基于PT4107的LED日光灯设计

颜重光

华润矽威科技（上海）有限公司

摘要：LED光源作为第四代新型节能光源诞生之时即被用来做各类灯具的发光光源。0.06W的白光LED草帽灯、食人鱼是最早被用在LED日光灯的发光灯条上的，每个LED日光灯管使用数量不等，约280-360颗。现在新一代的LED日光灯发光灯条使用从0.06-1W、显色为纯白、青白、暖白、冷白的贴片LED平面光源。节能省电是LED日光灯的最大特点，以T8日光灯为例，标称36W的萤光日光灯（CFL），其附加镇流器耗电8W，工作时实际耗电44W，照明流明为420lm，使用寿命3千小时；而同样规格的LED日光灯，工作时实际耗电仅16W，照亮流明为550lm，使用寿命可达3万小时。

关键词：PWM LED；NTC；无源PFC

1 PWM LED驱动控制器PT4107

LED日光灯的LED灯条电源驱动方案有很多种，目前非隔离方案因其效率高而占主流，而用PWM LED驱动控制器来做LED日光灯驱动电源的又占绝大多数。

PT4107是一个典型的PWM LED驱动控制器，其内部拓扑结构如图1。

PT4107是一款高压降压式PWM LED驱动控制器。通过外部电阻和内部的齐纳二极管，可以将经过整流的110V或220V交流电压嵌位于20V。当Vin上的电压超过欠压闭锁阀值18V后，晶片开始工作，按照峰值电流控制的模式来驱动外部的MOSFET。在外部MOSFET的源端和地之间接入电流采样电阻，该电阻上的电压直接传递到PT4107晶片的CS端，当CS端电压超过内部的电流采样阀值电压后，GATE端的驱动信号终止，外部MOSFET关断。阀值电压可以由内部设定，或者通过在LD端施加电压来控制。如果要求软启动，可以在LD端并联电容，以得到需要的电压上升速度，并和LED电流上升速度相一致。

PT4107的主要特点是：从18-450V的宽电压输入范围，恒流输出；采用频率抖动减少电磁干扰，利用随机源来调制振荡频率，这样可以扩展音频能量谱，扩展后的能量谱可以有效减小带内电磁干扰，降低系统级设计难度；可用线性及

