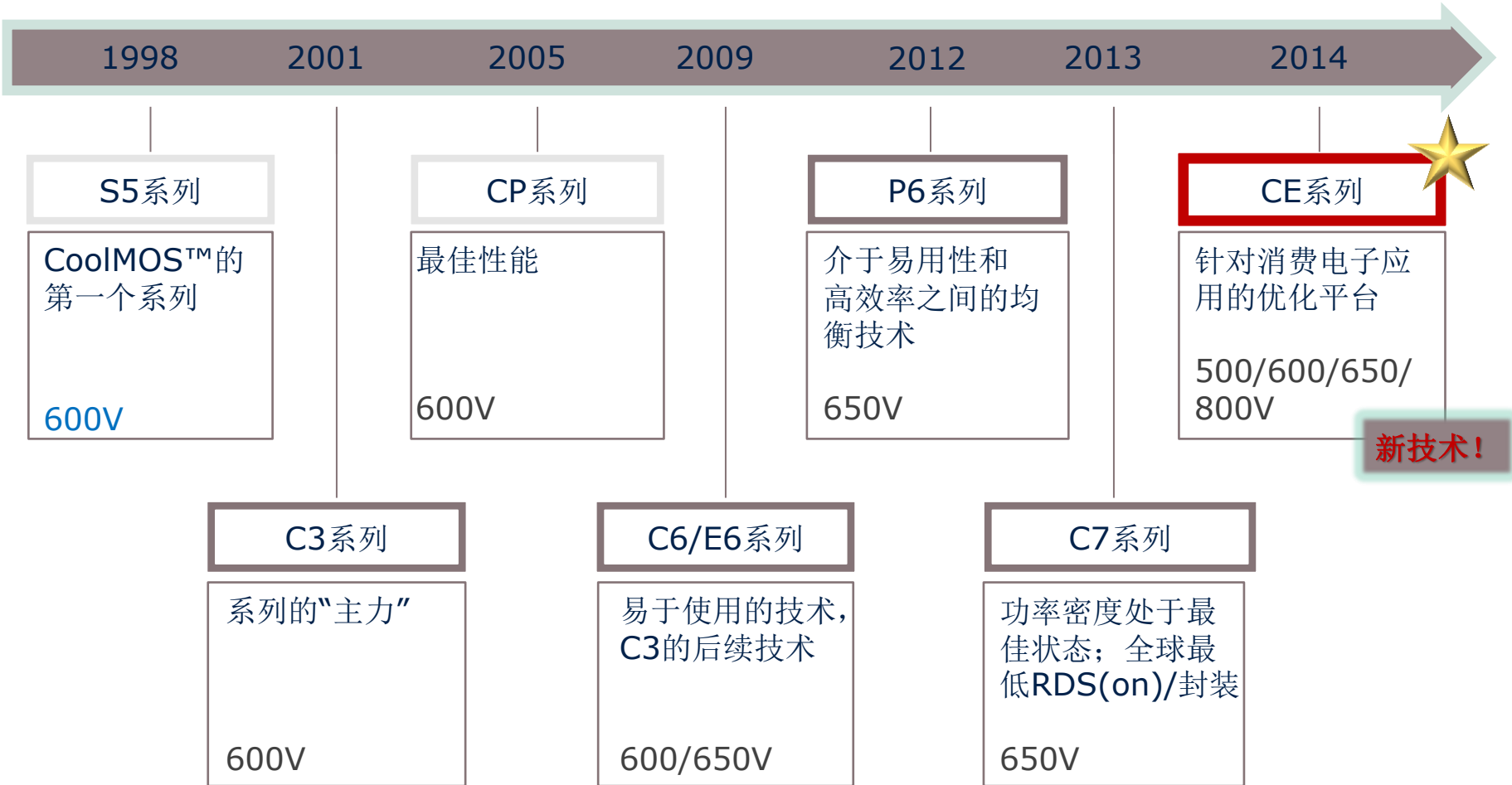


半桥 MOSFET:  
IPD60R650CE  
 $T_c= 78.9^{\circ}\text{C}$



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# 英飞凌是超级结功率管的创造者 超级结这一项技术经验已持续了15年之久



