



PT4201

电流模式 PWM 控制器

概述

PT4201是一款电流模式PWM控制器,低启动电流、低工作电流、优化设计的操作模式以及完善的保护功能适用于高性能、高可靠性低待机功耗要求开关电源应用,也适用于对于电流精度及可靠性要求较高的LED照明系统。

优化设计的启动电路使PT4201所需的启动电流极小(典型3uA),正常工作时消耗电流仅需1mA,这样启动电路可以用更大的启动电阻以降低待机状态下启动电路的功耗。PT4201可以根据负载状况自动调整其工作状态,当系统进入轻载或无负载情况下PT4201自动进入突发工作模式,并降低PWM频率来减少开关损耗,因而降低了待机功耗。PT4201内部振荡器的可编程特性可通过一个外接电阻对PWM频率进行设定。

PT4201采用峰值电流控制模式,内部具有电流斜率补偿功能避免CCM工作模式下潜在的次谐波振荡问题。同时PT4201在每一个PWM打开周期自动屏蔽电流采样输入瞬间毛刺,这样可以省掉电流采样外部所需的RC滤波器,从而节省了外部系统元件数量和PCB的空间。

PT4201 提供完善的保护功能以提高开关电源的可靠性,包括逐周期过流保护(OCP)、过功率保护(OLP)、VDD 过压保护(OVP)以及 VDD 欠压保护(UVLO)等。GATE 输出脉冲高电压被嵌制在 18V 保护外部功率 MOS。

PT4201 可以提供 SOT-23-6 和 SOP-8 和 DIP-8 三种封装。

特点:

- 频率抖动改善系统 EMI 性能
- 轻载自动降频有效降低系统待机功耗
- 无音频噪声
- PWM 频率外部可调
- 内建斜率补偿
- 低启动电流(典型 3uA),低操作电流(典型 1mA)
- 适用大范围 AC 输入的恒定输出功率限制
- 电流采样前沿消除
- 输出钳位 18V 保护外部功率 MOSFET。
- 完善的保护功能:
 - 自动恢复 VDD 过压保护(OVP)以及欠压锁定保护(UVLO)
 - 线电压补偿的逐周期过流保护实现在宽电压范围内恒定电流限制
 - 锁定的负载过功率保护(OLP)

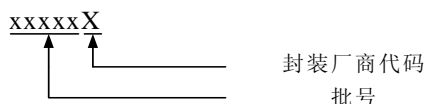
应用:

- 通用开关式电源
- 电源适配器
- 电池充电器适配器
- 1-30W LED 照明应用

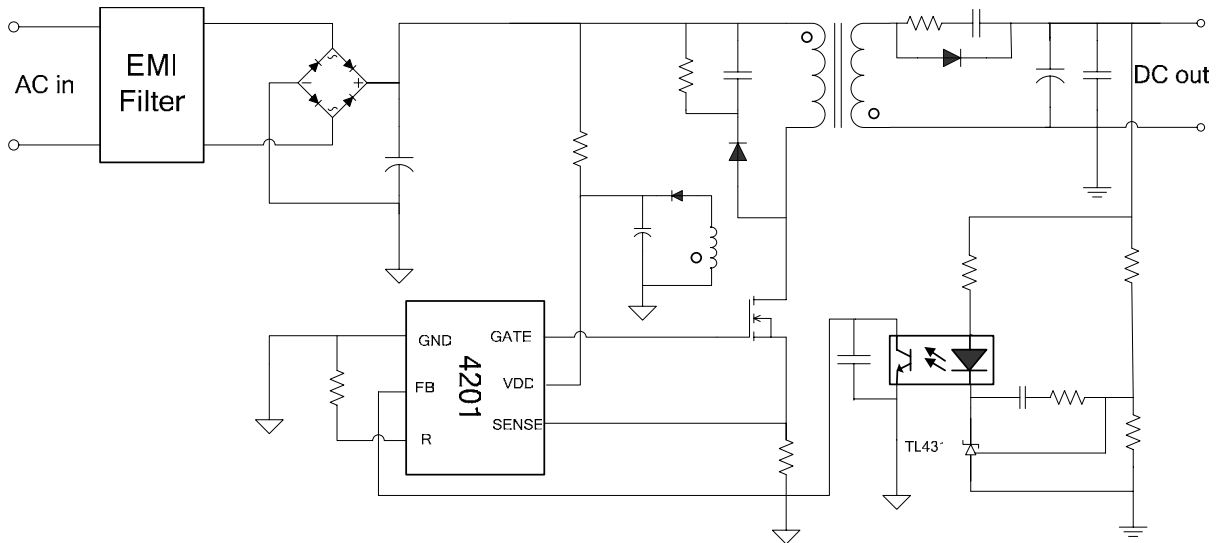
订货信息

封装	温度范围	名称	包装方式	标识
SOT23-6	-40°C to 85°C	PT4201E23F	Tape and Reel	4201
SOP8	-40°C to 85°C	PT4201ESOH	Tape and Reel	PT4201 xxxxxX
DIP8	-40°C to 85°C	PT4201EDIH	Tube	PT4201 xxxxxX

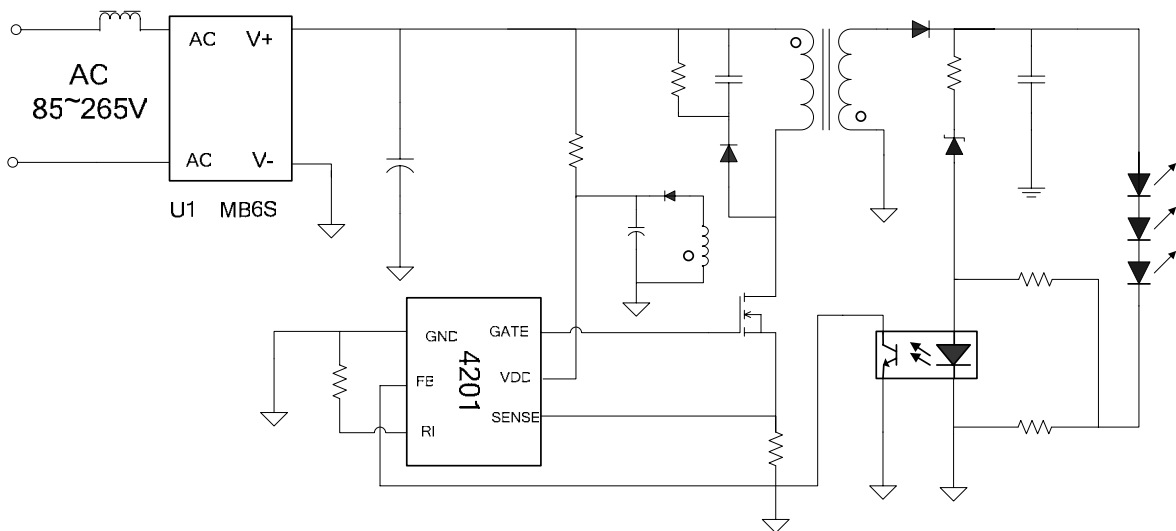
注释:



典型应用

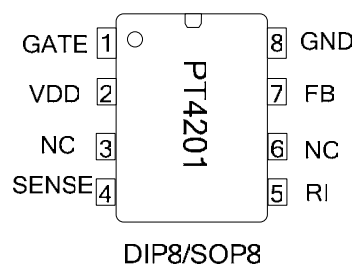
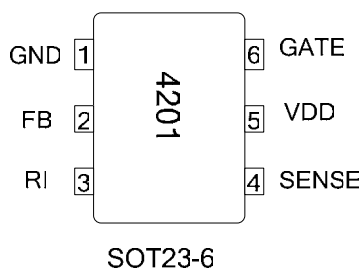


开关电源应用



LED 照明驱动典型应用

封装形式及引脚排列





引脚说明

脚号		符号	描述
SOT23-6	SOP8/DIP8		
1	8	GND	接地脚，直接连接到接地层。
2	7	FB	反馈输入引脚，FB 脚电压和 SENSE 脚输入电压共同决定了 PWM 占空比
3	5	RI	内部振荡器频率设定脚，通过接一个电阻到地设定内部振荡器频率
4	4	SENSE	过流保护输入引脚，通过检测串接在外部 MOSFET 和地之间电阻上的电压实现电流检测和逐周期过流保护
5	2	VDD	芯片工作电源输入端
6	1	GATE	PWM 驱动输出脚，连接到功率 MOSFET 的栅极
	3, 6	NC	无连接脚

最大极限值 (标注 1)

符号	项目	额定值	单位
VDD	输入电源电压	30	V
VDD _{CLAMP}	VDD 输入嵌位电压	33	V
IDD _{CLAMP}	VDD 嵌位连续电流	10	mA
V _{FB}	FB 输入范围	-0.3~7	V
V _{SENSE}	SENSE 输入范围	-0.3~7	V
V _{RI}	RI 输入电压范围	-0.3~7	V
T _{opt}	工作结温度范围	-40 to 150	°C
T _{stg}	存储温度范围	-55 to 150	°C
HBM	ESD 放电电压等级	2000(标注 2)	V
R _{θJA}	SOT-23-6	250	°C/W
	SOP8	150	
	DIP8	90	

推荐工作范围 (标注 3)

符号	项目	额定值	单位
VDD	输入电源电压	10~30	V
RI	频率设定电阻 RI 大小	100	Kohm
TA	环境温度	-20~85	°C

标注:

1. 如果工作条件超过最大极限值，芯片有可能损坏。
2. ESD 放电人体模型，100pF 电容通过 1.5Kohm 电阻放电。
3. 如果器件工作在推荐工作范围之外，不保证能满足所有参数指标。



电气特性参数

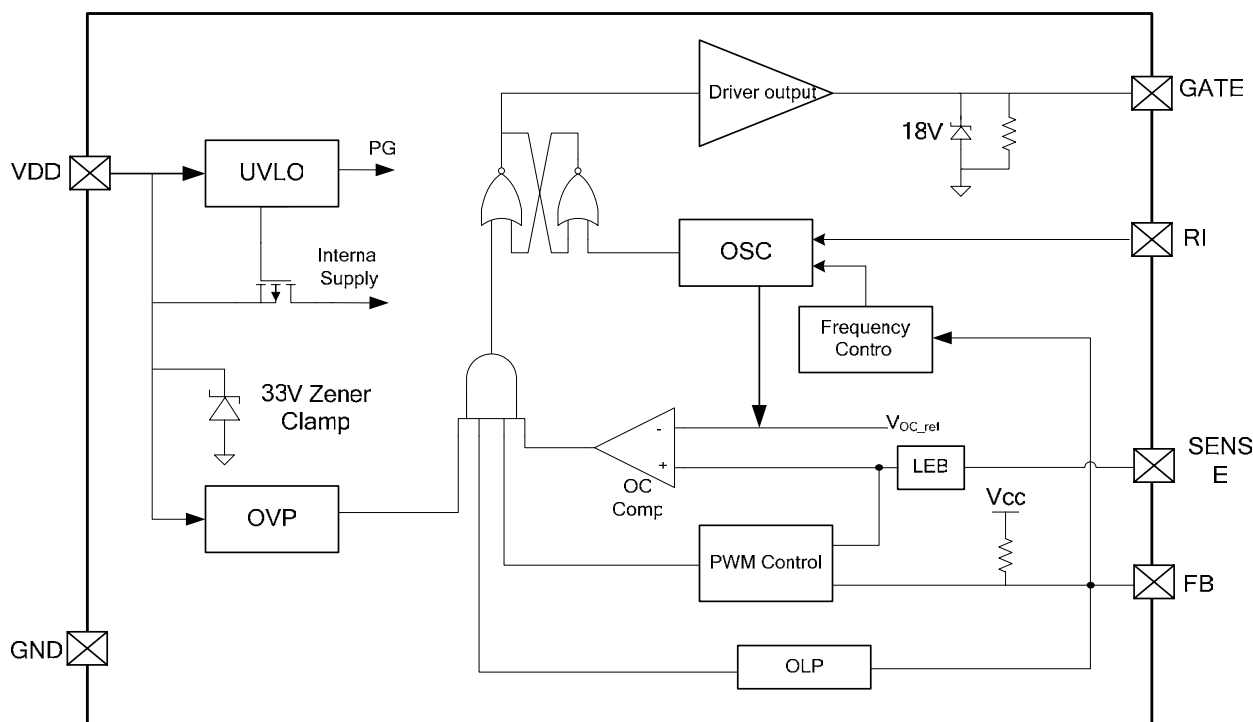
($T_{OPT}=25^{\circ}C$, $V_{DD}=16V$, 除非另外指定)

符号	项目	测试条件	最小	典型	最大	单位
输入电压 VDD						
V_{DD_ON}	V_{DD} 启动电压	V_{DD} 上升	14.0	15.0	16.0	V
V_{DD_MIN}	V_{DD} 最低工作电压	V_{DD} 下降	6.5	7.5	8.5	V
V_{DD_OVP}	V_{DD} 过压保护阈值	V_{DD} 上升	22.5	24.0	25.5	V
$V_{DD_OVP_OFF}$	V_{DD} 过压保护解除阈值	V_{DD} 下降	21.0	22.5	24.0	V
V_{OVP_HYS}	V_{DD} 过压保护迟滞	$V_{DD_OVP}-V_{DD_OVP_OFF}$		1.5		V
V_{ZENER}	V_{DD} 内部 ZENER 嵌位电压	$I(V_{DD})=5mA$		33		V
输入电流 VDD						
I_{VDD_START}	V_{DD} 启动电流	$V_{DD}=13.5V$ 测流进 V_{DD} 的电流		3	20	μA
I_{VDD_OPER}	V_{DD} 工作电流	$V_{DD}=16V, RI=100Kohm$ $V_{FB}=3V, Gate$ 悬空		1		mA
反馈 FB						
V_{OFB}	V_{FB} 开路输出电压	$V_{DD}=16V$		4.8		V
V_{PL}	过功率保护 FB 阈值电压			3.7		V
V_{GM}	降频操作 FB 阈值电压			1.6		V
V_{BM}	突发模式 FB 阈值电压			1.2		V
V_{ZD}	零占空比 FB 阈值电压	$V_{DD}=16V, RI=100Kohm$			0.70	V
T_{PL_DELAY}	过功率保护延迟时间	$RI=100Kohm$		32		ms
Z_{FB}	FB 引脚输入阻抗			6.0		Kohm
I_{FB}	FB 引脚对地短路电流	FB 短路到 GND, 测量从 FB 流出的电流		0.8		mA
振荡器 OSC						
F_{osc}	振荡频率	$RI=100Kohm$	60	65	70	kHz
ΔF_{JIT}	振荡器频率调制度	$RI=100Kohm$	-3		3	%
$T_{JITTRING}$	振荡器频率调制周期	$RI=100Kohm$		32		mS
F_{MIN}	突发模式下振荡频率	$V_{DD}=16V, RI=100Kohm$		22		kHz
RI	RI 电阻范围		50	100	250	Kohm
F_{DT}	振荡频率温度稳定度	$V_{DD}=16V, RI=100Kohm$ -20°C 到 100°C		2		%
F_{DV}	振荡频率输入电压稳定度	$V_{DD}=12\sim 25V, RI=100Kohm$		2		%
PWM						
A_V	PWM 输入增益	$\Delta V_{FB}/\Delta V_{CS}$		2.0		V/V
T_{BLK}	采样输入屏蔽时间			300		ns
D_{MAX}	PWM 最大占空比			75		%

电气特性参数 (继续)

符号	项目	测试条件	最小	典型	最大	单位
D_{MIN}	PWM 最小占空比				0	%
电流采样输入 SENSE						
V_{TH_OC0}	零占空比时 SENSE 过流保护阈值	$FB=3V, V_{GATE}<0.3V$	0.70	0.75	0.80	V
T_{OC_DELAY}	过流到输出关断延迟时间	$V_{DD}=16V, CS>V_{TH_OC},$ GATE 加 1000pF 负载电容		100		nS
输出 GATE						
V_{OL}	输出最低电平电压	$V_{DD}=16V, I_o=-20mA$			0.8	V
V_{OH}	输出最高电平电压	$V_{DD}=16V, I_o=20mA$	10			V
T_r	输出脉冲上升时间	$V_{DD}=16V, CL=1000pF$		220		nS
T_f	输出脉冲下降时间	$V_{DD}=16V, CL=1000pF$		70		nS
V_{GMAX}	输出高电平箝制电压			18		V

电路模块图

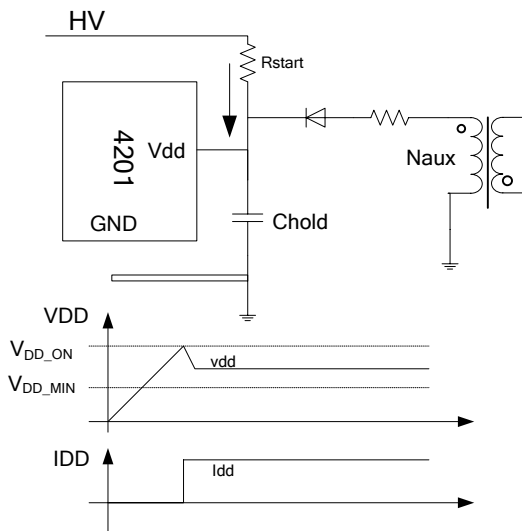


基本功能描述

集成了多种增强功能的 PT4201 以其极低的启动和工作电流和优化的控制模式使离线式开关电源设计满足高性能同时，更容易满足严格的待机功耗限制。

启动及 UVLO:

PT4201 通过一个连接到高压线上的电阻 R_{start} 对连接在 VDD 脚上的电容 $Chold$ 充电实现启动。在上电之初， $Chold$ 电容上的电压为 0，PT4201 处于关断状态，从 R_{start} 上流下的电流对 $Chold$ 进行充电从而使 V_{dd} 电压升高，当 V_{dd} 脚电压达到芯片启动电压 V_{DD_ON} 之后芯片开始工作，工作之后流进 V_{dd} 电流增加，由辅助绕组开始对芯片进行供电。优化设计的启动电路使 PT4201 启动之前 VDD 只消耗极低的电流，这样可以选用比较大的启动电阻 R_{start} 来减小待机功耗。对于一般的通用输入范围的应用来说，一个 2Mohm, 1/8W 的电阻和一个 10uF/50V 的电容可以组成一个简单可靠的启动电路。

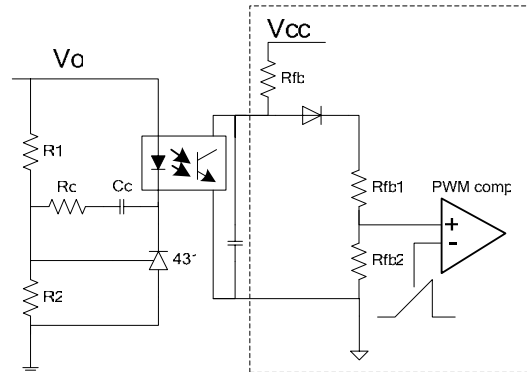


工作电流:

采用 BiCMOS 工艺制造的 PT4201 正常工作电流典型状况下只需 1mA，小的工作电流可提高系统效能，同时启动电路中可以选用较小的启动电容 $Chold$ 以缩短启动时间。

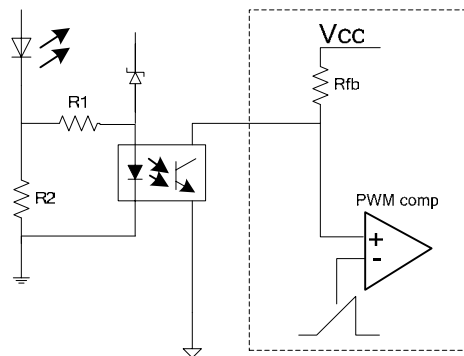
电压反馈及 PWM (开关电源应用):

PT4201 采用电流模式控制，电压反馈通过连接到输出端的 TL431 和光耦改变 PT4201 FB 引脚电压实现。如图所示，TL431 内部有一 2.5V 的基准，当 R_1, R_2 的分压超过内部基准时，TL431 驱动光耦发光管发光，光耦内部光敏三极管根据接收到的发光强度输出与发光管电流成比例的电流改变 FB 引脚电压，PT4201 根据 FB 电压的大小改变输出脉冲占空比实现 PWM 控制。



电流采样及恒流控制 (LED 驱动应用):

当用作 LED 驱动时，PT4201 采用光耦检测输出 LED 串的电流并通过改变输出脉冲占空比达到输出电流控制目的。如图所示，当 LED 电流达到设定值时，LED 电流在采样电阻 R_2 上的压降达到光耦发光管导通电压，发光管导通使 FB 电压下降，PT4201 根据 FB 电压的大小改变输出脉冲占空比实现恒定电流输出。



轻载操作 (开关电源应用):

由于系统损耗随单位时间内 MOSFET 的开关次数增加而增加，在轻载时为了维持系统转换效率，PT4201 自动减小 MOSFET 开关次数来降低损耗。通过检测 FB 电压大小自动改变工作频率和操作方式。当负载降低时流过初级绕组的电流减小，FB 电压降低，当 FB 降低到小于 1.6V 时，PWM 频率开始随 FB 降低而线性降低。 $R_i=100K$ 时内部振荡器工作频率限制在 20KHz 以上，可以避免在轻负载下系统发出音频噪声。如果负载继续降低，那么 FB 继续降低，当 FB 低于内部设置的阈值时 PT4201 进入突发工作模式，这时会跳过一些开关周期以进一步减少开关次数。若 FB 电压降低到零占空比阈值以下，那么 PWM 将会立即关闭。

LED 开路 (LED 驱动应用):

LED 负载开路时,流过稳压管得电流在电阻 R1 和 R2 上产生一个压降使光耦发光管打开,使 PT4201 的 FB 降低。当 FB 降低到一定程度时 PT4201 进入突发模式,整个系统进入低功耗模式。因此 LED 灯开路是安全的。

LED 短路及采样电阻短路保护 (LED 驱动应用):

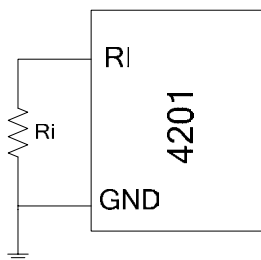
当 LED 负载发生短路时,光耦发光管两端电压等于输出电压,由于输出功率很小因此整个系统工作是安全的。当采样电阻发生短路时,由于光耦发光管两端电压为零,发光管不导通导致 FB 电压快速爬升到保护阈值。在 R_{osc} 为 100Kohm 情况下,过 32mS 后 PT4201 将自动关闭。

工作频率及频率抖动:

PT4201 的 RI 引脚为设定 PWM 频率提供了方便,用一个电阻接在 RI 引脚和 GND 之间可以对 PWM 频率进行设定。PWM 频率与设定电阻之间的关系遵循以下关系: $F_{osc} = 6500/R_I$ 。F_{osc} 单位 KHz, R_I 单位 Kohm。

PT4201 在正常工作时会周期性地改变 PWM 操作频率。周期性改变的频率把 EMI 传导干扰扩展到更宽的频谱范围内降低了传导段 EMI 干扰,从而使系统 EMI 设计更容易满足苛刻的要求。

需要注意的是,由于轻载状态下 PT4201 自动将频率降低到正常工作时的 1/3,如果 R_I 过大,可能造成轻载状态下有噪声产生。因此过大的 R_I 值是不推荐的。



电流采样以及前沿消隐:

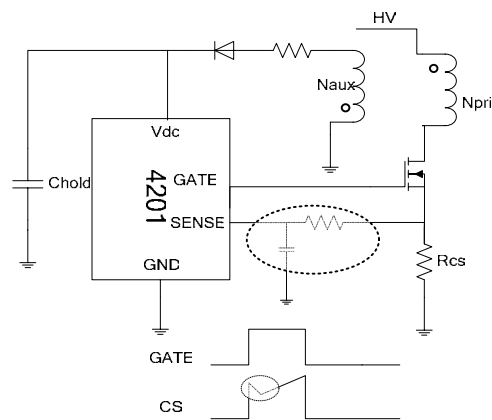
PT4201 的 SENSE 引脚的功能之一是采样外部功率 MOSFET 电流进行电流斜率补偿,二是提供逐周期的 MOSFET 过流保护功能。PT4201 通过采样与功率 MOSFET 串联的采样电阻来采样流过 MOSFET 的电流,流过 MOSFET 的电流在采样电阻 R_{cs} 上转换成电压信号,SENSE 上电压和 FB 电压共同决定了 PWM 脉冲占空比。

在 PWM 每个导通周期当 SENSE 引脚的电压超过内部门限电压时 MOSFET 将立即被关掉防止过流对器件的损伤。过流门限电压与 MOSFET 的电流可由以下关系确定:

$$I_{OC} = V_{oc} / R_{cs}$$

其中 I_{oc} 为 MOSFET 电流, V_{oc} 为过流门限电压, R_{cs} 为采样电阻大小。内部过流的门限值与 PWM 占空比大小有关,当 PWM 占空比为 0 时,过流门限值为 0.75V。

由于变压器副绕组整流电路反向恢复时间以及初级绕组寄生电容等因素影响,在每一个 PWM 周期开启瞬间会在采样电阻上产生一个持续时间很短的尖峰电压。为此 PT4201 会在 MOSFET 开启后屏蔽 SENSE 采样输入一段时间 T_{BLK},在这段时间内,过流保护被关闭不会关掉外部 MOSFET。这样可以避免 MOSFET 开启瞬间在采样电阻上产生的电压毛刺而造成误动作。PT4201 提供的这种功能可以省去电流采样电路所需的 RC 滤波器。



内部斜率补偿:

连续电流模式方式当 PWM 占空比超过 50% 时存在次谐波振荡问题。PT4201 内部具有斜率补偿功能,在每一个 PWM 开通周期会有一个固定斜率的电压叠加到 SENSE 引脚采样电压上,有效改善了连续电流模式下闭环稳定性。省去了外部电流斜率补偿所需元件。

过流补偿:

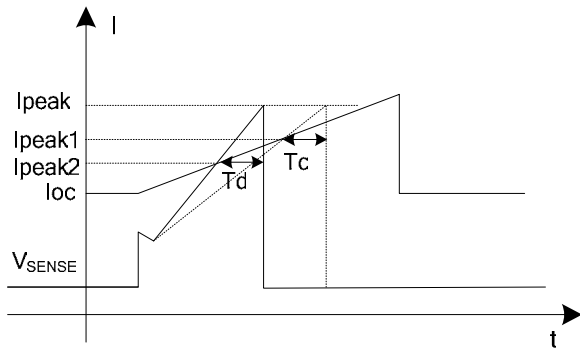
在过流情况下,由于从过流发生到 MOSFET 关闭有一个延迟时间 T_d,因而实际的过流点与设定过流保护点有一定的差异。如下图所示,考虑内部过流延迟时实际的过流点为:

$I_{peak} = I_{peak1} + I_{slope1} * T_d$, 其中 $I_{slope1} = V_{indc1} / L_{pri}$, 而在一个较高输入电压情况下,实际过流点为:

$I_{peak} = I_{peak2} + I_{slope2} * T_d$ 。 $I_{slope2} = V_{indc2} / L_{pri}$ 。 L_{pri} 为变压器初级绕组电感大小, T_d 是一个固定不变的值,所以实际过流保护点与设定过流保护点的差异随输入电压升高而变大。

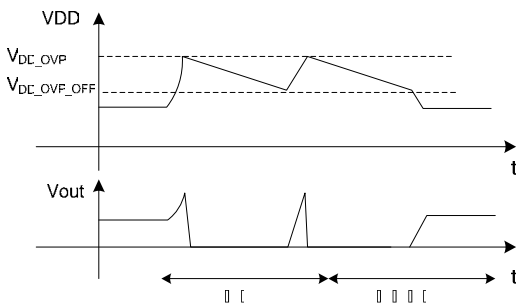
为了补偿这样的差异,PT4201 的过流保护阈值设计为随占空比变化的形式对 I_{peak} 进行补偿,当输入电压升高时 PWM 占空比降低, I_{oc} 也降低降低,因而 I_{peak2} < I_{peak1}, 使在不同的输入电压条件下 I_{peak} 保持不变,从而实现宽输入电压范围内过流保护大小的一致性。SENSE 引脚的过流保护阈值与占空比 PWM 占空比的关系遵循以下关系式:

$$V_{oc} = 0.75 + 0.52 * Duty, \text{ Duty 为 PWM 脉冲占空比。}$$



VDD 过压保护:

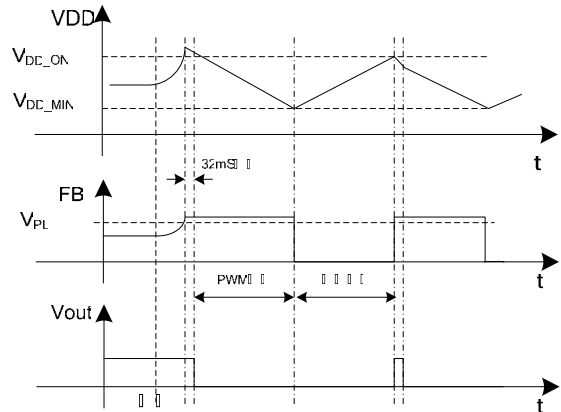
当反馈环路发生开路故障时，流过光耦的电流接近为零致使 FB 端电压上升。与 OLP 情况相似，FB 电压上升将会使 PT4201 工作在过流保护状态，由于有多余的电流供给负载，如果超出了负载所需电流大小会使输出电压升高。如果 OLP 不能及时触发那么输出电压将会爬升过高损坏元器件。由于辅助绕组的电压与输出电压成一定的比例，输出电压升高引起辅助绕组电压升高进而使 VDD 电压升高，当 PT4201 检测到 VDD 引脚电压达到过压保护点时会关闭 PWM。当 OVP 被触发时由于没有能量供给负载及辅助绕组，VDD 电压和输出电压下降，当降低到 OVP 解除电压时将重新开启正常工作。这时如果故障解除则正常工作，如果故障依然存在将重新进入 OVP 保护状态。



过功率保护 OLP:

为了保护开关电源在过载或负载短路时不被损坏，PT4201 设置了过功率保护功能，这是通过检测 FB 引脚的电压实现的。当发生过载或负载短路时，光耦的电流减小致 FB 电压升高，当 FB 电压高于 3.7V 时 PT4201 将启动内部过流保

护定时器。在时钟频率为 65KHz 情况下，延时 32mS 后如果过载情况仍然存在，那么 PWM 将会被关闭，直到 VDD 下降到 UVLO 电压以下重新复位才能重新开启。过功率保护的时序如下图所示:

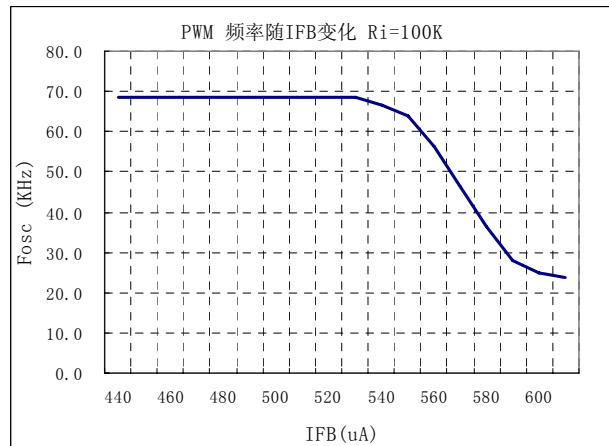
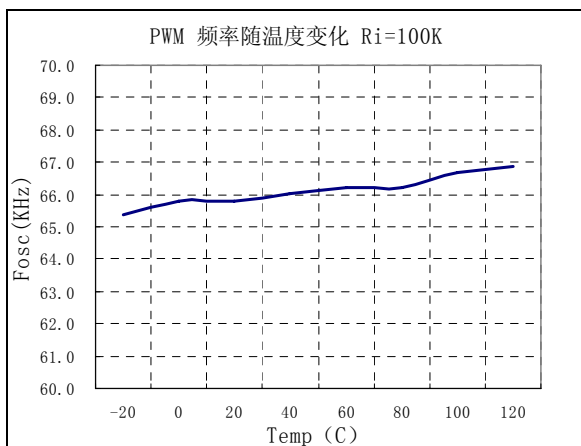
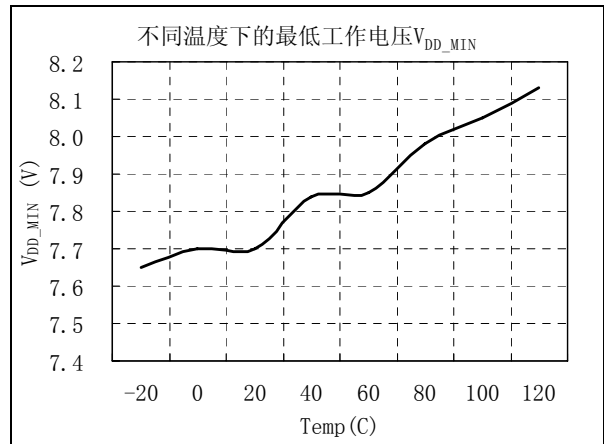
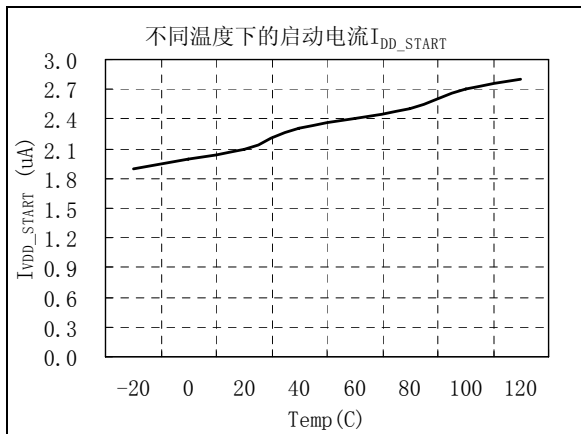
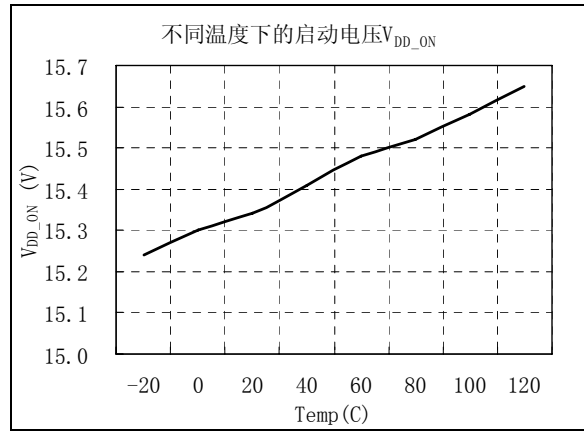
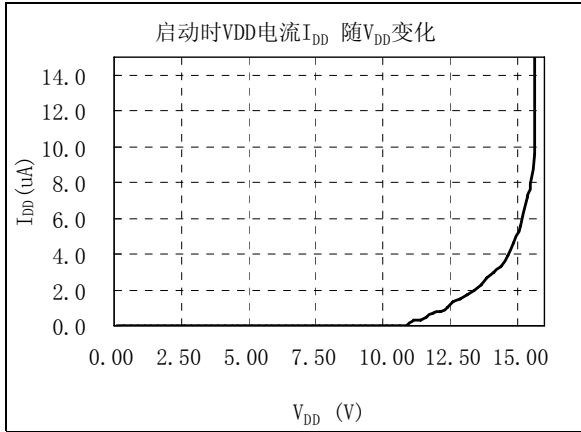


GATE 输出驱动:

PT4201 的 GATE 用来驱动功率 MOSFET 的栅极。优化设计图腾柱形式输出的驱动能力使驱动强度和 EMI 得到良好的折中。同时，GATE 的输出高电位被限制到了 18V，从而可以保护由于 VDD 升高可能对 MOSFET 造成的损伤。内部 GATE 和 GND 之间有一个电阻，可以在芯片不工作时将外部 MOSFET 的栅极可靠置为 0 电位。