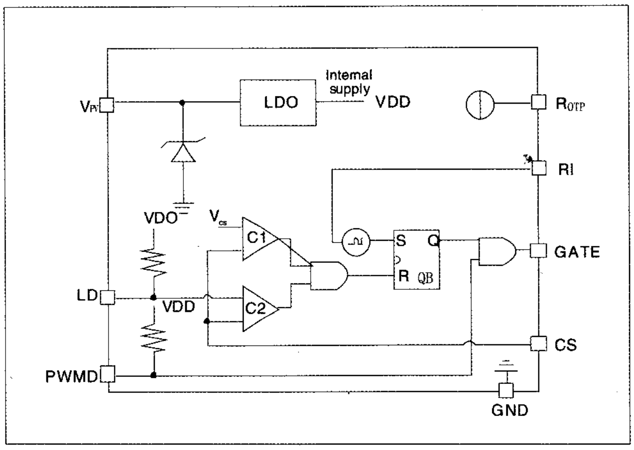


图1 PT4107内部拓扑结构

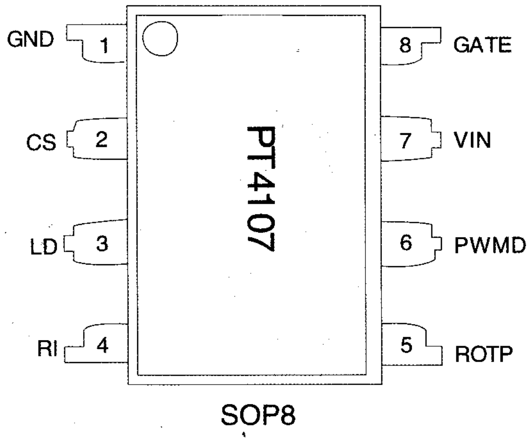


图2 PT4107封装

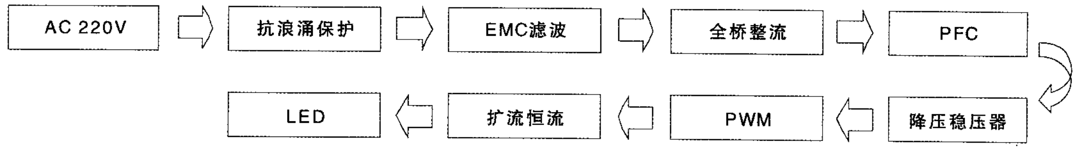


图3 全电压20W日光灯开关恒流源方案图

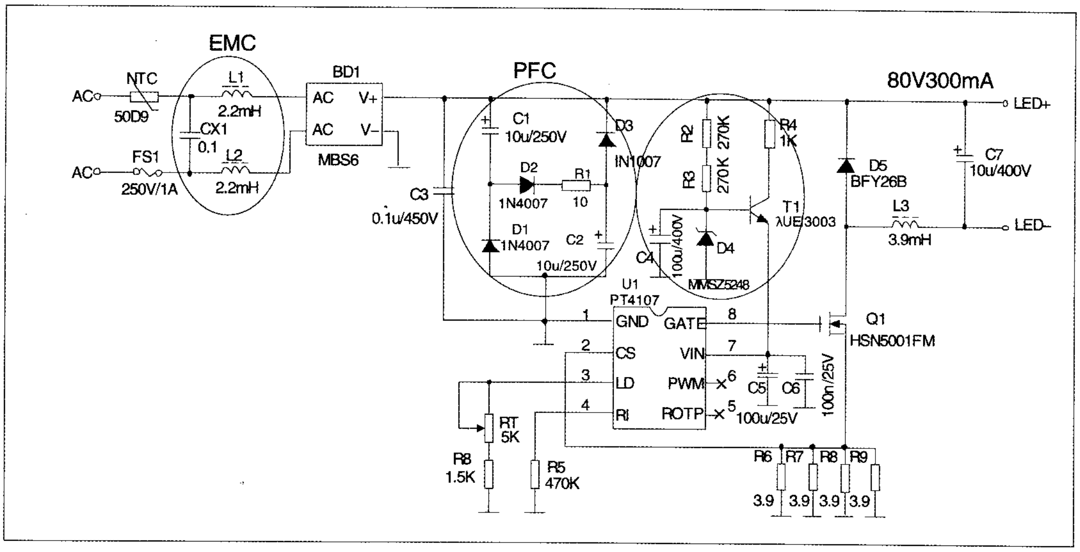


图4 全电压20W日光灯开关恒流源原理图

PWM调光，支持上百个0.06W LED的驱动应用，工作频率25-300kHz，可通过外部电阻来设定。PT4107封装如图2。

2 设计全电压20W日光灯开关恒流源

以AC85-245V全电压输入为例，采用PT4107 PWM LED驱动控制器来做LED日光灯驱动电源的主晶片，设计一个比较理想的应用电路方案如图3，全电路由抗浪涌保护、EMC滤波、全桥整流、无源功率因素校正（PFC）、降压稳压器、PWM LED驱动控制器、扩流恒流电路组成。

据此理念，设计成的全电压20W日光灯开关恒流源电原理图如图4所示。从AC220V看进去，交流市电入口接有1A保险丝FS1和抗浪涌负温度系数热敏电阻NTC；之后是EMI滤波器，由L1、L2和CX1组成；BD1是整流全桥，内部是4个高压矽二极体；C1、C2、R1、D1-D3组成无源功率因数校正电路；PT4107晶片由T1、D4、C4、R2-R4组成的电子滤波器降压稳压后供电，这个滤波器输入阻抗很高，输出阻抗很小，整流后近300V直流高压经此三极管降压向PT4107 Vin提供约18-20V稳定电压，确保晶片在全电压范围下稳定工作，而且这个电路不像先前方案的电阻降压电路耗能而且发烫；PWM控制晶片U1（PT4107）和功率MOS管Q1、镇流功率电感L3、续流二极体D5组成降压稳压电路，U1采集电流采样电阻R6-R9上的峰值电流，由内部逻辑在单周期内控制GATE脚信号的脉冲占空比进行恒流控制，输出恒流与D5、L3的续流电路合并向LED光源恒流供电，改变电阻R6-R9的阻值可改变整个电路的输出电流，但D5、L3也要随之改动。R5是晶片振荡电路的一部分，改变它可调节振荡频率；电位器RT在本电路中不是用来调光，而是用来微调恒流源的电流，使电路达到设计功率。由于器件的分散性，批量生产时每一块电源板的输出电流会略有不同，在生产线上可用此电位器来调整每块电源板的输出电流，为了保