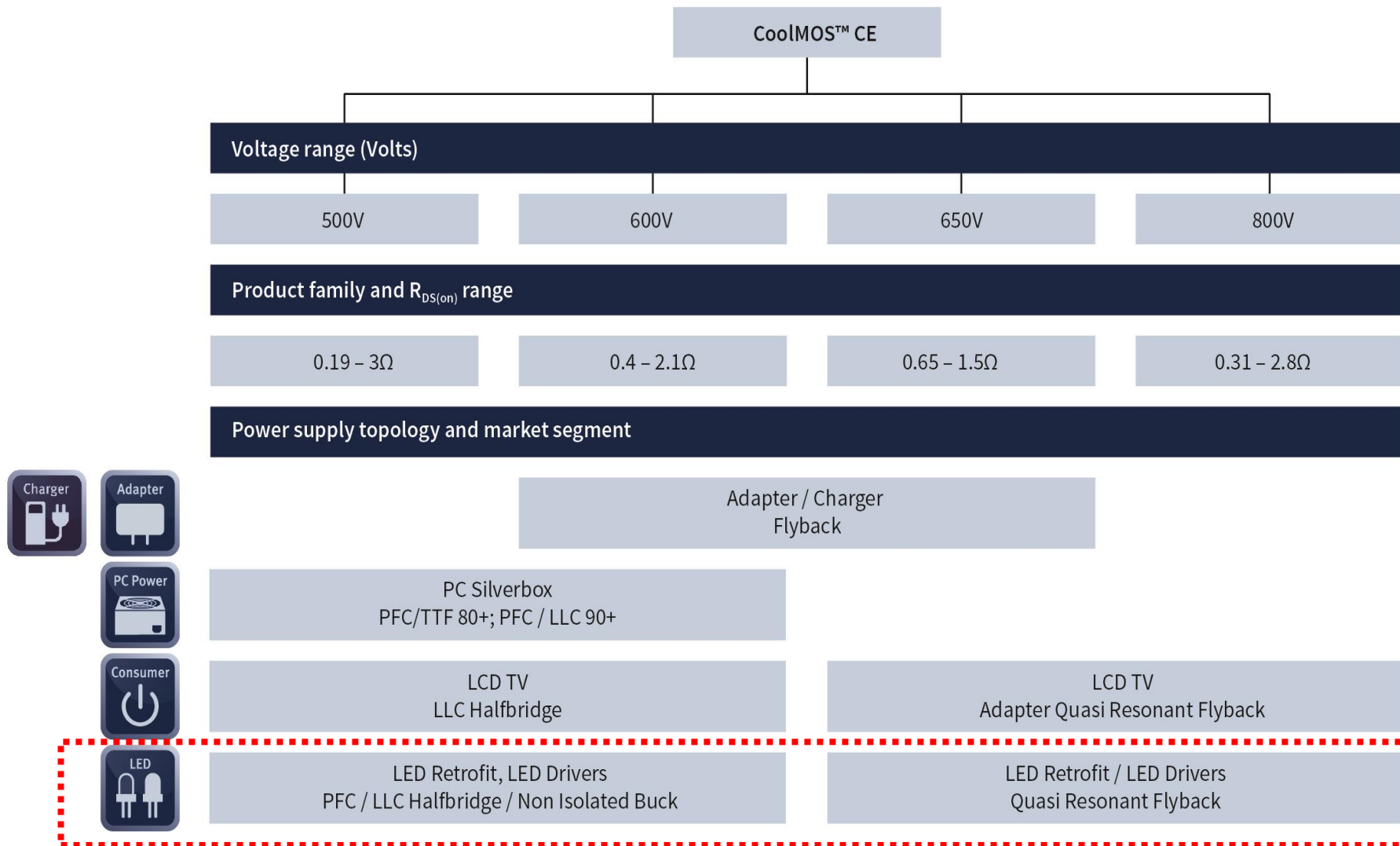
# CoolMOS™ CE

## CoolMOS™ CE 是什么？



- **CoolMOS™ CE** 是超级结CoolMOS™的其中一个系列，设计并用于满足 **消费电子，LED驱动** 需求
- **CoolMOS™ CE**系列提供500V、600V、650V和800V设备，面向低功率充电器、适配器、LCD、LED电视和LED照明以及电动工具充电器等应用
- 这一新的CoolMOS™系列经过了成本优化以满足**消费电子**中的典型需求，并且在价格仍然具有吸引力的同时不会对经过检验的CoolMOS™质量和可靠性产生负面影响
- **CoolMOS™ CE**适用于**硬开关和软开关**应用，并且作为现代SJ，它实现了较低的导通损耗和开关损耗，同时提供了效率并最终降低了功耗
- **CoolMOS™ CE**的易用性使客户能够缩短设计导入周期并在不断变化的市场中参与竞争

# CoolMOS™ CE 总览



# CoolMOS™ CE








Voltage	$R_{DS(ON)}$ [mΩ]	TO-220 FullPAK	TO-252 DPAK	TO-251 IPAK
	600V	2100		
1500			IPD60R2K1CE	IPU60R2K1CE
1000			IPD60R1K5CE	IPU60R1K5CE
800		IPA60R800CE	IPD60R1K0CE	IPU60R1K0CE
650		IPA60R650CE	IPD60R800CE	
500		IPA60R500CE	IPD60R650CE	
400	IPA60R400CE	IPD60R500CE		
			IPD60R400CE	
650V	$R_{DS(ON)}$ [mΩ]	TO-220 FullPAK	TO-252 DPAK	TO-251 IPAK SL
	1500			
	1000			IPS65R1K5CE
	650	IPA65R650CE	IPD65R650CE	IPS65R1K0CE