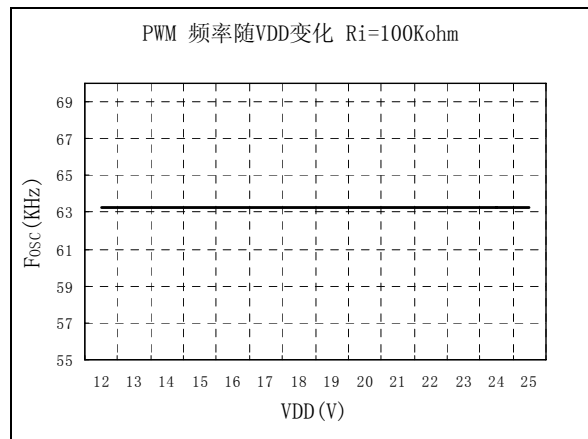
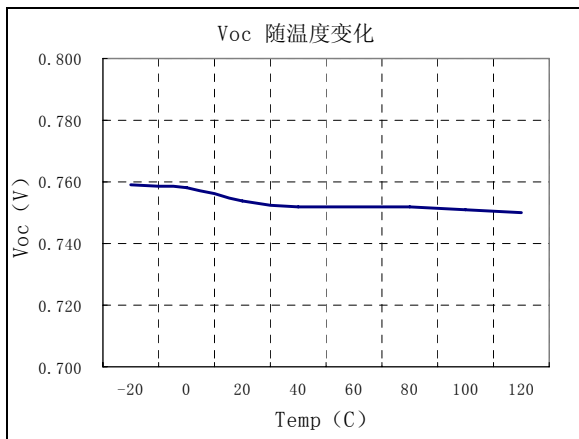
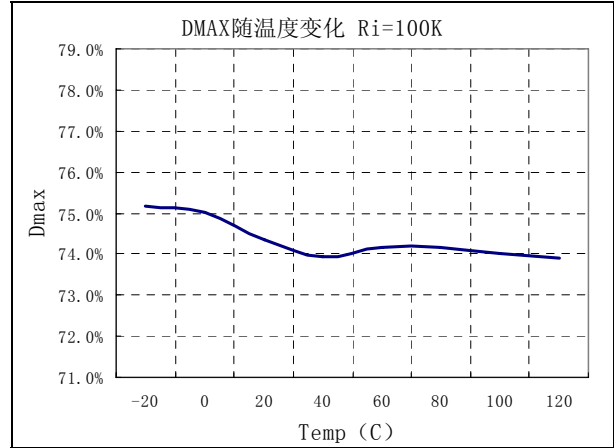
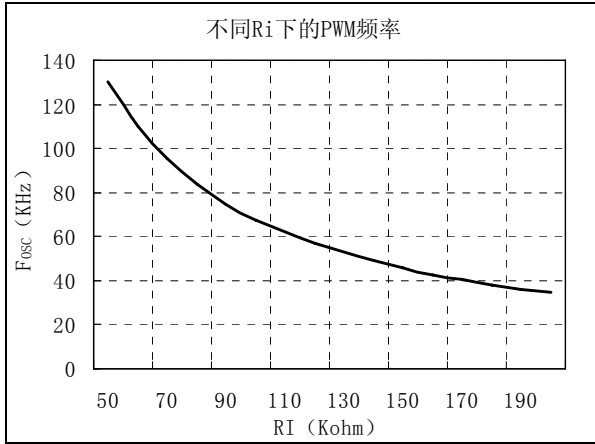


典型工作特性



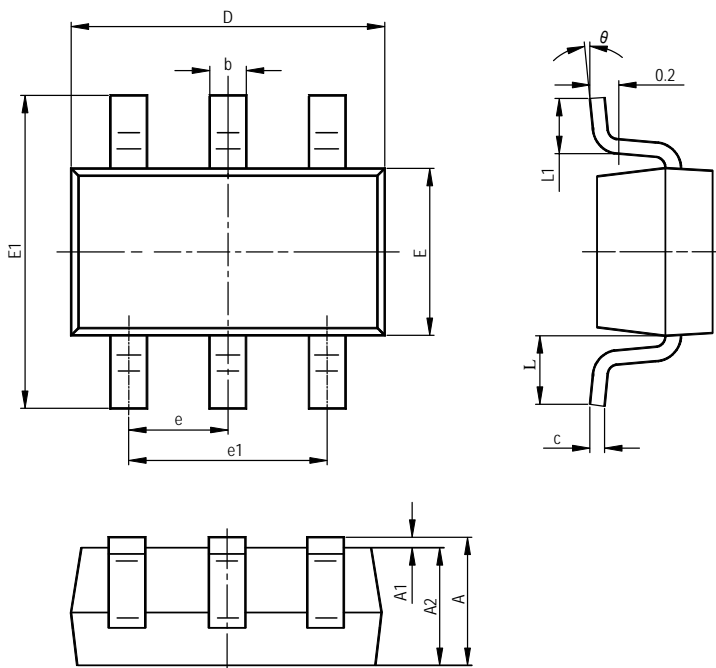


典型工作特性 (继续)



封装信息

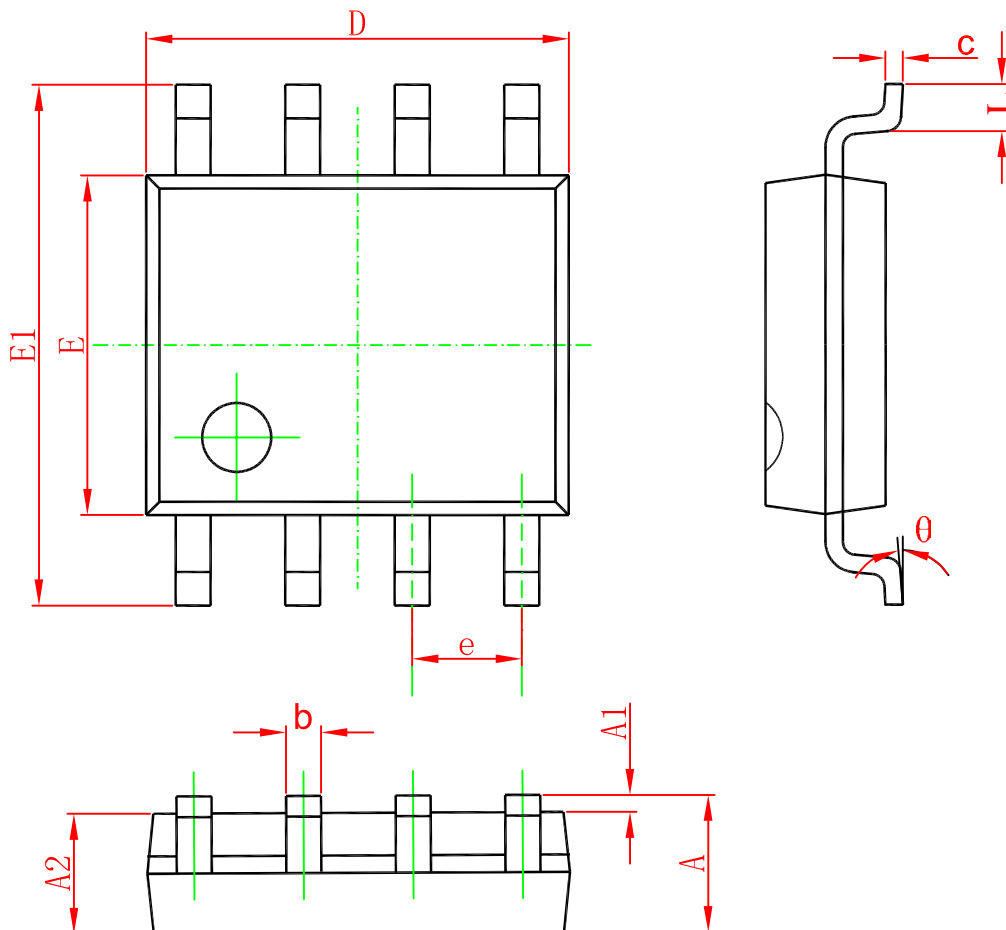
SOT23-6



SYMBOL	MILLIMETERS		INCHES	
	MIN	MAX	MIN	MAX
A	1.050	1.250	0.041	0.049
A1	0.000	0.100	0.000	0.004
A2	1.050	1.150	0.041	0.045
b	0.300	0.400	0.012	0.016
c	0.100	0.200	0.004	0.008
D	2.820	3.020	0.111	0.119
E	1.500	1.700	0.059	0.067
E1	2.650	2.950	0.104	0.116
e	0.950TYP		0.037TYP	
e1	1.800	2.000	0.071	0.079
L	0.700REF		0.028REF	
L1	0.300	0.600	0.012	0.024
θ	0°	8°	0°	8°

封装信息

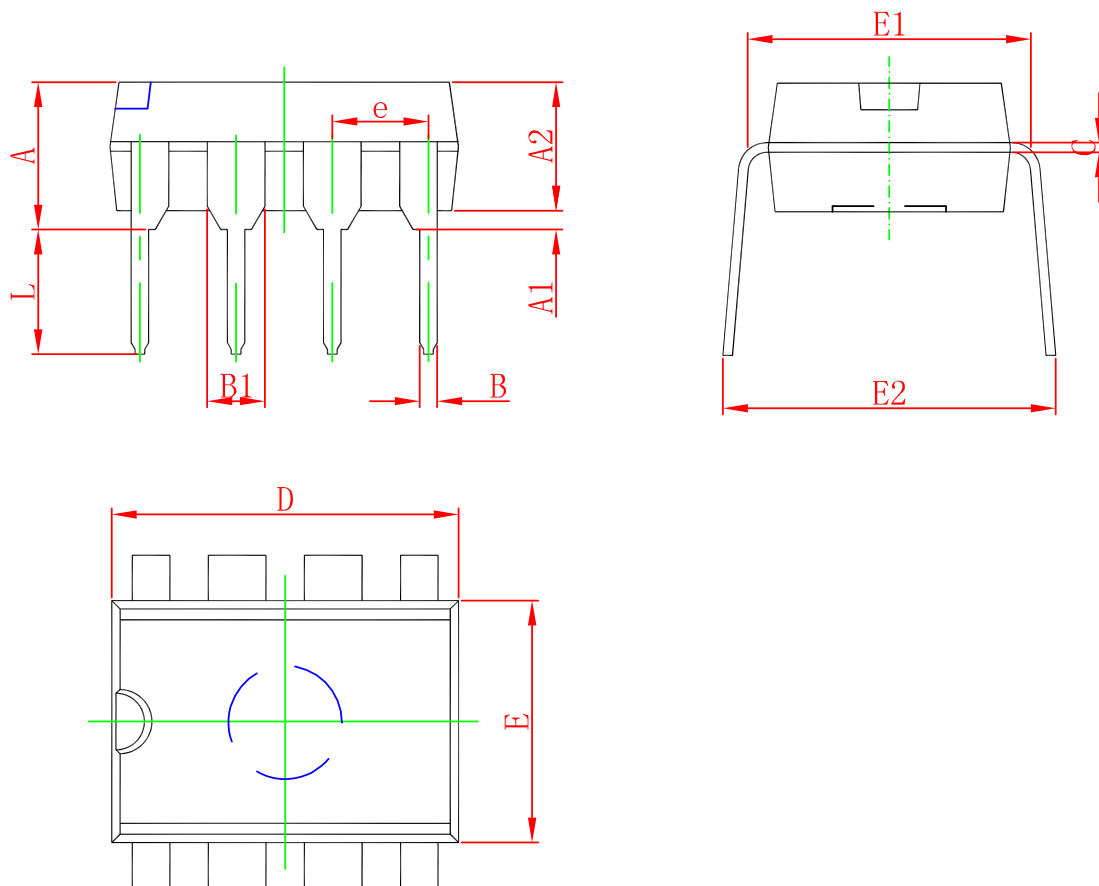
SOP8



SYMBOL	DIMENSIONS IN MILLIMETERS		DIMENSIONS IN INCH	
	MIN	MAX	MIN	MAX
A	1.350	1.750	0.053	0.069
A1	0.100	0.250	0.004	0.010
A2	1.350	1.550	0.053	0.061
b	0.330	0.510	0.013	0.020
c	0.170	0.250	0.006	0.010
D	4.700	5.100	0.185	0.200
E	3.800	4.000	0.150	0.157
E1	5.800	6.200	0.228	0.244
e	1.270(BSC)		0.050(BSC)	
L	0.400	1.270	0.016	0.050
θ	0°	8°	0°	8°

PACKAGE INFORMATION

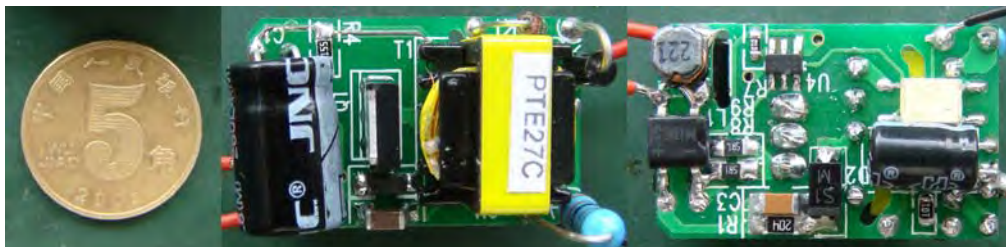
DIP8



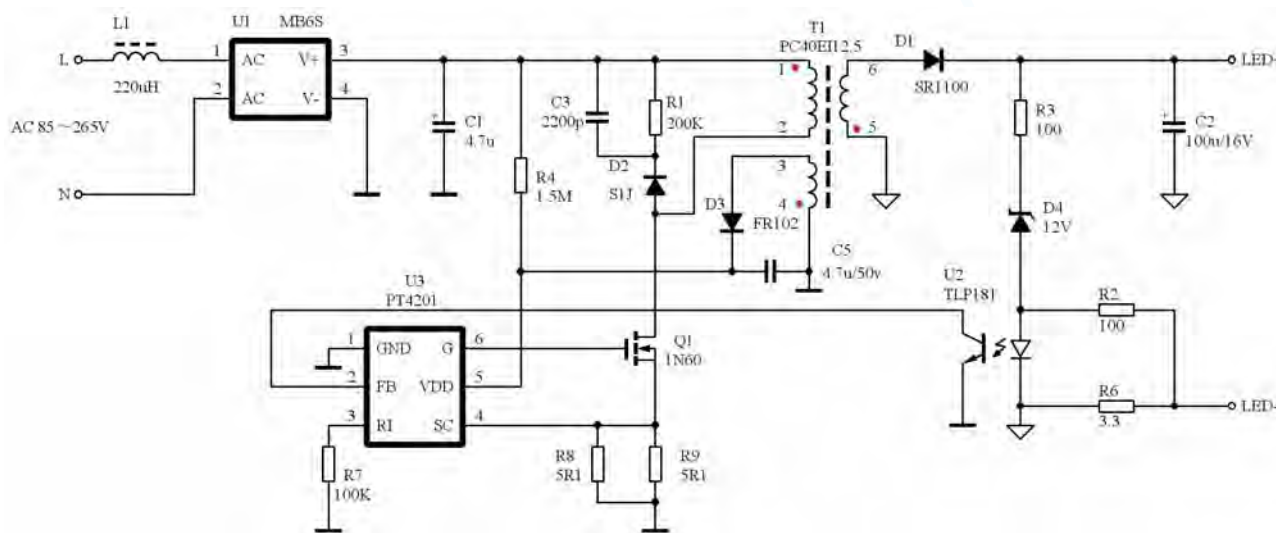
SYMBOL	DIMENSIONS IN MILLIMETERS		DIMENSIONS IN INCHES	
	MIN	MAX	MIN	MAX
A	3.710	4.310	0.146	0.170
A1	0.510		0.020	
A2	3.200	3.600	0.126	0.142
B	0.380	0.570	0.015	0.022
B1	1.524 (BSC)		0.060 (BSC)	
C	0.204	0.360	0.008	0.014
D	9.000	9.400	0.354	0.370
E	6.200	6.600	0.244	0.26
E1	7.320	7.920	0.288	0.312
e	2.540(BSC)		0.100(BSC)	
L	3.000	3.600	0.118	0.142
E2	8.400	9.000	0.331	0.354

E27 3W

芯片	拓扑结构	输入电压范围	输出电压	输出功率	LED 数量
PT4201	反激式	85V~265VAC	12V	3W	3



<参考应用线路>

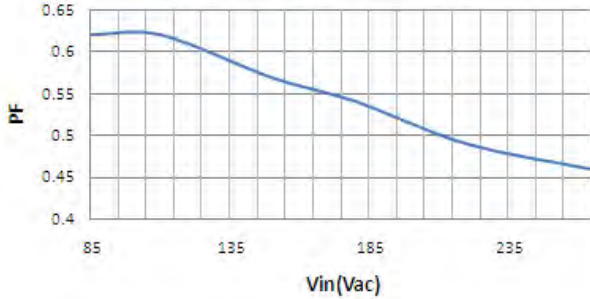




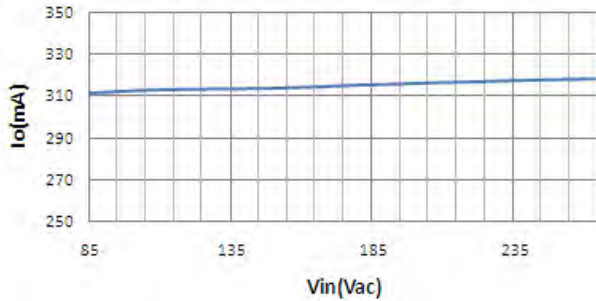
离线式 LED 射灯解决方案

<典型性能参数>

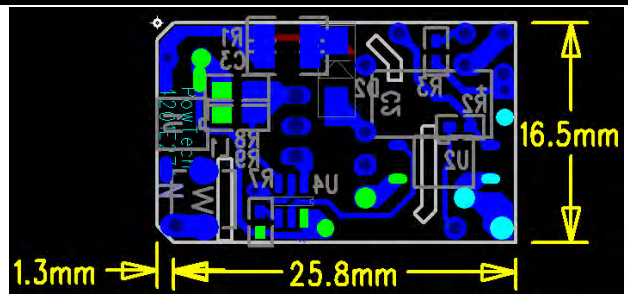
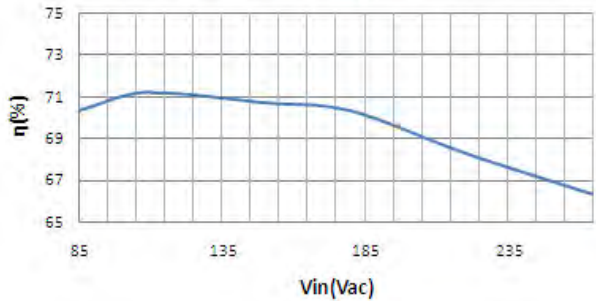
输入电压与PF值



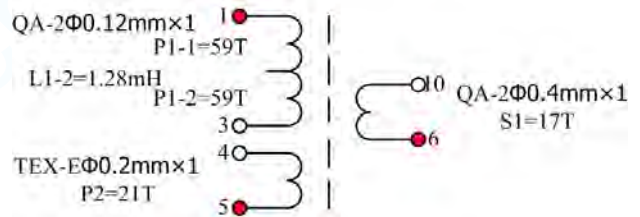
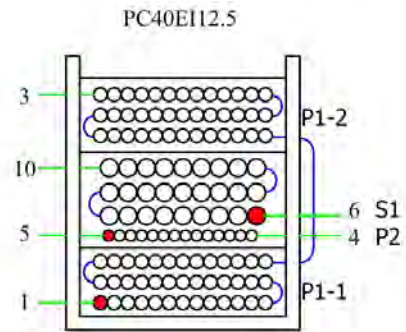
输入电压和输出电流