图5 T10恒流源的实物照片

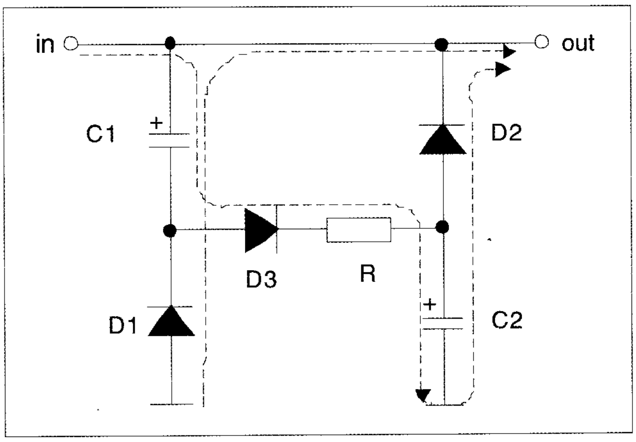


图6 平衡半桥PFC电路

护已调好电源板的稳定性，一定要选用涡轮涡杆微调电位器，并在调好后滴胶固封。

本电路的参数是按22个0.06W LED串联，15串并联，驱动330个60mW的白光LED负载设计的，每串的电流是17.8mA，设计输出36-80V/250mA。改变LED数量需要修正R6-R9的参数。

PCB板的排列是做好产品的关键，因此PCB板的走线要按电力电子规范要求来设计。本电路可同样用于T10、T8日光灯管，因两管空间大小不同，二块PCB板的宽度将不同，要降低所有零件的高度，以便放入T10、T8灯管。图5是T10恒流源板的实物照片，33个元件安装在235×25×0.8毫米的环氧单面印制板上。

3 关键资料及元器件选择

（1）抗浪涌的NTC

抗浪涌的NTC选用300Ω/0.3A热敏电阻，如改变此方案的输出，如电流增大，则NTC的电流也要选大，以免过流自发热。

（2）EMC滤波

在交流电源输入端，一般需要增加由共轭电感、X电容和Y电容组成的滤波器，以增加整个电路抗EMI的效果，滤除掉传导干扰信号和辐射杂讯。本电路采用共轭电感+X电容器的简洁方式，主要还是出于整体成本的考虑，本着够用就好的设计原则。X电容器应标有安全认证标志和耐压AC275V字样，其真正的直流耐压在2000V以上，外观多为橙色或蓝色。共轭电感是绕在同一个磁芯上的两个电感量相同的电感，主要用来抑制共模干扰，电感量在10-30mH范围内选取。为了缩小体积和提高滤波效果，优先选用高导磁率微晶材料磁芯制作的产品，电感量应尽量选较大的值。使用二个相同电感替代一个共轭电感也是一个降低成本的方法。

（3）全桥整流

全桥整流器BD1主要进行AC/DC变换，因此需要给予1.5系数的安全馀量，建议选用600V/1A全桥整流器。

（4）无源PFC

普通的桥式整流器整流后输出的电流是脉冲直流，电流不连续，谐波失真大，功率因数低。因此需要增加低成本的无源功率因数补偿电路，如图6所示。这个电路叫做平衡半桥补偿电路，C1和D1组成半桥的一臂，C2和D2组成半桥的另一臂，D3和R组成充电连接通路，利用填谷原理进行补偿。滤波电容C1和C2相串联，电容上的电压最高充到输入电压的一半（VAC/2），一旦线电压降到VAC/2以下，二极体D1/D2就会被正向偏置，这样使C1和C2开始并联放电。这样一来，正半周输入电流的导通角从原来的75-105°上升到30-150°；负半周输入电流的导通角从原来的255-285°上升到210-330°（图7）。与D3串联的电阻R有助于平滑输入电