# CoolMOS™ CE

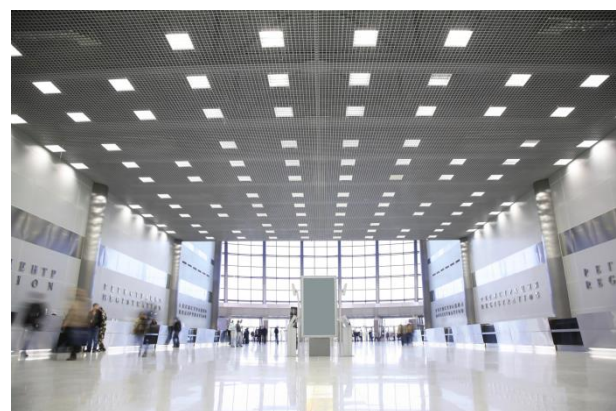
**500V**

$R_{DS(ON)}$ [mΩ]	 <b>TO-220 FullPAK</b>	 <b>TO-252 DPAK</b>	 <b>TO-220</b>	 <b>TO-247</b>	 <b>TO-251 IPAK</b>
<b>3000</b>		IPD50R3K0CE			IPU50R3K0CE
<b>2000</b>		IPD50R2K0CE			IPU50R2K0CE
<b>1400</b>		IPD50R1K4CE			IPU50R1K4CE
<b>950</b>	IPA50R950CE	IPD50R950CE			IPU50R950CE
<b>800</b>	IPA50R800CE	IPD50R800CE			
<b>650</b>	IPA50R650CE	IPD50R650CE			
<b>500</b>	IPA50R500CE	IPD50R500CE	IPP50R500CE		
<b>380</b>	IPA50R380CE	IPD50R380CE	IPP50R380CE		
<b>280</b>	IPA50R280CE	IPD50R280CE	IPP50R280CE	IPW50R280CE	
<b>190</b>	IPA50R190CE		IPP50R190CE	IPW50R190CE	

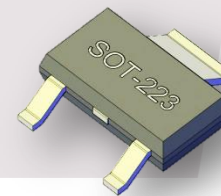


**800V**

$R_{DS(ON)}$ [mΩ]	 <b>TO-220 FullPAK</b>	 <b>TO-252 DPAK</b>	 <b>TO-251 IPAK</b>
<b>2800</b>		IPD80R2K8CE	IPU80R2K8CE
<b>1400</b>	IPA80R1K4CE	IPD80R1K4CE	IPU80R1K4CE
<b>1000</b>	IPA80R1K0CE	IPD80R1K0CE	IPU80R1K0CE
<b>650</b>	IPA80R650CE		
<b>460</b>	IPA80R460CE		
<b>310</b>	IPA80R310CE		



# CoolMOS™ CE SOT-223 小型封装系列

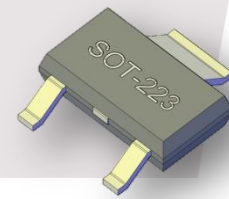


$R_{DS(ON)}$ [mΩ]	500V	600V	650V	700V
3400		IPN60R3K4CE		
3000	IPN50R3K0CE			
2000 / 2100	IPN50R2K0CE	IPN60R2K1CE		
1400 / 1500	IPN50R1K4CE	IPN60R1K5CE	IPN65R1K5CE	IPN70R1K5CE
950 / 1000	IPN50R950CE	IPN60R1K0CE		
800	IPN50R800CE			
650	IPN50R650CE			

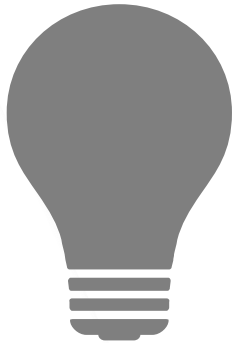
## Applications



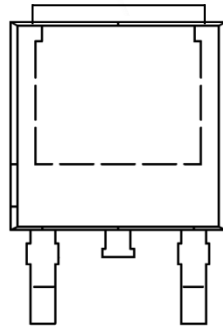
# SOT-223 用于LED 驱动



60 W

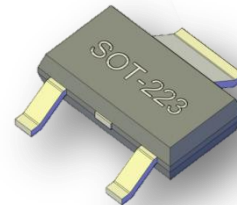


12 W



1.400 mΩ

3-9 W



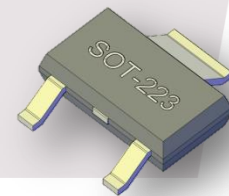
2.100 – 3.300 mΩ

优势

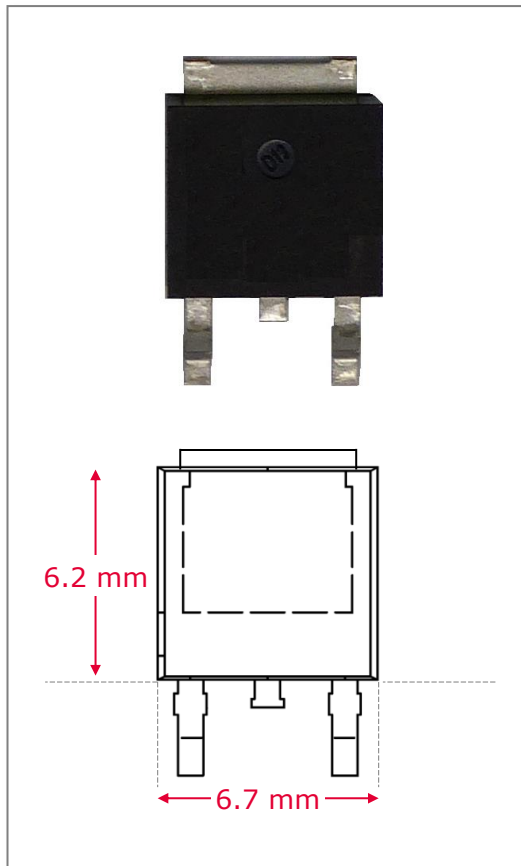
- › 更低成本
- › 更小封装
- › 兼容DPAK布板
- › 可接受的温升影响