输入电压和效率

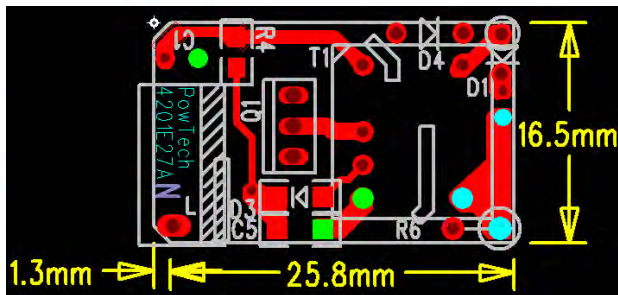


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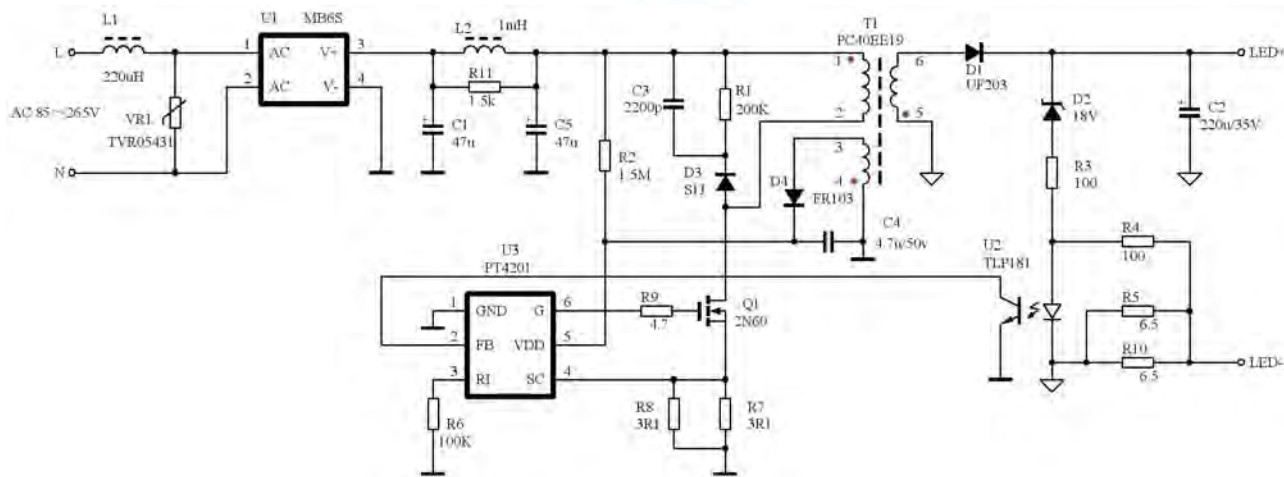
标号	描述	供应商
C1	电解电容,4.7uF/400V,8×12.5mm	Sawha
C2	电解电容,100uF/16V,5×8mm	Sawha
C3	陶瓷电容,2200pF/1kV,1206	KYOCERA MITA
C5	陶瓷电容,4.7uF/50V,1206	KYOCERA MITA
D1	肖特基二极管,SR1100,DIP	On semi
D2	快速恢复二极管,S1J,SMD	MCC semi
D3	快速恢复二极管,FR102,SMD	Vishay
D4	稳压管,12V/0.5W,DIP	Microsemi Corp
L1	功率电感,220uH/0.1A,SMD	Coilcraft
R1	贴片电阻,200KΩ,5%,1206	TA-I
R2,R3	贴片电阻,100Ω,5%,0603	TA-I
R4	贴片电阻,1.5MΩ,5%,0805	TA-I
R6	金属膜电阻,3.3Ω/0.5W,1%,DIP	TA-I
R7	贴片电阻,100KΩ,1%,0603	TA-I
R8,R9	贴片电阻,5.1Ω,1%,0805	TA-I
U1	整流桥,MB6S,SMD	Diodes Inc
U2	光耦,TLP181,SMD	Toshiba
U4	PWM控制器,PT4201,SOT23-6	PowTech
Q1	MOSFET,N-Channel,1N60	UTC
T1	变压器,PC40EI12.5	海宁联丰东进

E27 5W

芯片	拓扑结构	输入电压范围	输出电压	输出功率	LED 数量
PT4201	反激式	85V~265VAC	22V	5W	5



<参考应用线路>

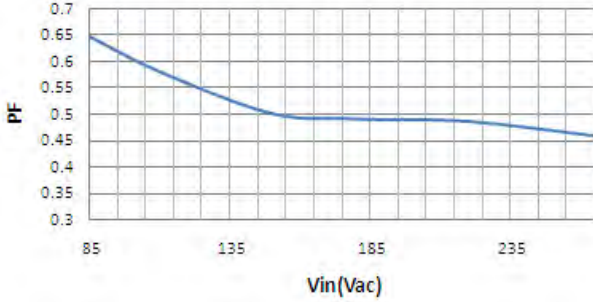




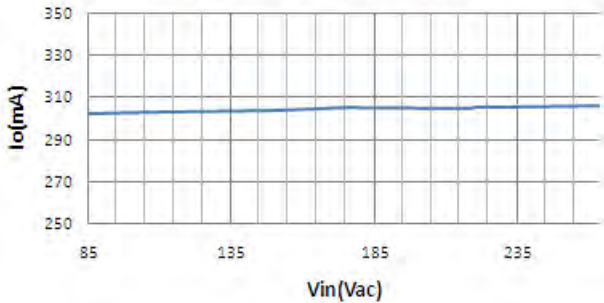
离线式 LED 射灯解决方案

<典型性能参数>

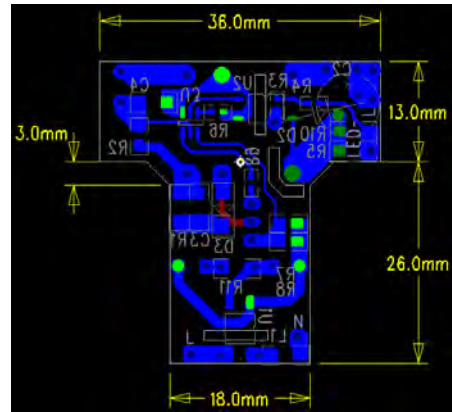
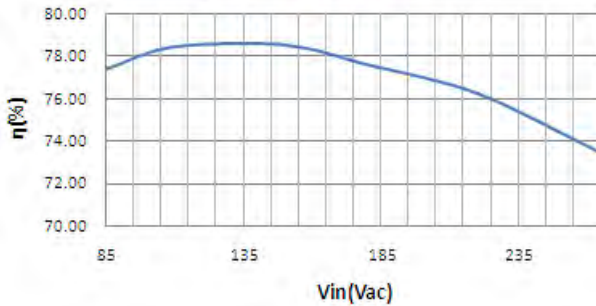
输入电压与PF值



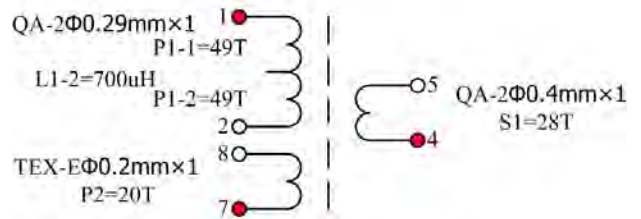
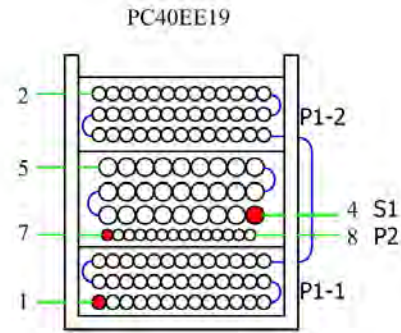
输入电压和输出电流



输入电压和效率

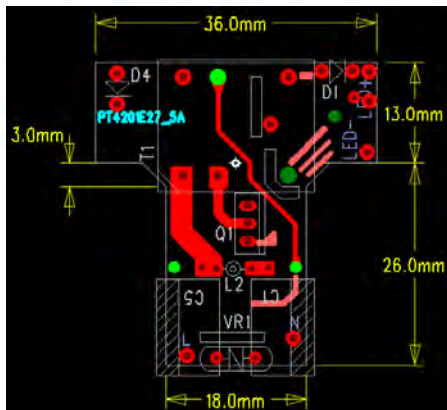


<变压器>



<BOM>

<PCB 布局>





标号	描述	供应商
C1,C5	电解电容,4.7uF/400V,8×12.5mm	Sawha
C2	电解电容,220uF/35V,8×11.5mm	Sawha
C3	陶瓷电容,2200pF/1kV,1206	KYOCERA MITA
C4	陶瓷电容,4.7uF/50V,1206	KYOCERA MITA
D1	快速恢复二极管,UF203,DIP	PANJIT
D2	稳压管,18V/0.5W,DIP	Microsemi Corp
D3	快速恢复二极管,S1J	MCC semi
D4	快速恢复二极管,FR103,DIP	Vishay
L1	功率电感,220uH/0.1A,SMD	Coilcraft
L2	色环电感,1mH,0410,DIP	Amode Tech
R1	贴片电阻,200KΩ,5%,1206	TA-I
R2	贴片电阻,1.5MΩ,5%,0805	TA-I
R3,R4	贴片电阻,100Ω,5%,0603	TA-I
R5,R10	贴片电阻,6.5Ω,1%,1206	TA-I
R6	贴片电阻,100KΩ,1%,0603	TA-I
R7,R8	贴片电阻,3Ω,1%,0805	TA-I
R11	贴片电阻,1.5KΩ,5%,1206	TA-I
U1	整流桥,MB6S,SMD	Diodes Inc
U2	光耦,TLP181,SMD	Toshiba
U3	PWM控制器,PT4201,SOT23-6	PowTech
Q1	MOSFET,N-Channel,2N60	UTC
T1	变压器,PC40EE19	PowTech
VR1	压敏电阻,TVR05431,DIP	Thinking

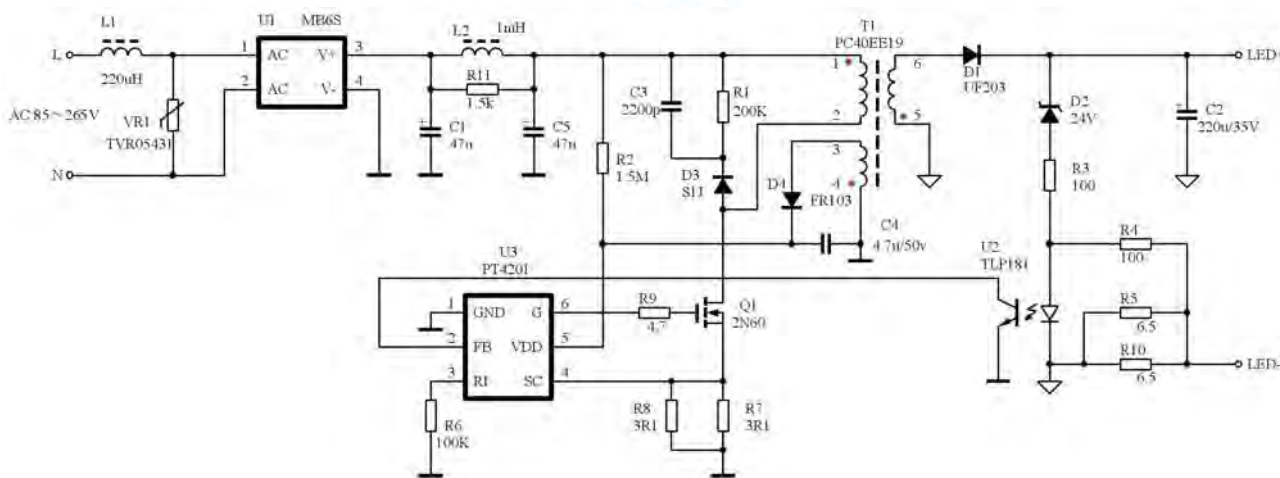


PAR30 7W

芯片	拓扑结构	输入电压范围	输出电压	输出功率	LED 数量
PT4201	反激式	85V~265VAC	27V	7W	7



<参考应用线路>

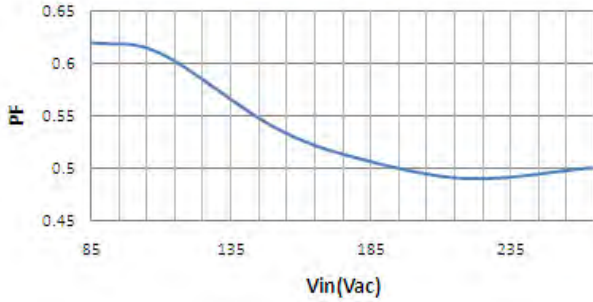




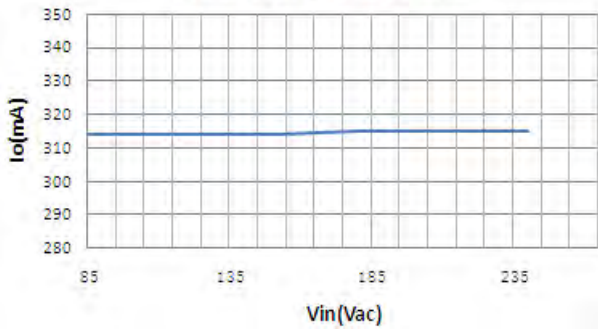
离线式 LED 射灯解决方案

<典型性能参数>

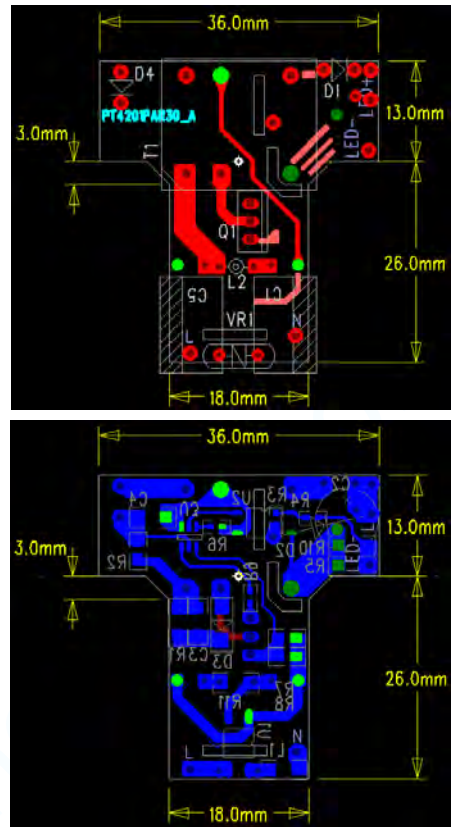
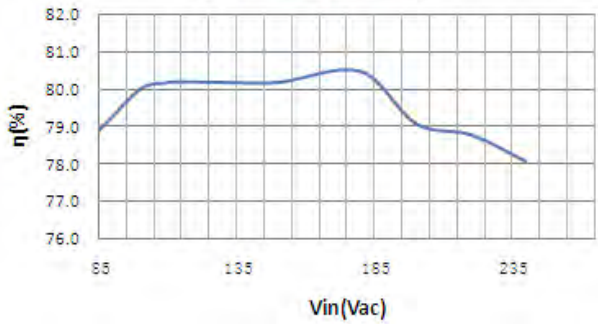
输入电压与PF值



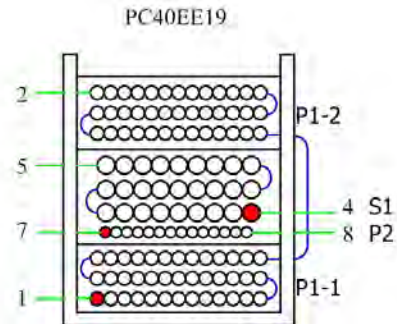
输出电流和输入电压



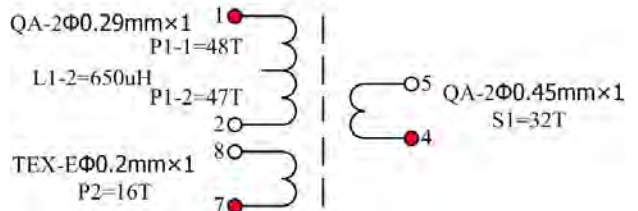
效率和输入电压



<变压器>



<PCB 布局>



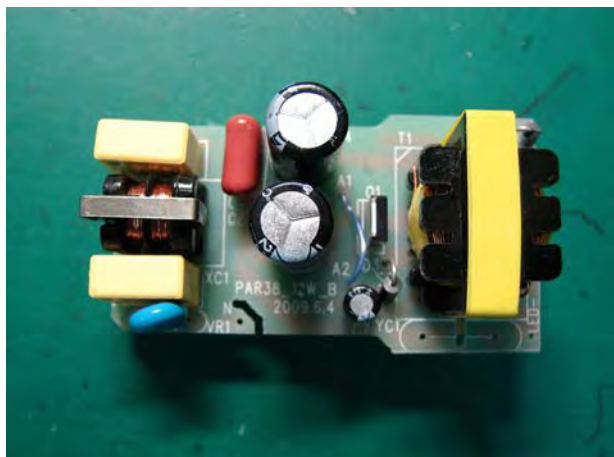
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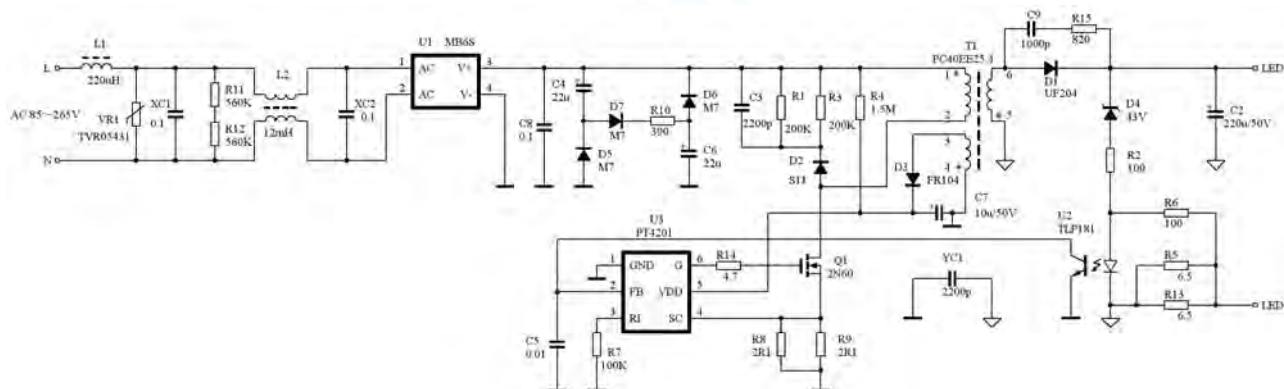
标号	描述	供应商
C1,C5	电解电容,4.7uF/400V,8×12.5mm	Sawha
C2	电解电容,220uF/35V,8×11.5mm	Sawha
C3	陶瓷电容,2200pF/1kV,1206	KYOCERA MITA
C4	陶瓷电容,4.7uF/50V,1206	KYOCERA MITA
D1	快速恢复二极管,UF203,DIP	PANJIT
D2	稳压管,24V/0.5W,DIP	Microsemi Corp
D3	快速恢复二极管,S1J	MCC semi
D4	快速恢复二极管,FR103,DIP	Vishay
L1	功率电感,220uH/0.1A,SMD	Coilcraft
L2	色环电感,1mH,0410,DIP	Amode Tech
Q1	MOSFET,N-Channel,2N60	UTC
R1	贴片电阻,200KΩ,5%,1206	TA-I
R2	贴片电阻,1.5MΩ,5%,0805	TA-I
R3,R4	贴片电阻,100Ω,5%,0603	TA-I
R5,R10	贴片电阻,6.5Ω,1%,1206	TA-I
R6	贴片电阻,100KΩ,1%,0603	TA-I
R7,R8	贴片电阻,3Ω,1%,0805	TA-I
R9	贴片电阻,4.7Ω,5%,0603	TA-I
R11	贴片电阻,1.5KΩ,5%,1206	TA-I
U1	整流桥,MB6S,SMD	Diodes Inc
U2	光耦,TLP181,SMD	Toshiba
U3	PWM控制器,PT4201,SOT23-6	PowTech
T1	变压器,PC40EE19	PowTech
VR1	压敏电阻,TVR05431,DIP	Thinking