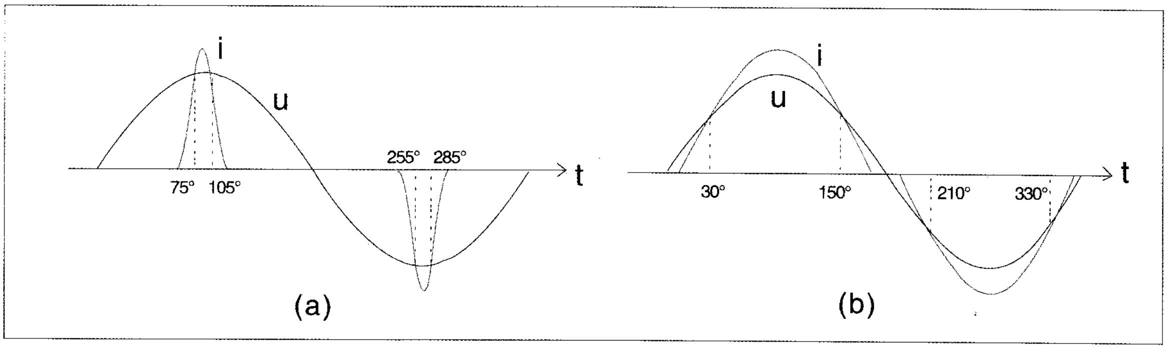


图7 平衡半桥PFC电路的效果

流尖峰，还可以通过限制流入电容C1和C2的电流来改善功率因数。采用这个电路后，系统的功率因数从0.6提高到0.89。R有浪涌缓冲和限流功能，因此不宜省略。

（5）降压稳压电路

给PT4107供电的电路是倍容式纹波滤波器，具有电容倍增式低通滤波器和串联稳压调整器双重作用，如图8。在射极输出器的基极到地接一个电容C4，由于基极电流只有射极电流的1/（1+β），相当于在发射极接了一个（1+β）C4的大电容，这就是电容倍增式滤波器的原理。如果在基极到地再连接一个齐纳二极体，就是一个简单的串联稳压器，该电路能有效地消除高频开关纹波。注意T1要选择双极型电晶体的Vbceo>500V，Ic=100mA。稳压二极体D4要用20V、1/4W任何型号的小功率稳压管。

（6）镇流功率电感

镇流功率电感L3与Q1 MOS管，以及R6、R7、R8、R9并联的电流采样电阻是此电路恒流输出的三大关键元件。镇流功率电感L3要求Q值高、饱和电流大、电阻小。标称3.9mH的电感，在40-100kHz频率范围里Q值应大于90。设计时要选用饱和电流是正常工作电流2倍的功率电感。本电路设计输出电流250mA，因此选500mA。选用功率电感的绕线电阻要小于2Ω，居里温度大于400℃的优质功率电感。一旦电感发生饱和，MOS管、LED光源、PWM控制晶片就会瞬间烧毁。建议使用高导磁率微晶材料的功率电感，它可以确保恒流源长期安全可靠地工作。

L3电感要选用EE13磁芯的磁路闭合电感器，或高度低一点的EPC13磁芯（图9）。现在LED日光灯大多数选用半铝半PV 塑胶的灯管，以帮助LED光源散热。工字磁芯电感器其磁路是开放的，当使用工字磁芯电感器的电源驱动板进入半铝半PV塑胶灯管时，由于金属铝能使其磁路发生变化，往往会使已调试好的电源驱动板输出电流变小。

（7）续流二极体

续流二极体D5一定要选用快恢复二极体，它要跟上MOS管的开关周期，如在此使用1N4007，那么在工作时会烧毁的。而且续流二极体通过的电流应是LED光源负载电流的1.5-2倍，本电路要选用1A的快恢复二极体。