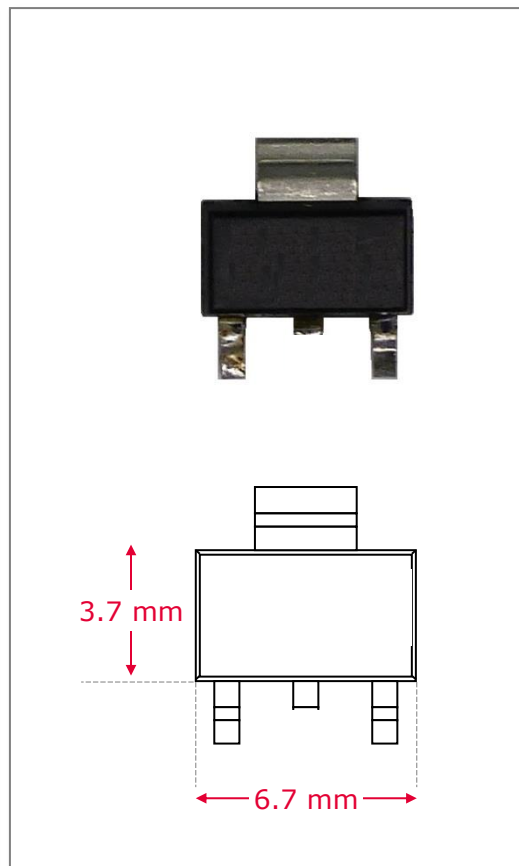
# SOT-223 更小的封装兼容 DPAK脚位



## DPAK



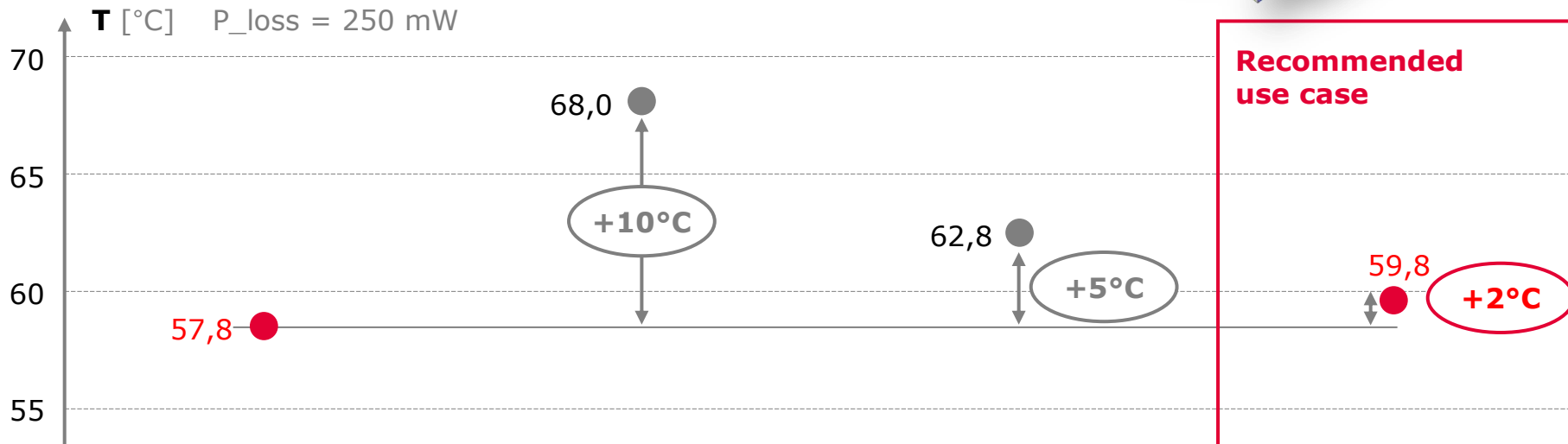
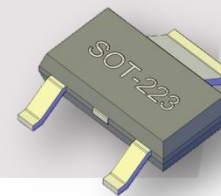
## SOT-223