PAR38 12W

芯片	拓扑结构	输入电压范围	输出电压	输出功率	LED 数量
PT4201	反激式	85V~265VAC	45V	12W	12



<参考应用线路>

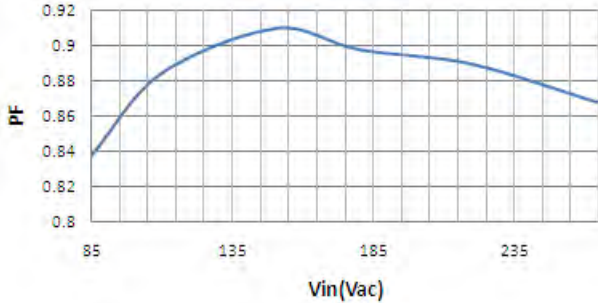




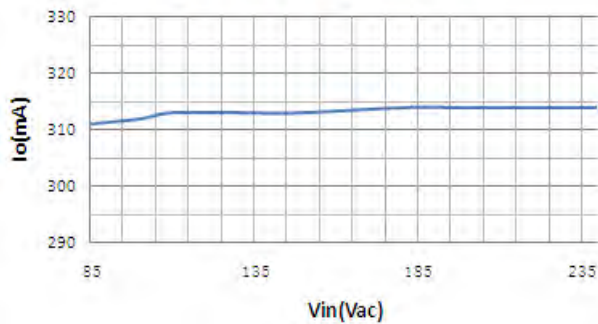
离线式 LED 射灯解决方案

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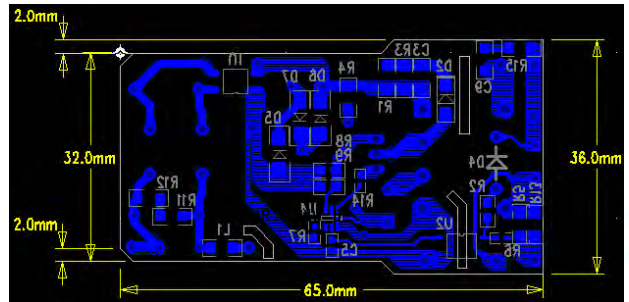
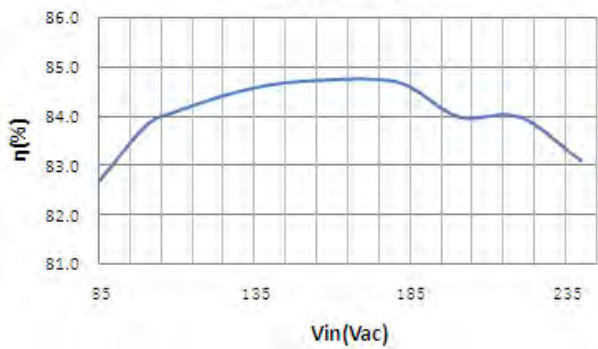
输入电压与PF值



输入电压和输出电流

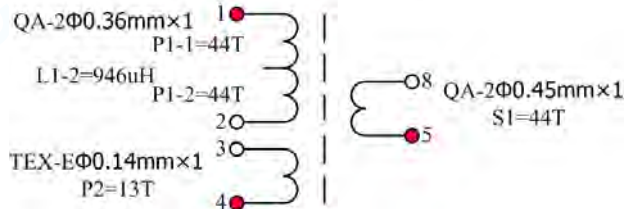
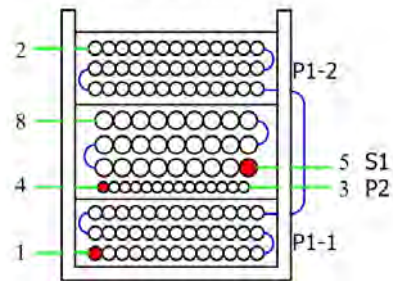


输入电压和效率



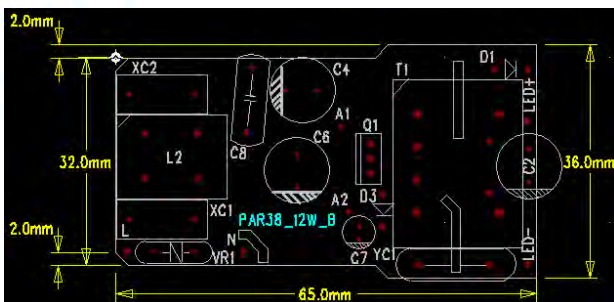
<变压器>

PC40EE25.4-Z



<BOM>

<PCB 布局>





标号	描述	供应商
C2	电解电容,220uF/50V,10×12.5mm	Sawha
C3	陶瓷电容,2200pF/1kV,1206	KYOCERA MITA
C4,C6	电解电容,22uF/250V,10×16mm	Sawha
C5	陶瓷电容,0.01uF/10V,0603	KYOCERA MITA
C7	电解电容,10uF/50V,5×11mm	Sawha
C8	CBB 电容,0.1uF/400V,DIP	GRP
C9	陶瓷电容,1000pF/50V,1206	Murata
D1	快速恢复二极管,UF204,DIP	PANJIT
D2	快速恢复二极管,S1J	MCC semi
D3	快速恢复二极管,FR104,DIP	Vishay
D4	稳压管,43V/0.5W,DIP	Microsemi Corp
D5,D6,D7	整流二极管,M7,SMD	JRT
L1	功率电感,220uH/0.2A,SMD	Coilcraft
L2	共模电感,12mH/1A,UU 10.5 Bobbin	PowTech
Q1	MOSFET,N-Channel,2N60	UTC
R1,R3	贴片电阻,200KΩ,5%,1206	TA-I
R2,R6	贴片电阻,100Ω,5%,0603	TA-I
R4	贴片电阻,1.5MΩ,5%,0805	TA-I
R5,R13	贴片电阻,6.5Ω,1%,1206	TA-I
R7	贴片电阻,100KΩ,1%,0603	TA-I
R8,R9	贴片电阻,2Ω,1%,0805	TA-I
R10	金属膜电阻,390Ω/1W,5%,DIP	SAMSUNG
R11,R12	贴片电阻,560KΩ,5%,1206	TA-I
R14	贴片电阻,4.7Ω,5%,0603	TA-I
R15	贴片电阻,820Ω,5%,1206	TA-I
U1	整流桥,MB6S,SMD	Diodes Inc
U2	光耦,TLP181,SMD	Toshiba
U3	PWM控制器,PT4201,SOT23-6	PowTech
T1	变压器,PC40EE25.4	PowTech
VR1	压敏电阻,TVR05431,DIP	Thinking
XC1,XC2	安规电容,0.1uF/250Vac,DIP	Vishay
YC1	Y电容,2200pF/275Vac,DIP	Vishay



Current-mode PWM Controller

GENERAL DESCRIPTION

PT4201 is a highly integrated current mode PWM controller, providing low standby power and cost effective system solution for the sub 30W flyback converter applications. It is also suitable for high precision and high reliable LED lighting applications.

It features power saving operation at no load or light load condition, PWM frequency is reduced to minimize switching loss and low standby power and high efficiency is thus achieved. PT4201 also features low VDD startup current which also contributes to low standby power. The built in LEB on the current sense input removes the signal glitch due to snubber circuit diode reverse recovery thus reduce the external component count and system cost in the design.

Rich protection is implemented in PT4201 including cycle-by-cycle current limiting (OCP), over load protection (OLP), VDD over voltage clamp and under voltage lockout (UVLO). Gate drive output is clamped at 18V to protect the power MOSFET. By limiting the minimum frequency above 22 kHz eliminates the potential audible noise when the system works under light or no load conditions.

Excellent EMI performance is achieved with C.R.PowTech proprietary frequency Jittering technique together with soft driving control at totem pole gate drive output.

The PT4201 is available in SOT23-6, SOP-8 and DIP-8 packages.

FEATURES

- Frequency Jittering for Improved EMI Performance
- Green-Mode PWM for Improved Efficiency and Minimum standby power design
- Low start up current 20uA (Typ. 3uA) and Low operation current 2mA (Typ. 1mA)
- Current mode operation
- Leading-edge blanking on current sense input
- Programmable PWM frequency
- Constant output power limit for universal AC input
- Built-in power limit control (OLP)
- Cycle-by-cycle current limiting (OCP)
- Under voltage lockout (UVLO)
- GATE output maximum voltage clamped at 18V
- Totem pole output includes soft driving for better EMI

APPLICATIONS

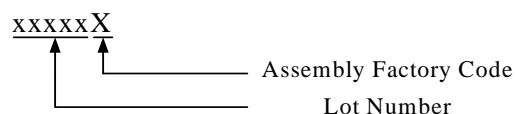
Offline AC/DC flyback converter for

- Power Adapter
- Open-frame SMPS
- Battery Charger Adapter
- 1W-30W HB LED lighting.

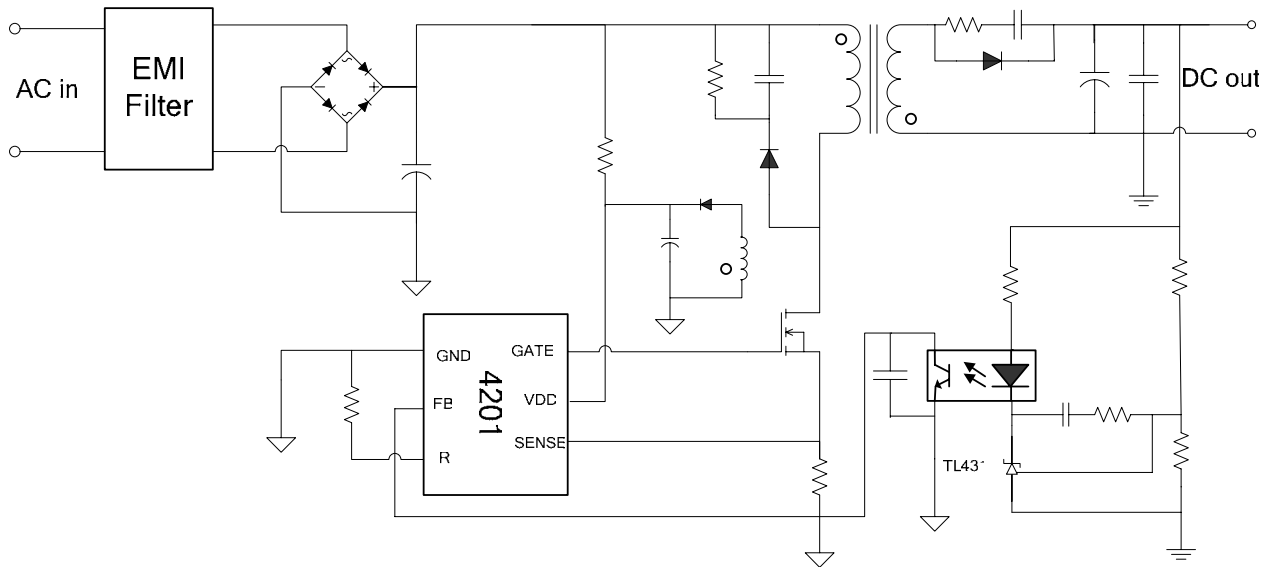
ORDERING INFORMATION

PACKAGE	TEMPERATURE RANGE	ORDERING PART NUMBER	TRANSPORT MEDIA	MARKING
SOT23-6, Pb free	-40°C to 85°C	PT4201E23F	Tape and Reel	4201
DIP8, Pb free	-40°C to 85°C	PT4201EDIH	Tube	PT4201 xxxxxX
SOP8, Pb free	-40°C to 85°C	PT4201ESOH	Tape and Reel	PT4201 xxxxxX

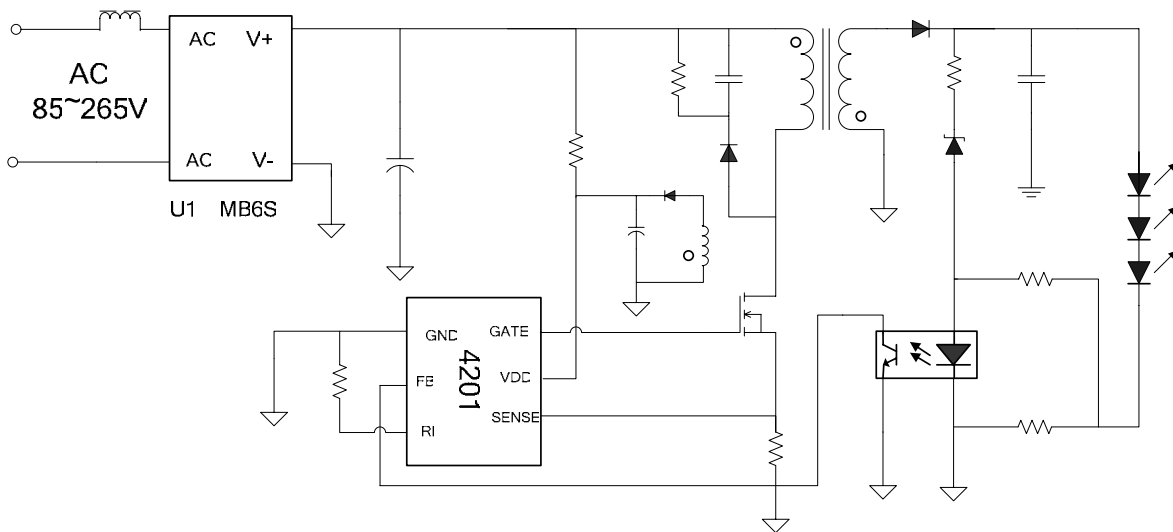
Note:



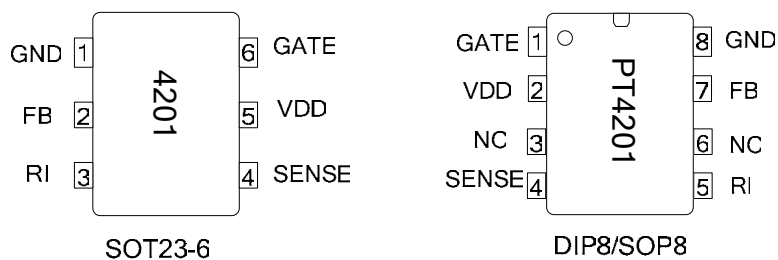
TYPICAL APPLICATIONS (Switching Power Supply)



TYPICAL APPLICATIONS (HB LED Lighting)



PIN ASSIGNMENT





PIN DESCRIPTIONS

NAMES	PIN No. (SOT23-6)	PIN No. (SOP8, DIP8)	DESCRIPTION
GND	1	8	Ground
FB	2	7	Feedback input pin. PWM duty cycle is determined by voltage level into this pin and SENSE pin voltage level.
RI	3	5	Internal Oscillator frequency setting pin. A resistor connected between RI and GND sets the PWM frequency.
SENSE	4	4	Current sense input pin. Connected to MOSFET current sensing resistor node.
VDD	5	2	DC power supply pin.
GATE	6	1	Totem-pole gate drive output for power MOSFET.
		3, 6	No Connection

ABSOLUTE MAXIMUM RATINGS (note1)

SYM	PARAMETER	VALUE	UNIT
V _{DD}	V _{DD} DC Supply Voltage	30	V
V _{Clamp}	V _{DD} Clamp Voltage	33	V
I _{DD -Clamp}	V _{DD} DC Clamp Current	10	mA
V _{FB}	V _{FB} PIN Input Voltage	-0.3~7	V
V _{SENSE}	V _{SENSE} Input Voltage	-0.3~7	V
V _{RI}	V _{RI} Input Voltage	-0.3~7	V
T _J	Min/Max Operating Junction Temperature T _J	-40~150	°C
T _{STG}	Storage Temperature Range	-55~160	°C
HBM	ESD Capability, HBM model(note 2)	2.0	KV

PACKAGE DISSIPATION RATING

SYM	PARAMETER	VALUE	UNIT
R _{θJA}	DIP8	90	°C/W
	SOP8	150	°C/W
	SOT23-6	250	°C/W

OPERATING RANGE

SYM	PARAMETER	VALUE	UNIT
V _{DD}	V _{DD} Supply Voltage	10~30	V
RI	RI Resistor Value	100	Kohm
T _A	Operating Ambient Temperature	-20~85	°C

Note 1: Absolute Maximum Ratings indicate limits beyond which damage to the device may occur. Recommended Operating Range indicates conditions for which the device is functional, but do not guarantee specific performance limits. Electrical Characteristics state DC and AC electrical specifications under particular test conditions which guarantee specific performance limits. This assumes that the device is within the Operating Range. Specifications are not guaranteed for parameters where no limit is given, however, the typical value is a good indication of device performance.



Note 2: Human body model, 100pF discharged through a 1.5kΩ resistor.