（8）PT4107开关频率设定

PT4107开关频率的高低决定功率电感L3和输入滤波电容器C1、C2、C3的大小，开关频率高了，可以选用更小体积的电感器和电容器，但Q1 MOSFET管的开关损耗也将增大，会导致效率下降。因此对AC220V的电源输入来说，50-100kHz是比较适合的。PT4107开关频率设定电阻R5计算公式如下：

$$f=2500/R\ (kHz) \rightarrow R=2500/f\ (k\Omega)$$

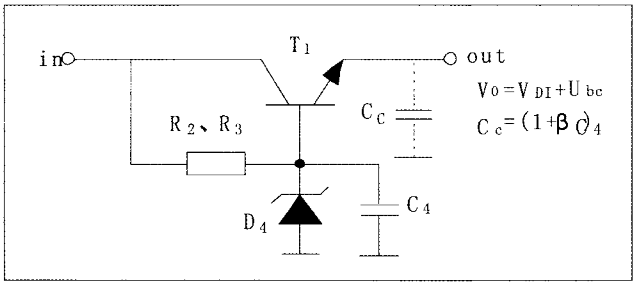


图8 倍容式纹波滤波器

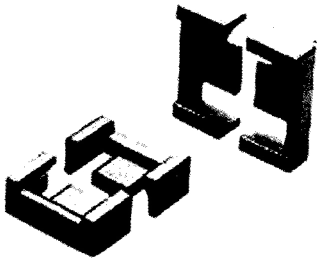


图9 EPC13磁芯

这样，当f=50 kHz时，R5=500 kΩ；如R5=470kΩ，f=53.2 kHz。

（9）MOSFET管的选择

MOSFET管Q1是本电路输出的关键器件，首先它的RDS（ON）要小，它工作时本身功耗就小，它的耐压要高，它在工作中遇高压浪涌不易被击穿。

在MOSFET的每次开关过程中，采样电阻R6-R9上将不可避免的出现电流尖峰，为避免这种情况发生，晶片内部设置了400nS的采样延迟时间。因此，传统的RC滤波器可以被省去，在这段延迟时间内，比较器将失去作用，不能控制GATE引脚的输出。使出现电流尖峰前沿消隐。

（10）电流采样电阻

电阻R6、R7、R8、R9并联作为采样电阻，这样可以减小电阻精度和温度对输出电流的影响，并且可以方便地改变其中一个或几个的阻值，达到修改电流的目的。建议选用千分之一精度，温度系数为50ppm的SMD（1206）1/4W电阻。电流采样电阻R6-R9的总阻值设定和功率选用，要按整个电路的LED光源负载电流为依据来计算：

$$R_{6\text{-}9}=0.275/I_{LED}$$

$$P_{R6\text{-}9}=I_{LED}^{2}\times R_{6\text{-}9}$$

（11）电解电容器

LED光源是一种长寿命光源，理论寿命可达50000小时，但是应用电路设计不合理、电路元器件选用不当、LED光源散热不好，都会影响它的使用寿命。特别是在驱动电源电路里，作为AC/DC整流桥的输出滤波器的电解电容器，它的使用寿命在5000小时以下，这就成了制造长寿命LED灯具技术的拦路虎。本电路设计使用了C1、C2、C4、C5、C7多颗铝电解电容器。铝电解电容器的寿命还与使用环境温度有很大关系，环境温度升高电解质的损耗加快，环境温度每升高6℃，电解电容器寿命就会减少一半。LED日光灯管内温度因空气不易流动，如电源驱动板设计不合理，管内温度会比较高，电解电容器的寿命因此大打折扣。选用固态电解电容器，也许是延长寿命的好办法之一，但导致成本上升。

4 小结

应用PT4107可以设计以多颗0.06W WLED光源串并联为负载的，AC110V或AC220V的T10、T8、T5的LED日光灯方案，以及类似应用的吸顶灯、满天星灯、野外照明工作灯、球泡灯。也可设计以高亮度1W WLED光源串联为负载的LED庭院灯、LED路灯、LED隧道灯。

2009年初日本政府为降低公共照明的碳排放，强制企业执行节能减碳政策，日本办公室节能照明需求逐渐升温，大力推广LED日光灯，促进了中国LED日光灯的生产。因此参照本电路设计的适用AC 110V的LED日光灯电路已被广泛用于生产。