## 优势

- 直接替换降低成本
- 节省空间

# SOT-223 仅仅提高少许温升

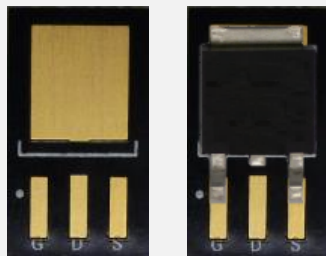


**Recommended use case**

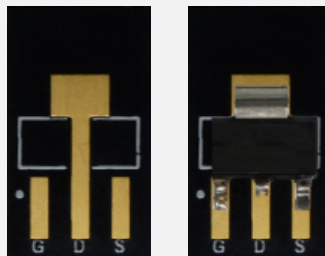
有较大铜箔下替换 DPAK

有满意的温升表现

**DPAK on DPAK footprint (reference)**

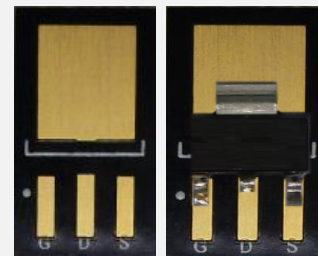


**SOT-223 on SOT-223 footprint**



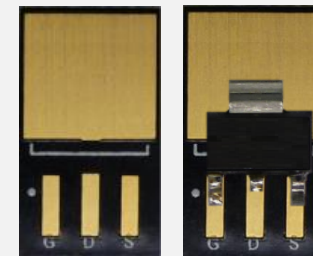
- › 适合小功率
- › 节省空间

**SOT-223 on DPAK footprint**



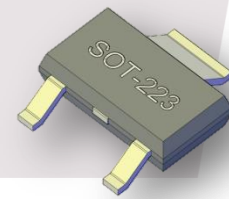
- › 可直接替换 DPAK
- › 温升仍有余量

**SOT-223 on Footprint of DPAK + 20 mm² Cu**

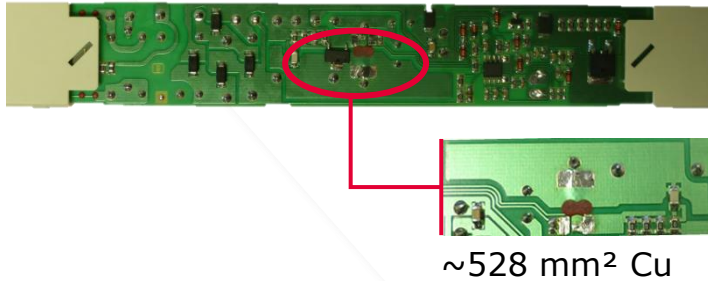


- › 有较大铜箔下替换 DPAK
- › 有满意的温升表现

# Practical 1: SOT-223 替换DPAK ( 52W LED driver )



## Test platform



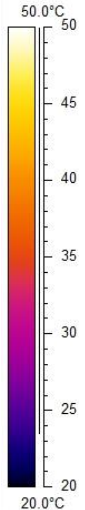
- › 52W LED driver
- › 输入电压: 220V/50Hz
- › 输出电压: 55-120V
- › 测试步长: 25V
- › 输出电流: 0.35A

## Thermal measurement

**DPAK:** IPD65R1K4C6 - 64,2 °C



**SOT-223:** IPN65R1K5CE - 66,5 °C



- › 比**DPAK**只增加**2.3 °C**
- › **SOT-223** 在**PCB**铜箔合适的情况下可直接替换**DPAK**

- 概述
- PFC+ LLC恒压方案
- PFC+ LCC恒流方案
- 创新的CoolMOSTM
- 结论
- 设计支持

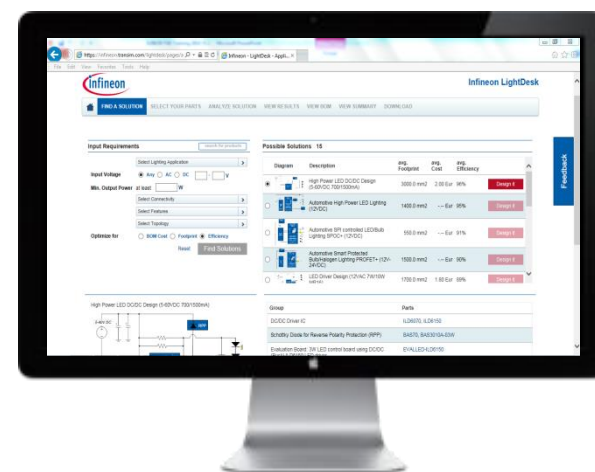
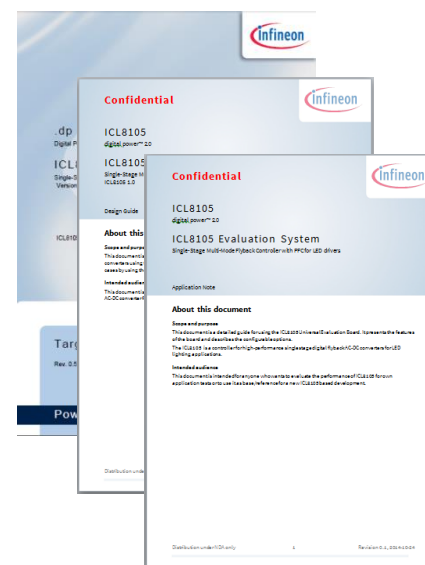
- › ICL5101集成PFC和半桥谐振驱动有利于减少零件数目
- › 采用PFC+LLC拓扑适合恒压输出
- › 采用PFC+LCC拓扑方便实现恒流状态下宽范围的电压输出，有利于精简平台
- › 采用INFINEON的 CoolMOS™有利于效率的进一步提高，CE系列具有更高的性价比
- › 其中SOT223的小封装优势有利于小型化，并进一步优化性价比