ELECTRICAL CHARACTERISTICS

($T_{OPT}=25^{\circ}C$, $V_{DD}=16V$, unless specified otherwise)

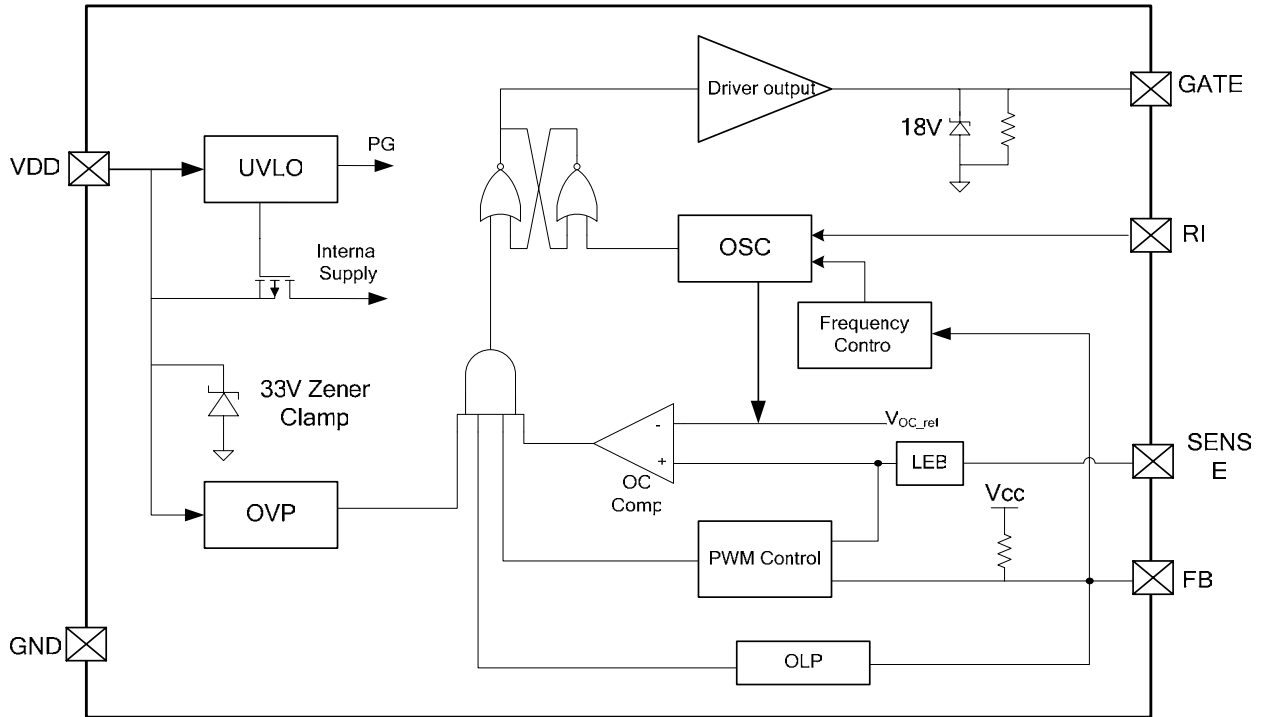
SYMBOL	PARAMETER	TEST CONDITION	MIN	TYP	MAX	UNIT
SUPPLY VOLTAGE (VDD)						
V_{DD_ON}	V_{DD} Start-up voltage	V_{DD} rising	14.0	15.0	16.0	V
V_{DD_MIN}	V_{DD} minimum operating level	V_{DD} falling	6.5	7.5	8.5	V
V_{DD_OVP}	V_{DD} Over Voltage Protection Level	V_{DD} rising	22.5	24.0	25.5	V
$V_{DD_OVP_OFF}$	V_{DD} Over Voltage Protection Release Level	V_{DD} falling	21.0	22.5	24.0	V
V_{OVP_HYS}	V_{DD} Over Voltage Hysteresis	$V_{DD_OVP}-V_{DD_OVP_OFF}$		1.5		V
V_{ZENER}	V_{DD} Pin Zener Diode Clamp Voltage	$I(V_{DD})=5mA$		33		V
Current Into VDD						
I_{VDD_START}	V_{DD} Start-up Current	$V_{DD}=13.5V$ Measuring Current into V_{DD}		3	20	uA
I_{VDD_OPER}	V_{DD} Operating Current	$V_{DD}=16V$, $RI=100Kohm$ $V_{FB}=3V$, Gate Floating		1		mA
FEED BACK PIN (FB)						
V_{OVB}	V_{FB} Open Loop Voltage	$V_{DD}=16V$,		4.8		V
V_{PL}	FB Over Load Protection level			3.7		V
V_{GM}	Green Mode FB Threshold			1.6		V
V_{BM}	Burst Mode Entering Threshold			1.2		V
V_{ZD}	Zero Duty Cycle FB Threshold	$V_{DD}=16V$, $RI=100Kohm$			0.70	V
T_{PL_DELAY}	Over Load Protection Delay Time	$RI=100Kohm$		32		ms
Z_{FB}	FB Pin Input Impedence			6.0		Kohm
I_{FB}	FB Pin Supply Current	FB Short To GND, Measuring Current Flowing From FB Pin		0.8		mA
OSCILLATOR (OSC)						
F_{osc}	Oscillator Frequency	$RI=100Kohm$	60	65	70	kHz
ΔF_{JIT}	$\Delta F_{osc}/F_{osc}$	$RI=100Kohm$	-3		3	%
$T_{JITTRING}$	Frequency Modulation Period	$RI=100Kohm$		32		mS
F_{MIN}	Minimum PWM Frequency	$V_{DD}=16V$, $RI=100Kohm$		22		kHz
RI	Acceptable RI Range		50	100	250	Kohm



ELECTRICAL CHARACTERISTICS (Continued)

SYMBOL	PARAMETER	TEST CONDITION	MIN	TYP	MAX	UNIT
F _{DT}	Oscillator Frequency Stability At Different Temperature	V _{DD} =16V, RI=100Kohm -20°C 到 100°C		2		%
F _{DV}	Oscillator Frequency Stability At Different VDD Input Level	V _{DD} =12~25V, RI=100Kohm		2		%
PWM SECTION						
A _V	PWM Input GAIN	$\Delta V_{FB}/\Delta V_{CS}$		2.0		V/V
T _{BLK}	Leading Edge Blanking Time			300		ns
D _{MAX}	PWM Maximum Duty Cycle			75		%
D _{MIN}	PWM Minimum Duty Cycle				0	%
CURRENT SENSE INPUT (SENSE)						
Z _{CS}	SENSE Input Impedence			80		Kohm
V _{TH_OC}	OCP Threshold at Duty=0	FB=3V, V _{GATE} <0.3V	0.70	0.75	0.80	V
T _{OC_DELAY}	Delay Time From OCP to Gate Output OFF	V _{DD} =16V, CS>V _{TH_OC} , C _{GATE} =1000pF		100		nS
GATE OUTPUT						
V _{OL}	GATE Output Low Level	V _{DD} =16V, I _o =-20mA			0.8	V
V _{OH}	GATE Output High Level	V _{DD} =16V, I _o =20mA	10			V
T _r	GATE Output Rising time	V _{DD} =16V, CL=1000pF		220		nS
T _f	GATE Output Falling Time	V _{DD} =16V, CL=1000pF		70		nS
V _{GMAX}	GATE Output Clamp Voltage			18		V

SIMPLIFIED BLOCK DIAGRAM



OPERATION DESCRIPTION

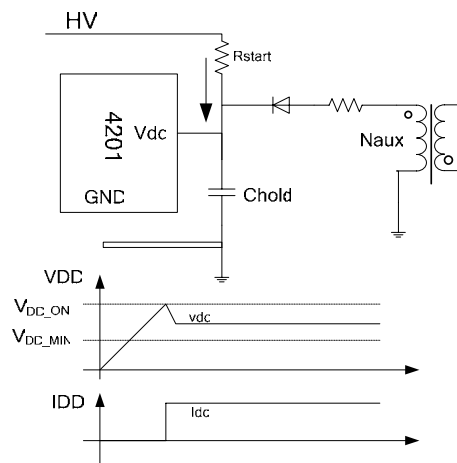
With enhanced functions and extremely low start up current and low operating current together with optimized controlling mode, the PT4201 is easy to meet the high performance as well as low standby power requirement in the SMPS application. Its detail features are described as below:

STARTUP AND UVLO:

The start up of PT4201 is realized through the current provided by a resistor connecting to HV line charges the capacitor connecting to VDD pin to the start up threshold voltage. As shown below, initially the voltage on Chold is below the start up threshold the PT4201 stays in UVLO status. The current supplied by Rstart charges the Chold thus the voltage on VDD increases. The PT4201 starts to operate when the voltage on VDD reaches V_{DD_ON} start up threshold. After startup the PT4201 begins to deliver drive signal on GATE and the operating current is supplied by the auxiliary winding

of the transformer.

Since the PT4201 sinks a few macro amperes of current before start up, a large start up resistor could be used in the start up circuit to minimize standby power. As for the applications with general AC input range a 2Mohm 1/8W resistor and a 10uF/50V capacitor compose a simple and reliable start up circuit.



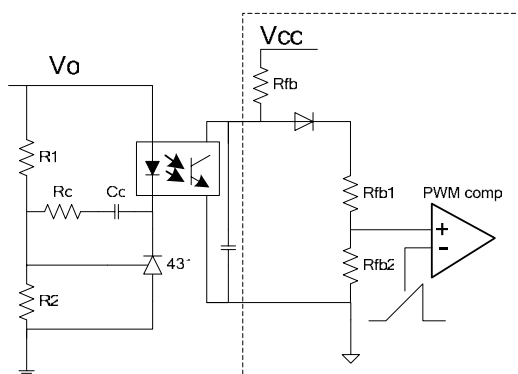
Current-mode PWM Controller

OPERATING CURRENT:

The PT4201 is fabricated with BiCMOS process, the operating current has been reduced to less 1mA when GATE is floating, thus the system efficiency is improved and at the same time, a smaller hold up capacitor can be used to speed up start up progress.

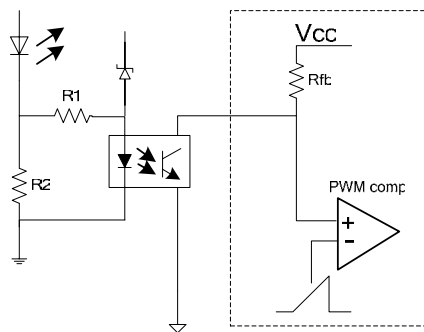
FEEDBACK AND PWM (SMPS application):

The PT4201 adopts current mode control scheme. the voltage feedback loop is closed by the TL431 and an opto-coupler connected between output node and FB pin, as shown below: A 2.5V reference voltage has been implemented in the TL431, if the divided voltage of R1 and R2 is less than 2.5V TL431 sinks current from Vo and the current is transferred to the FB pin by the opto-coupler. The transferred current is loaded by a resistor connected to the internal regulator output so FB pin voltage is determined and thus PWM signal is generated.



CONSTANT CURRENT OPERATION (LED application) :

PT4201 senses the LED current via an opto-coupler and generates a PWM driving signal to control the LED current. Reference to the following schematic, current sense resistor R2 and turn on voltage of the opto-coupler determine the LED current. When the voltage across R2 turns the opto-coupler on the current of the photo diode of the opto-coupler drives FB PIN decrease so the duty cycle of PWM signal is decreased thus the output current is limited. So the output current can be calculated as $I_{out} = V_{onopto} / R2$. Vonopto represents the LED turn on voltage of the opto-coupler.



ENERGY SAVE OPERATION AT LIGHT LOAD:

Generally the SMPS switching loss is proportional to switching frequency of power MOSFET. In order to achieve high conversion efficiency when the load decrease PT4201 automatically debase PWM frequency to reduce switching loss. The reduction of the load current results in the decrease of voltage on FB pin, when the voltage on FB pin is lower than 1.6V the PWM frequency will linearly decrease with V_{FB} until touch bottom which is 1/3 normal operating frequency. If the FB pin voltage drops below the preset level the PT4201 enters burst mode operation, some PWM cycles is skipped to minimize switching loss. Moreover if the FB pin voltage falls below Zero-Duty level the PWM is disabled immediately until it recovers to above Zero-Duty threshold.

LED OPEN CIRCUIT (LED application):

When LED open circuit occurs, the output voltage rises to break down the zener diode. The inverse current of the zener diode generates a voltage across R1 and R2 to turn on the opto-coupler, thus the voltage on FB pin decrease to reduce the PWM signal duty cycle, so that the power delivered to the output is limited. Therefore the system is safe under LED open circuit condition.

LED SHORT CIRCUIT (LED application):

When LED short circuit occurs, for the output voltage is low and the output current is limited thus the output power is so small that the system is safe. Because the voltage on auxiliary winding is proportion to the output voltage, VDD will then drops due to internal power consumption. When VDD drops below the V_{DD_MIN} turn-off threshold, the PT4201 will be totally shut down. When this happens, the start up sequence will kick in and VDD is charging up again. when the current sense



PT4201

Current-mode PWM Controller

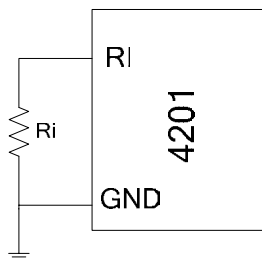
resistor is shorted, because the opto-coupler is turned off the voltage on FB will rise over the protection threshold which is set to be 3.7V, after a delay time the PT4201 will stop delivering PWM signal to protect the system from being damaged.

OSCILLATOR AND FREQUENCY JITTERING:

The operating frequency can be easily set via a resistor connected to the RI pin and GND. The relationship between operating frequency and RI follows the expression: $F_{osc} = 6500/RI$. Which F_{osc} represents normal operating frequency with unit in KHz, and RI with unit in Kohm.

The frequency jittering is implemented in the PT4201. The oscillation frequency is modulated so that the tone energy is spread out. The spread spectrum minimizes the conduction band EMI and therefore reduces system design challenge.

Care should be considered that the PWM frequency will be reduced to one third of normal operating frequency so a large RI is not recommended because the audible noise maybe exists when the load is too light.



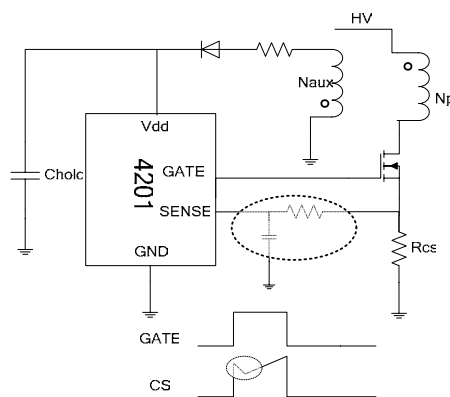
CURRENT SENSE AND LEB:

One function of the SENSE pin is sensing the current of the power MOSFET to generate a current slope and the other function is providing cycle by cycle current limit. The current of the power MOSFET is transferred to voltage signal through a resistor connected between source terminal and GND and feed to SENSE input. The voltage on SENSE and FB determines duty cycle of the PWM signal.

As for cycle by cycle current limit, at each PWM cycle when the voltage of SENSE input excess the internal threshold the PWM signal is terminated after a short delay to protect the power MOSFET. The relationship

between the OCP threshold and the current of power MOSFET follows below expression: $I_{OC} = V_{oc}/R_{cs}$; I_{oc} is the current of power MOSFET, V_{oc} is the threshold of OCP and R_{cs} represents sensing resistor. The internal OCP threshold is modulated by the PWM duty cycle, with zero PWM duty cycle the threshold is 0.75V.

A spike is inevitable on the sensed signal on R_{cs} at the instance when the power MOSFET is turned on due to the recovery time of the secondary rectifier and the snubber circuit. The LEB has been implemented in PT4201, during the LEB time the OCP comparator is disabled so the PWM signal can not be terminated by the turn-on spike on the sensed signal so the external RC filter can be removed.



INTERNAL SLOPE COMPENSATION:

To eliminate the potential sub-harmonic oscillation problem when the duty cycle excess 0.5, the slope compensation has been implemented in the PT4201. At each PWM duty cycle a constant slope is added to the sensed current ramp so that the system stability is improved.

UNIVERSAL INPUT OCP COMPENSATION:

Because there is always a constant delay time T_d from OCP is triggered to the power MOSFET is turned off, the actual current of the MOSFET at the instance it is turned off is different from the setting value. Taking the below figure as reference, considering the delay time of T_d the actual current is: $I_{peak} = I_{peak1} + I_{slope1} * T_d$, $I_{slope1} = V_{indc}/L_{pri}$. With a higher input level the actual OCP current is $I_{peak} = I_{peak2} + I_{slope2} * T_d$, $I_{slope2} = V_{indc2}/L_{pri}$. Which L_{pri} represents primary winding inductance of transformer; T_d is a constant delay time and does not vary with V_{in} . From above

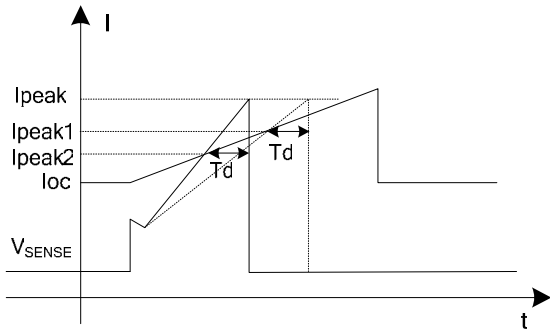


Current-mode PWM Controller

equations it can be derived that the actual OCP threshold of the power MOSFET is always larger than setting value due to the OCP delay time and the difference increases with the increase of V_{in} . In order to compensate the difference OCP threshold in PT4201 has been designed to vary with the duty cycle, it means that a smaller duty cycle results in a smaller OCP threshold. When the input AC voltage increase the duty cycle gets small and the OCP point decrease, thus the actual OCP threshold of power MOSFET maintains unchanged in the universal input range. The relationship between OCP threshold voltage and PWM signal duty cycle follows below expression:

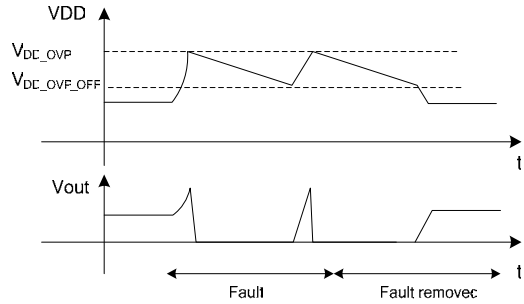
$$V_{oc} = 0.75 + 0.52 * \text{Duty}$$

Duty represents the duty cycle of PWM signal.



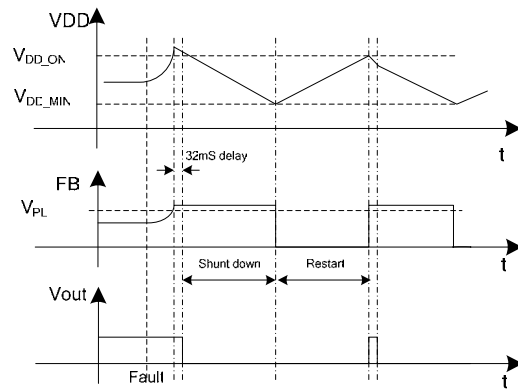
VDD OVER VOLTAGE PROTECTION:

When open loop occurs the opto-coupler does not sink current thus the voltage on FB rise and current limit will be triggered. If the load is not large enough the output voltage will increase because of redundant power is delivered to the load. Under this condition if the OLP is not triggered the output voltage will lost control and the load is in danger of damaged of over voltage. Because the voltage on auxiliary winding is proportional to the output voltage the VDD rises with the output. When the voltage on VDD reaches the OVP threshold the PT4201 stops delivering PWM signal to the power MOSFET, voltage on VDD begins to drop due to the internal power consumption, the PT4201 will recover from OVP status when voltage on VDD drops below the OVP release threshold. The OVP cycle will repeat after recovery until if the fault condition is removed.