- 概述
- PFC+ LLC恒压方案
- PFC+ LCC恒流方案
- 创新的CoolMOS™
- 结论
- **设计支持**

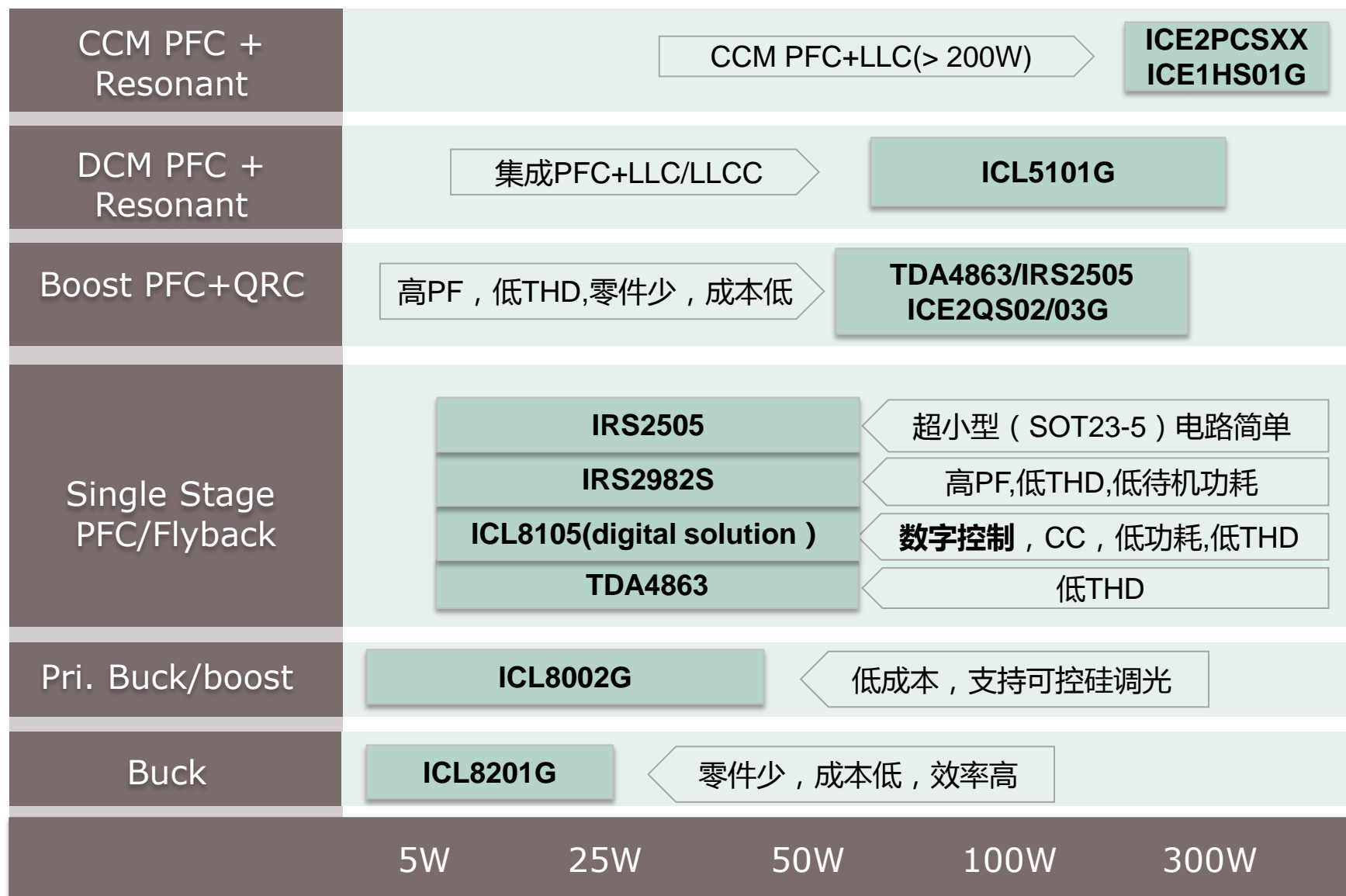
## › Documentation

- Datasheet
- Application notes

<http://www.infineon.com/ICL5101>

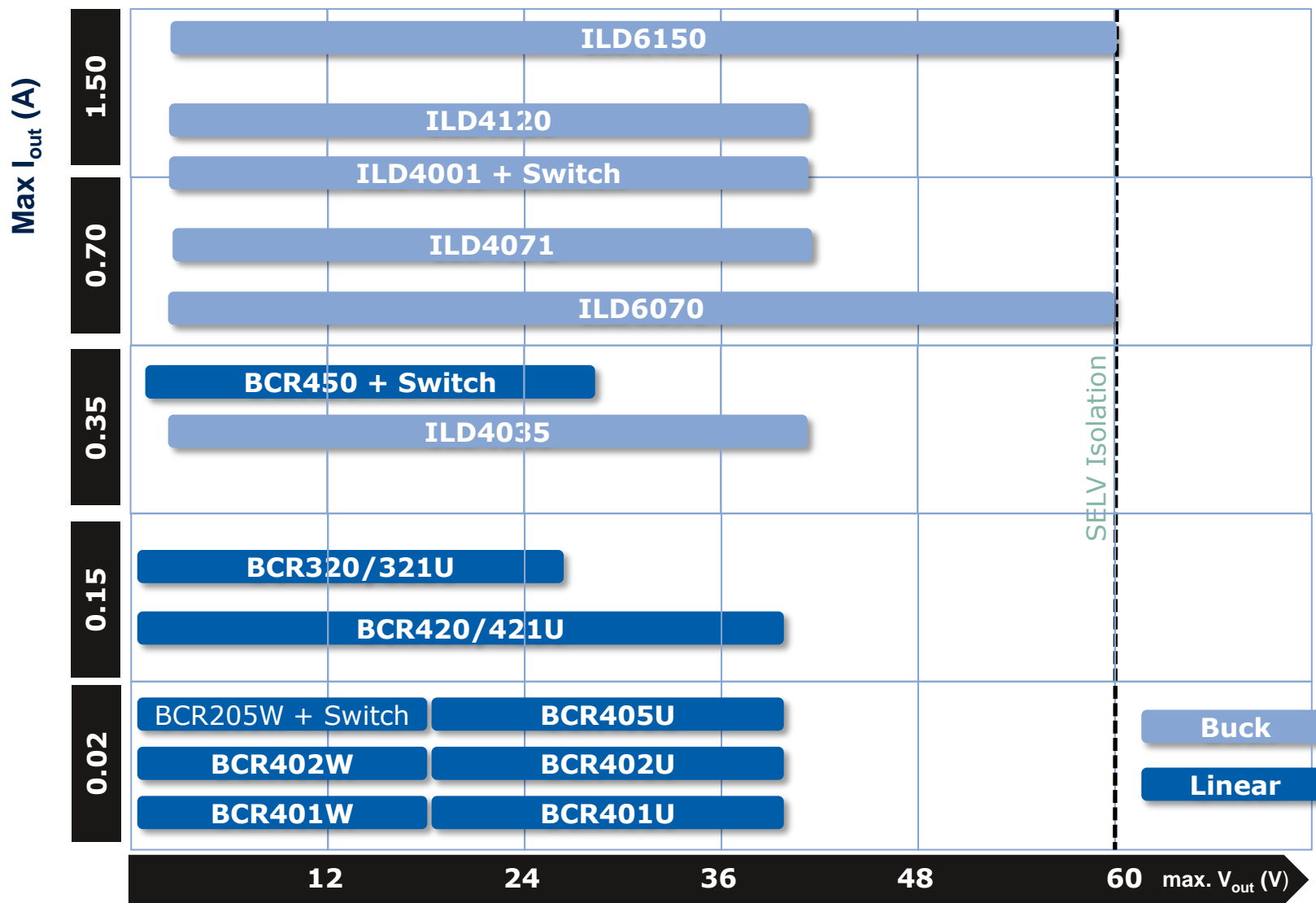


# 附录：AC/DC 照明方案

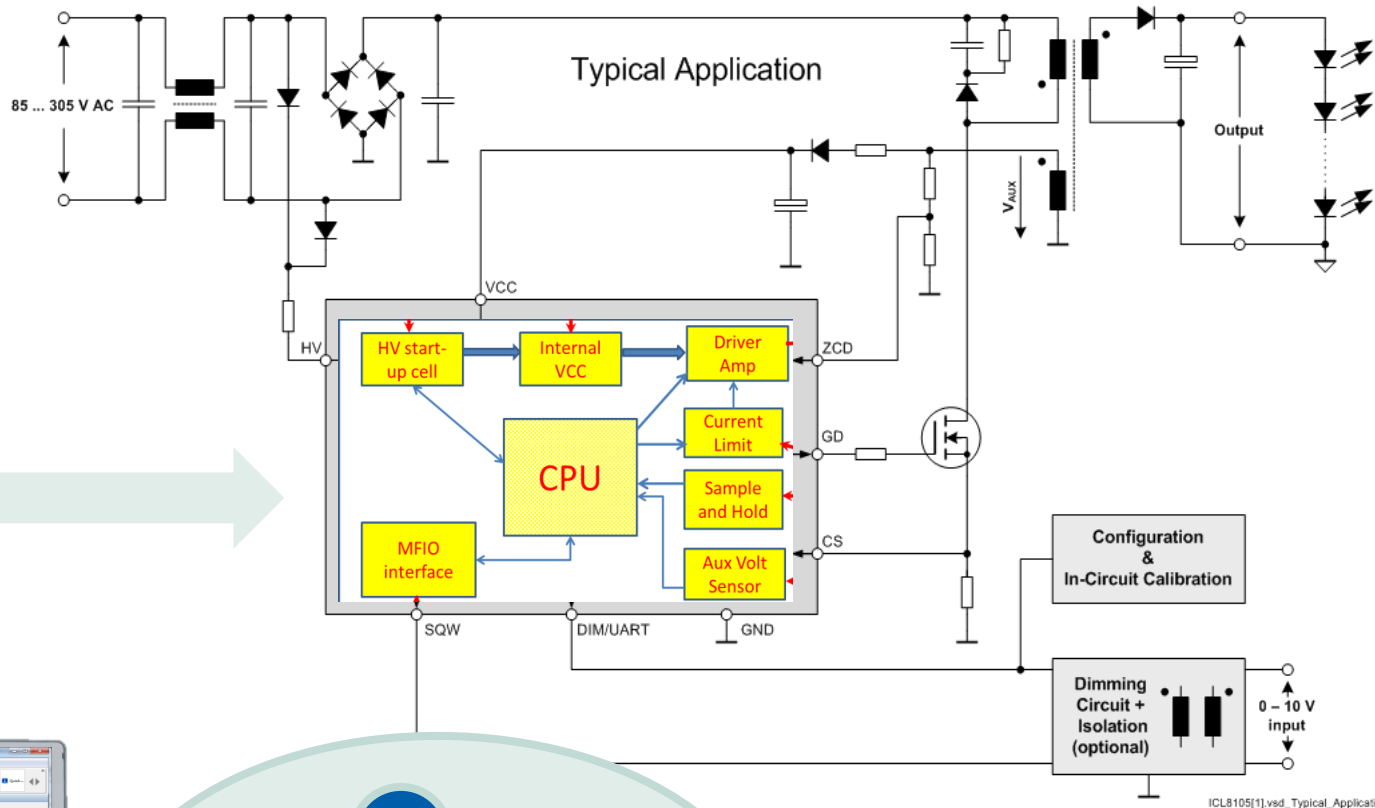




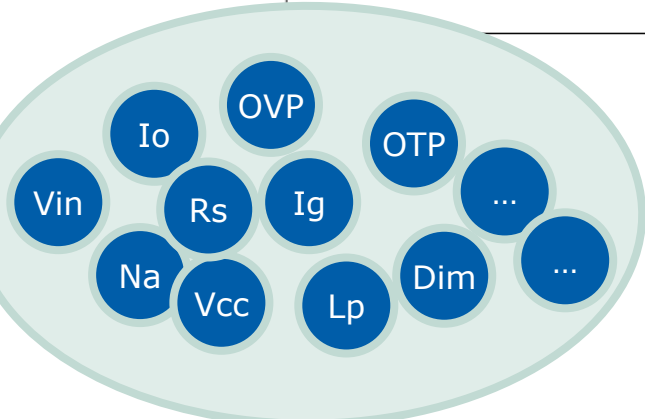
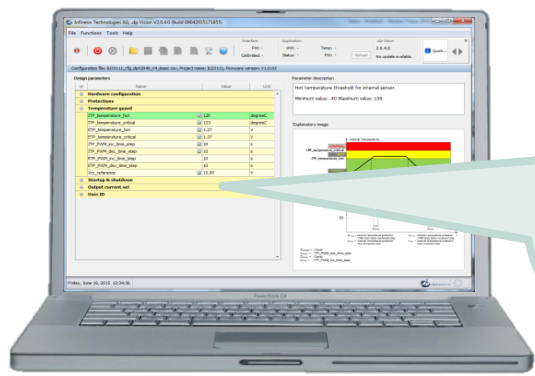
# 附录：DC/DC LED 驱动方案



# 附录：数字控制AC/DC方案 ICL8105



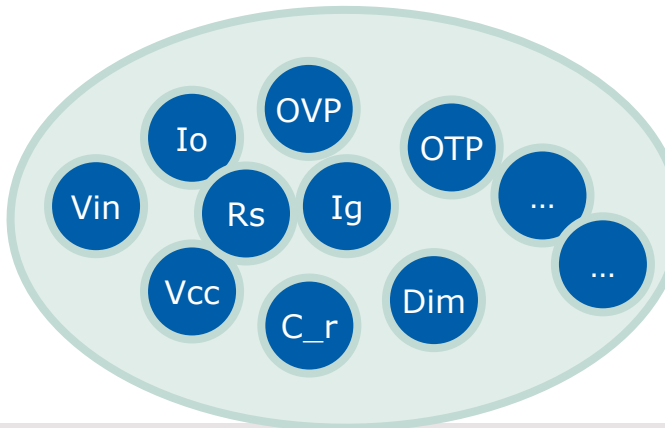
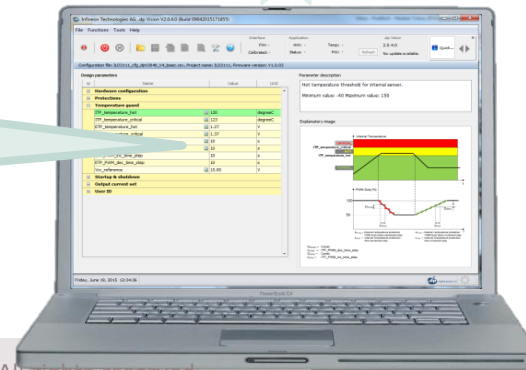
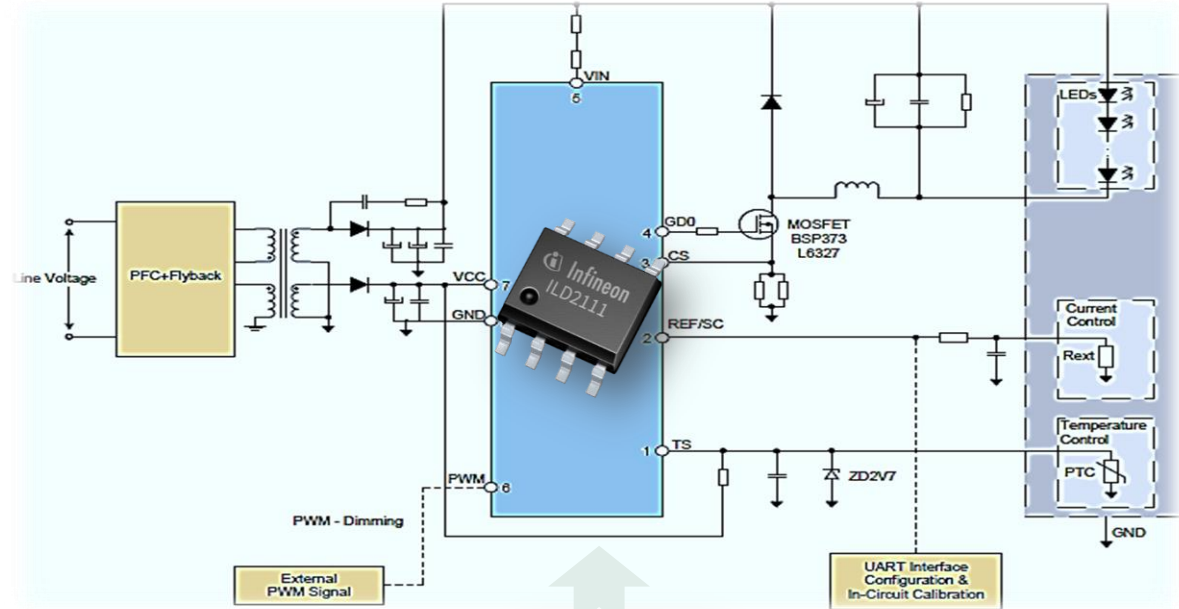
ICL8105[1].vsd\_Typical\_Application



# 附录：数字控制DC/DC方案 IDL2111



- Digital control
- Single stage PFC flyback+BUCK
- Output current selectable
- Platform design
- Configurable parameters





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