OVER LOAD PROTECTION:

The Over Load Protection function (OLP) provides another protection to the system from damage when load short circuit or over load occurs. In that condition the voltage on the FB rise, when the V_{FB} excesses 3.7V the PT4201 starts a timer, after a delay time T_{PL_DELAY} if the fault condition still exists the PWM signal is blocked. VDD will then drops due to internal power consumption. When VDD drops below the V_{DD_MIN} threshold, the PT4201 will be totally shut down. When this happens, the start up sequence will kick in and VDD is charging up again.



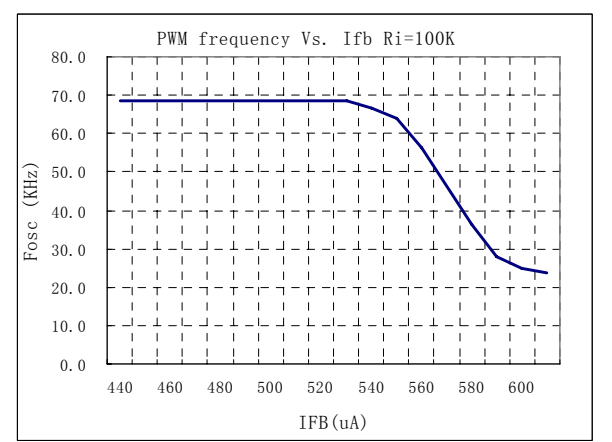
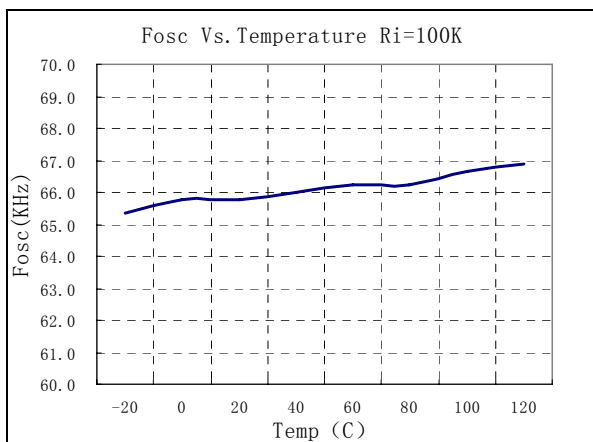
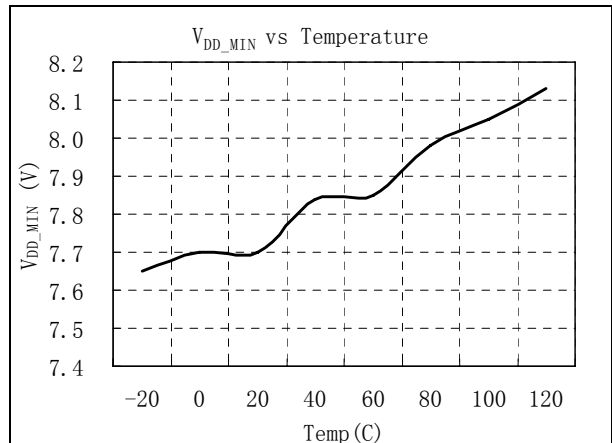
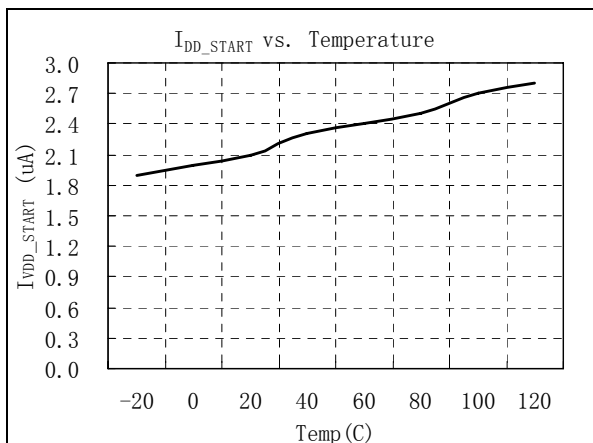
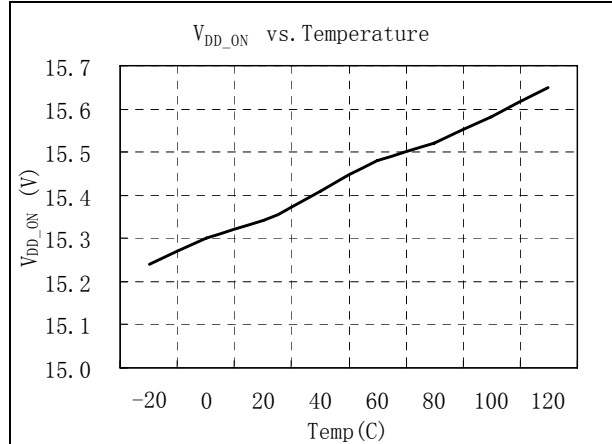
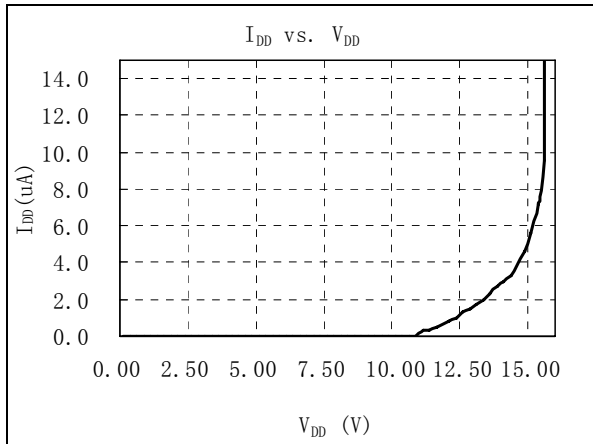
GATE OUTPUT:

The output drives the GATE of the power MOSFET. The optimized totem-pole type driver offers a good tradeoff between driving ability and EMI. Additionally the output high level is clamped to 18V by an internal clamp so that power MOSFET transistor can be protected against undesirable gate over voltage. A resistor between GATE and GND initials the gate voltage to zero at the off state.

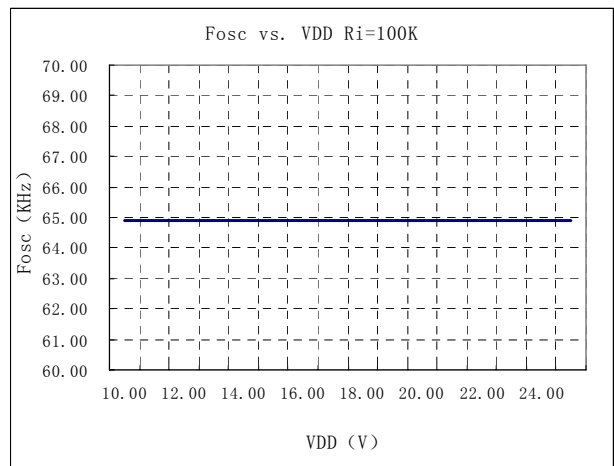
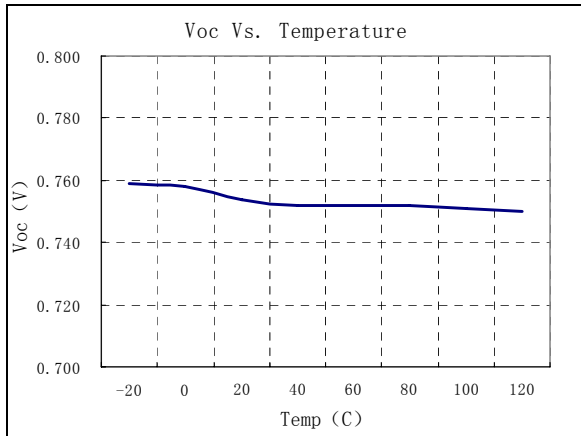
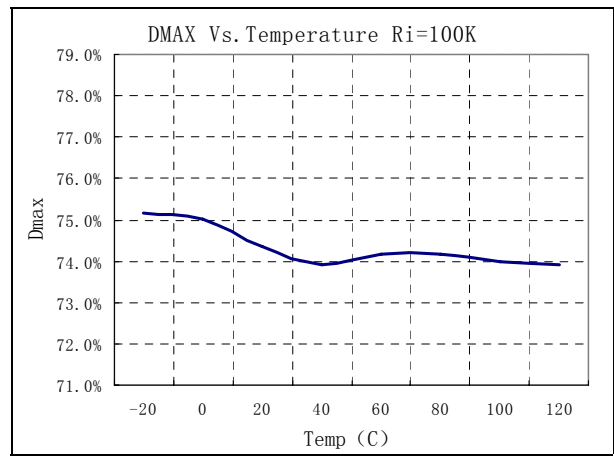
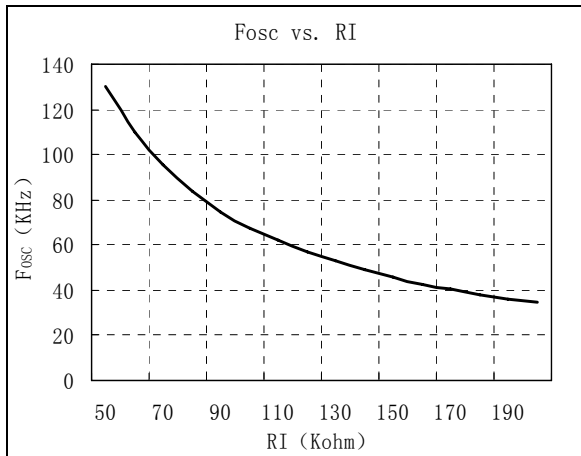


TYPICAL PERFORMANCE CHARACTERISTICS

$V_{DD}=16V$, $R_I=100K\Omega$, $T_A=25^\circ C$ if not otherwise noted

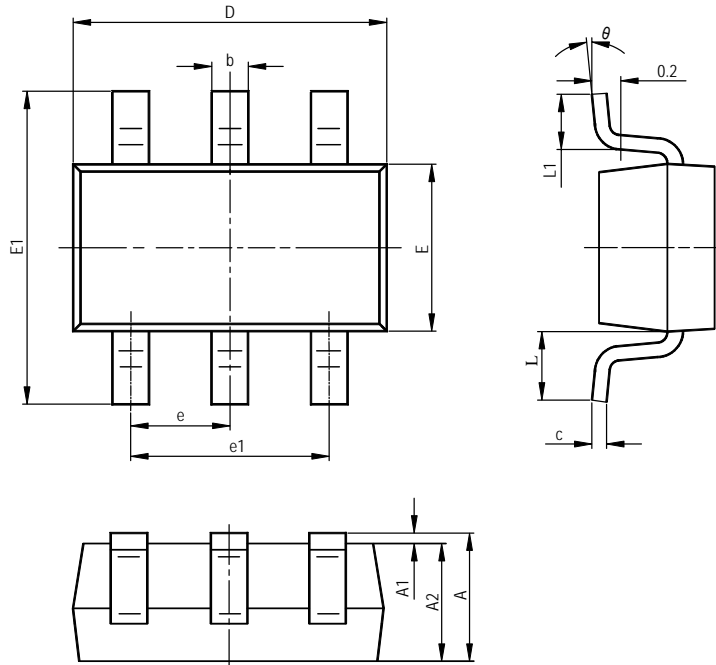


TYPICAL PERFORMANCE CHARACTERISTICS (continued)



PACKAGE INFORMATION

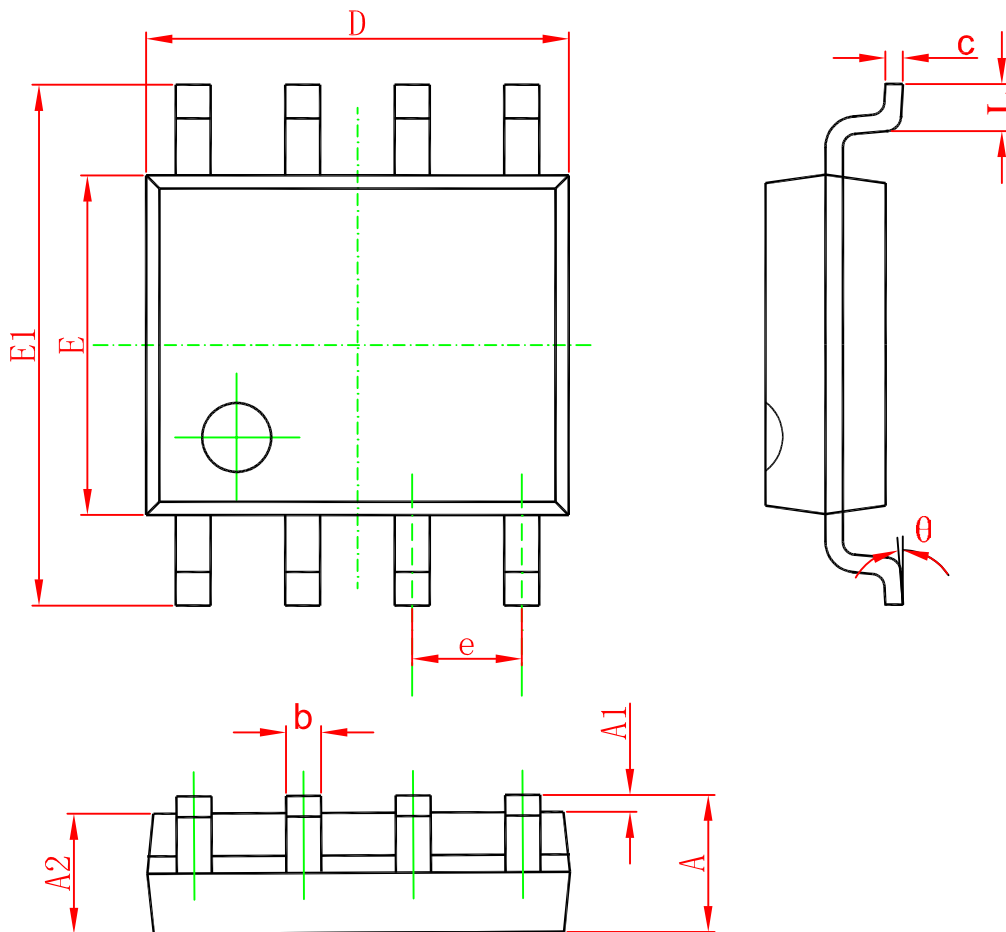
SOT23-6



SYMBOL	MILLIMETERS		INCHES	
	MIN	MAX	MIN	MAX
A	1.050	1.250	0.041	0.049
A1	0.000	0.100	0.000	0.004
A2	1.050	1.150	0.041	0.045
b	0.300	0.400	0.012	0.016
c	0.100	0.200	0.004	0.008
D	2.820	3.020	0.111	0.119
E	1.500	1.700	0.059	0.067
E1	2.650	2.950	0.104	0.116
e	0.950TYP		0.037TYP	
e1	1.800	2.000	0.071	0.079
L	0.700REF		0.028REF	
L1	0.300	0.600	0.012	0.024
θ	0°	8°	0°	8°

PACKAGE INFORMATION

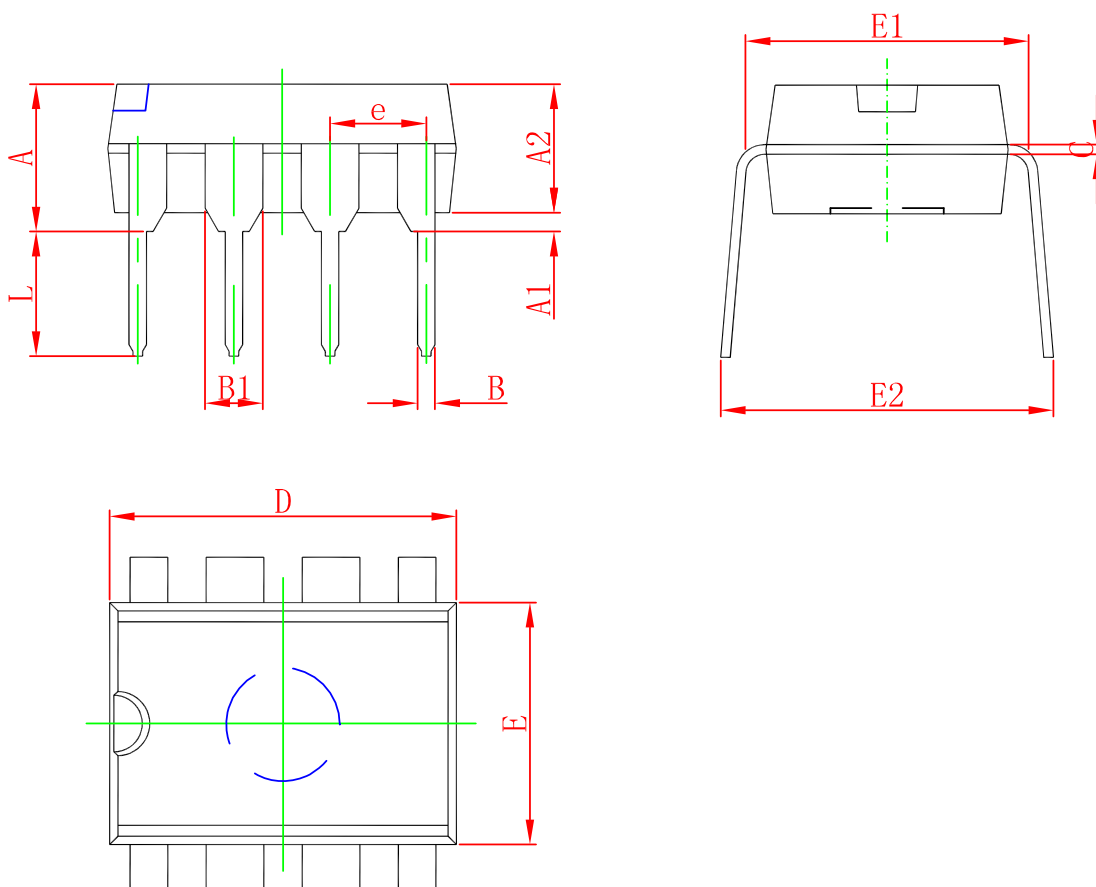
SOP8



SYMBOL	DIMENSIONS IN MILLIMETERS		DIMENSIONS IN INCH	
	MIN	MAX	MIN	MAX
A	1.350	1.750	0.053	0.069
A1	0.100	0.250	0.004	0.010
A2	1.350	1.550	0.053	0.061
b	0.330	0.510	0.013	0.020
c	0.170	0.250	0.006	0.010
D	4.700	5.100	0.185	0.200
E	3.800	4.000	0.150	0.157
E1	5.800	6.200	0.228	0.244
e	1.270(BSC)		0.050(BSC)	
L	0.400	1.270	0.016	0.050
θ	0°	8°	0°	8°

PACKAGE INFORMATION

DIP8



SYMBOL	DIMENSIONS IN MILLIMETERS		DIMENSIONS IN INCHES	
	MIN	MAX	MIN	MAX
A	3.710	4.310	0.146	0.170
A1	0.510		0.020	
A2	3.200	3.600	0.126	0.142
B	0.380	0.570	0.015	0.022
B1	1.524 (BSC)		0.060 (BSC)	
C	0.204	0.360	0.008	0.014
D	9.000	9.400	0.354	0.370
E	6.200	6.600	0.244	0.26
E1	7.320	7.920	0.288	0.312
e	2.540(BSC)		0.100(BSC)	
L	3.000	3.600	0.118	0.142
E2	8.400	9.000	0.331	0.354

基于PT4201的离线式LED射灯设计技术

华润矽威科技（上海）有限公司 黄裔玥

摘要：本文从市场和技术的角度分析了高压输入LED射灯电源的技术要求。

简述了基于PT4201的离线式LED射灯方案的工作原理。

关键词：市内照明， E27/Par30/Par38， 副边反馈（光耦反馈）

LED照明以其高节能、长寿命、利环保的特点成为大家广为关注的焦点。国内许多地方已经有应用于功能性照明领域的成功案例。我国半导体照明应用技术渐渐走在了世界的前列，随着国家和地方政府的政策鼓励，许多地方在室外照明如：路灯、景观照明等；室内照明如：地铁、地下车库、博物馆；特殊场合照明：如低温照明、矿灯照明、汽车灯等方面被应用广泛。一些传统照明企业开始投资转型LED灯具。LED室内照明和应用技术上正在突飞猛进。室内照明无疑是个巨大的市场，市场前景毋庸置疑。相信在2010年会在家居照明中占据较大的市场份额。

室内照明最普遍的灯具就是E27、GU10、PAR30、PAR38等AC220V高压直接输入的LED射灯。E27、Gu10 LED射灯需要AC直接转换成DC的LED恒流源，才能驱动高亮度LED光源发光。目前还不能提供单个SoC的集成电路产品，大多数是采用原边或副边反馈的开关电源方案。但是原边反馈的方案存在输出电流精度不高的问题，一般都在 $\pm 5\%$ 左右。而采用副边反馈的反激式恒流驱动方案，输出电流精度可达 $\pm 2\%$ 。

可用于副边反馈的反激式恒流驱动方案的驱动IC很多，本文将详细介绍基于PT4201控制芯片的离线式LED射灯设计技术。

1W-30W离线式高亮度LED驱动控制器 PT4201

PT4201是一款工作于电流模式、可驱动1W至30W照明或射灯的高亮度LED驱动控制器，适用于1W至30W的各种LED照明和射灯应用，包括E27、PAR30、PAR38等。基于PT4201的隔离式光耦反馈的高亮度LED驱动系统具有恒流精度高、外围电路简单、无闪烁和EMI辐射低的显著优点。在正常工作状态下控制器的振荡频率可以通过外部电阻精确设定。同时，PT4201的前侧消隐电路帮助克服外部功率器件开启瞬间的电压毛刺，能有效避免控制器的误动作造成的LED灯闪烁。内部集成的电流斜率补偿功能提高了系统稳定性。

PT4201 提供完善的保护功能以提高 LED 照明系统的可靠性，包括逐周期过流保护（OCP）、VDD 过压保护（OVP）以及 VDD 欠压保护（UVLO）等。OUT 输出脉冲高电压被嵌制在 18V 保护外部功率 MOS。短路保护功能防止 LED 负载短路时损坏系统。

PT4201 提供 SOT-23-6 封装，引脚排列见图 1。

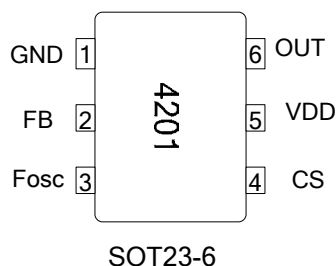


图 1 PT4201 引脚排列

PT4201基本功能描述

PT4201 集成了多种增强功能，并以其极低的启动和工作电流、多重保护功能为小功率 LED 照明驱动提供性能优良可靠的低成本解决方案。

启动及 UVLO:

PT4201 通过一个连接到高压线上的电阻 R_{start} 对连接在 Vdd 脚上的电容 $Chold$ 充电实现启动。在上电之初， $Chold$ 电容上的电压为 0，PT4201 处于关断状态，从 R_{start} 上流下的电流对 $Chold$ 进行充电从而使 Vdd 电压升高，当 Vdd 脚电压达到芯片启动电压 V_{DD-ON} 之后 PT4201 开始工作，工作之后流进 Vdd 电流增加，由辅助绕组开始对芯片进行供电。

优化设计的启动电路使 PT4201 启动之前 VDD 只消耗极低的电流，这样可以选用比较大的启动电阻 R_{start} 从而改善整机效率。对于一般的通用输入范围的应用，一个 2Mohm，1/8W 的电阻和一个 10uF/50V 的电容器可以组成一个简单可靠的启动电路（图 2）。

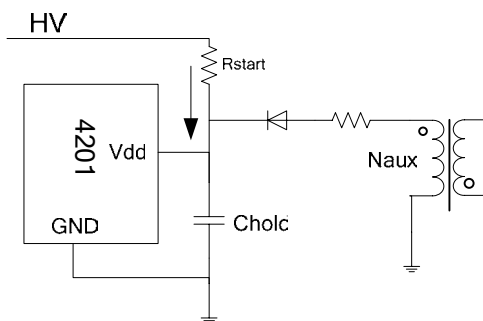


图 2 PT4201 启动电路

电流反馈及 PWM 控制:

PT4201 采用光耦检测输出 LED 串的电通过改变输出脉冲占空比达到输出电流控制目的。如图 3 所示，当 LED 电流达到设定值时，LED 电流在采样电阻 R_2 上的压降达到光耦发光管导通电压，发光管导通使 FB 电压下降，PT4201 根据 FB 电压的大小改变输出脉冲占空比实现恒定电流输出。

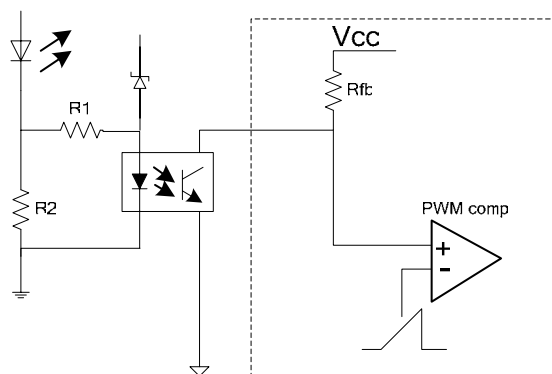


图 3 光耦电路

LED 开路:

LED 负载开路时, 流过稳压管的电流在电阻 R1 和 R2 上产生一个压降使光耦发光管被打开, 使 PT4201 的 FB 降低。当 FB 降低到一定程度时 PT4201 进入突发模式, 整个系统进入低功耗模式。因此 LED 灯开路是安全的。

LED 短路及采样电阻短路保护:

当 LED 负载发生短路时, 光耦发光管两端电压等于输出电压, 由于输出功率很小因此整个系统工作是安全的。当采样电阻发生短路时, 由于光耦发光管两端电压为零, 发光管不导通导致 FB 电压快速爬升到保护阈值。在 R_{osc} 为 100Kohm 情况下, 过 32ms 后 PT4201 将自动关闭。

工作频率设定:

PT4201 的 R_{osc} 引脚为设定 PWM 频率提供了方便, 用一个电阻接在 R_{osc} 引脚和 GND 之间可以对 PWM 频率进行设定 (图 4)。PWM 频率与设定电阻之间的关系遵循以下关系: $F_{osc} = 6500 / R_{osc}$ 。FOSC 单位 KHz, R_{osc} 单位 Kohm。

PT4201 在正常工作时会周期性地改变 PWM 工作频率进行频率抖动, 周期性改变的频率把 EMI 传导干扰扩展到更宽的频谱范围内从而降低了传导段的 EMI 干扰。

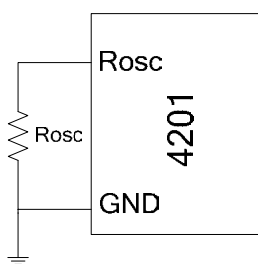


图 4 工作频率设定

电流采样以及前沿消隐:

PT4201 的 CS 引脚的功能之一是采样外部 MOSFET 电流进行电流斜率补偿, 二是提供逐周期的 MOSFET 过流保护功能。PT4201 通过采样与功率 MOSFET 串联的采样电阻来采样流过 MOSFET 的电流, 流过 MOSFET 的电流在采样电阻 R_{cs} 上转换成电压信号, CS 上电压和 FB 电压共同决定了 PWM 脉冲占空比。

在 PWM 每个导通周期当 CS 引脚的电压超过内部门限电压时 MOSFET 将立即被关掉防止过流对器件的损伤。过流门限电压与 MOSFET 的电流可由以下关系确定:

$$I_{oc} = V_{oc} / R_{cs}$$

其中 I_{oc} 为 MOSFET 电流， V_{oc} 为过流门限电压， R_{cs} 为采样电阻大小。内部过流的门限值与 PWM 占空比大小有关，当 PWM 占空比为 0 时，过流门限值为 0.80V。由于变压器副绕组整流电路反向恢复时间以及初级绕组寄生电容等因素影响，在每一个 PWM 周期开启瞬间会在采样电阻上产生一个持续时间很短的尖峰电压。为此 PT4201 会在 MOSFET 开启后屏蔽 CS 采样输入一段时间 T_{BLK} ，在这段时间内，过流保护被关闭不会关掉外部 MOSFET。这样可以避免 MOSFET 开启瞬间在采样电阻上产生的电压毛刺而造成误动作。PT4201 提供的这种功能可以省去电流采样电路所需的 RC 滤波器(图 5)。

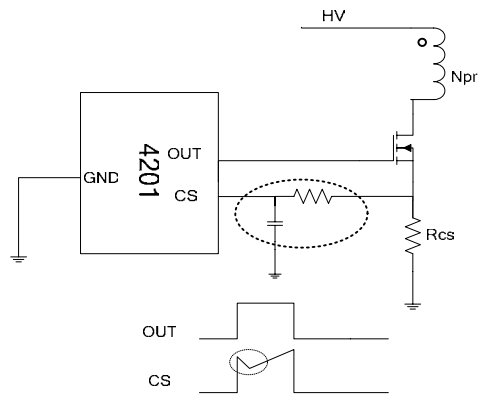


图 5 省略 RC 滤波器

VDD 过压保护

当系统发生严重故障时，例如对于光耦开路或者反馈开路的情况，光耦输出电流接近零致使 FB 端电压上升。FB 电压上升将会使 PT4201 工作在过流保护状态，因为有多余的电流供给负载，如果超出了负载所需电流大小会使输出电压迅速爬升。由于辅助绕组的电压与输出电压成一定的比例，输出电压升高引起辅助绕组电压升高进而使 VDD 电压升高，当 PT4201 检测到 VDD 引脚电压达到过压保护点时会关闭 PWM。当 OVP 被触发时由于没有能量供给负载及辅助绕组，VDD 电压和输出电压下降，当降低到 OVP 解除电压时将重新开启正常工作。这时如果故障解除则正常工作，如果故障依然存在将重新进入 OVP 保护状态(图 6)。

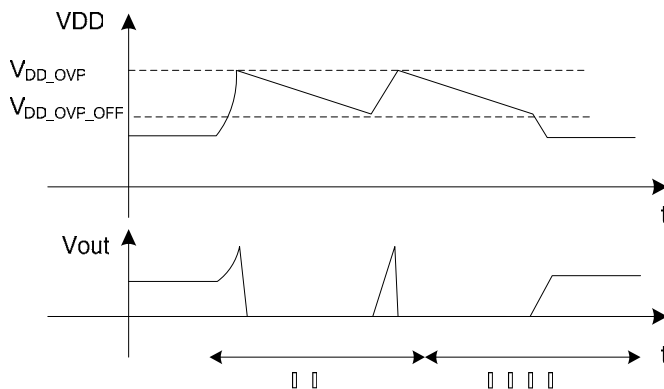


图 6 VDD 过压保护

OUT 输出驱动:

PT4201 的 OUT 脚用来驱动功率 MOSFET 的栅极。优化设计图腾柱形式输出的驱动能力使驱动强度和 EMI 得到良好的折衷。同时，OUT 的输出高电位被限制到了 18V，从而可以保护由于 VDD 升高可能对 MOSFET 造成的损伤。内部 OUT 和 GND 之间有一个电阻，可以在芯片不工作时将外部 MOSFET 的栅极可靠置为 0 电位。

基于 PT4201 的 E27 3W 离线式射灯方案

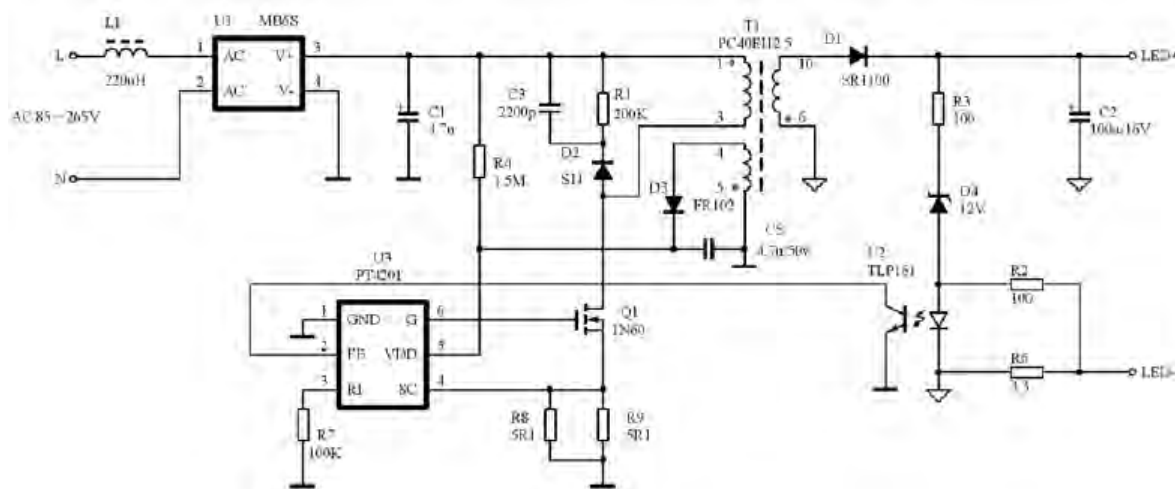


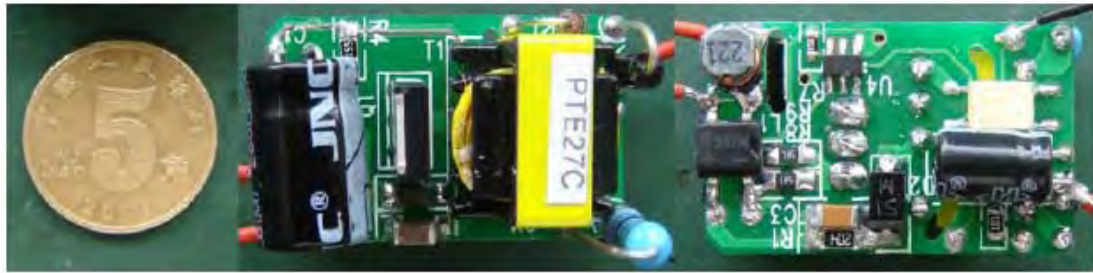
图 7 基于 PT4201 的 E27 3W 离线式射灯方案

基于PT4201的E27 3W离线式射灯方案应用线路是典型的反激式的拓扑结构，采用副边反馈（即光耦反馈），以提高输出电流精度。相比于原边反馈电路电流精度 $\pm 5\%$ ，副边反馈的电路精度在 $\pm 2\%$ 以内，成本只增加了0.3RMB，但却给大批量生产时提供了便利。

3W E27的应用一般负载接3颗1W的LED，每颗LED的VF在 $3.4V \pm 0.2V$ 左右。一般电流为300mA-350mA。工作原理如图7所示，AC85V-265V交流电输入，通过L1（相当于一个保险丝，抗浪涌）后接入整流桥，从整流桥出来的电压大约为 $1.4XV_{in}$ ，电流1A左右。C1是一个滤波电容，电容值的选择大约是负载功率的1-3倍即可，此处3W的应用采用4.7uF的电容，如选择太小的会导致纹波大，选择太大的空间又不允许。PT4201的VDD端一开始由R4降压后供电，18V启动，启动之后就通过变压器辅助绕组供电，电压在9-27V之间。R1、C3和D2是一个RCD吸收回路，用来吸收Q1开关时产生的尖峰。减小R1，可以提高吸收效果，但是会导致系统效率降低，建议采用折衷的方式。PT4201的RI端所接电阻R7是用来设定开关频率的，此处把频率设定在65kHz。PT4201的CS端连接采样电阻R8、R9，设置电流。变压器是一个重要的部件，采用反激式的拓扑结构，当Q1关断时，变压器5、6端导通，D1的耐压为变压器输入电压/匝数比+变压器输出电压。当Q1开时，变压器1、2端有电流，3、4、5、6端截止，D1的耐压为变压器输出电压X匝数比+变压器输入电压。D1、T1、Q1是影响效率的关键，D1反向耐压与T1匝数比互相牵制。电路右边SR1100是一个肖特基二极管或者可采用快恢复二极管整流。当空载时，R3是一个限流电阻，限制这条支路上的电流在10mA，D4在这里选用12V稳压管，起到一个整流限压的作用，在空载时才工作，R2是一个分流电阻，R2上流过的电流为10mA，R2左端的电压为1V。带负载时，R6两端的电压为1V左右，通过选择电阻值不同调节输出电流，这是1X3W的应用，工作电流设定在300mA左右。U2是光耦，当R6上的电流变大时，发光二极管上的电流变大，光敏电阻感应到之后，反馈电

流到PT4201FB端，FB端电压变小，PT4201通过调整占空比来使能量降低，随之降低R6上的电流。由于是从输出端采样电流反馈到芯片，这样的副边反馈，实时对电流进行微调，提高了输出电流的精度。

图 8 是这个 3W E27 方案的照片，体积很小，放入 E27 灯头绰绰有余。



改变这个方案的部分设计数据，可以设计 5W、7W、12W 的各种方案，工作原理雷同。由于 5W-12W 的应用空间较大，所以允许在 3W 的基础上加上一些辅助电路。如增加抗雷击器件、可以提高 EMC 的共轭电感、PFC、 Π 滤波器等等，以提高整个电路过 EMC 的能力、工作效率、PFC。

参考文献：

《Powtech 离线式 LED 射灯解决方案》
《PT4201Datasheet》

2009-8-18