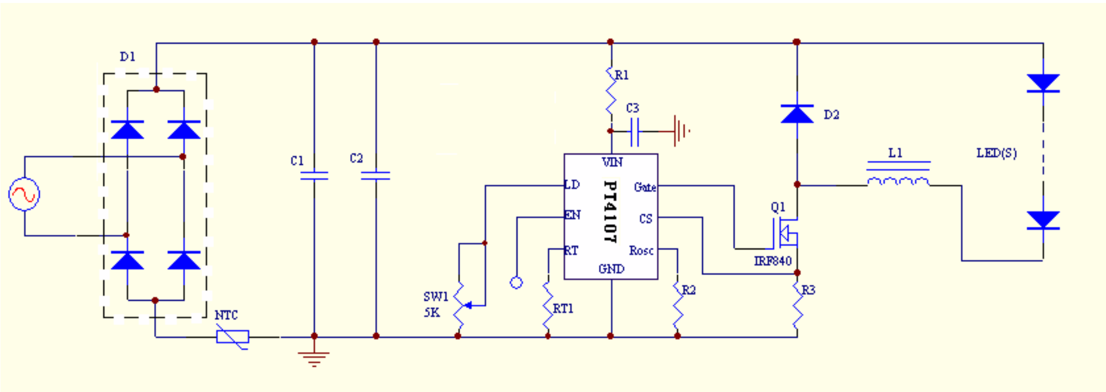
选自《无线电技术》

用 PT4107 制作 BUCK 电路的 LED 驱动电路

利用 BUCK 电路制作离线式无隔离的 LED 驱动应该是一个很好的选择，它可以为 LED 提供连续的供电电流，同时整体的系统成本与其他电路形式相比也是非常低的。PT4107 提供了一个峰值电流检测同时为 LED 提供连续电流的连续模式的 BUCK 转换器。它具有两种调光功能，低频的 pwm 信号调光和线性可变电阻调光；另外提供了温度检测功能，通过一个热敏电阻检测整个系统的环境温度，为整个系统的可靠的工作提供了安全的保证。PT4107 为我们提供了方便的低成本的大功率 LED 驱动解决方案，是大功率 LED 驱动的最好选择。

下面我们讨论一下用 PT4107 制作以 buck 电路为基础的 LED 驱动器的参数计算和元器件的选择方法和步骤，其他任何 buck 电路为基础利用 PT4107 的 LED 驱动都可以按照这样的步骤做为设计参考。

电路原理图如下：



AC Input Voltage Range：Vnom,ac＝220V rms　Vmin,ac=176V rms　Vmax,ac=264V rms　freq=50Hz

Expected LED string voltage: Vo,min＝10V　Vo,max=24V

Stabilized LED CURRENT: Io,max＝350mA

Expected Efficiency：η＝90％

第一步：确定开关频率

由于开关频率的大小决定了电感 L1 和输入滤波电容 C1 的尺寸。开关频率越高，我们就可以选用更小体积的电感和电容，节省了系统的成本，但同时 MOSFET 管的开关损耗将大大的增大，会造成效率的降低。对于 AC220V 的交流输入来说，我们综合考虑选用 50KHz 的振荡频率比较合适。相应的振荡频率的电阻 R2 有下面的公式计算得到：

$$f = \frac{25000}{R}\ (\mathrm{KHz}) \Rightarrow R = \frac{25000}{f}\ (\mathrm{Kohm})$$

所以此例中取 R2 为 500Kohm。

第二步：选择输入整流桥（D1）和热敏电阻 NTC

输入整流桥的额定电压的确定是根据交流输入电压的最大值选择的；额定电流的选择是根据系统正常工作时的输入平均电流决定的。

$$V_{bridge} = 1.5 \times \left(\sqrt{2} \times V_{\max, ac}\right) \qquad (1)$$

$$I_{bridge} = \frac{V_{o,\max} \times I_{o,\max}}{V_{\min, dc} \times \eta} \qquad (2)$$

注：公式中的 1.5 的系数是一个安全余量，这个设计中我们选择 600V1A 的整流桥。

在输入端放置一个压敏电阻，是限制输入冲击电流的最简单实用的方法。压敏电阻的额定参数的选择决定于输入电压和要求冲击电流的大小。当冲击电流要求较高时，相应的压敏电阻的数值就要取得较大，这样就会产生较大的损耗，当压敏电阻选择的较小时会提高整个系统的效率但对整流桥的冲击电流就比较大，就要求选择更高额定的整流桥。综合考虑的情况下，我们一般按下面的公式来选择压敏电阻的阻值：

$$R_{cold} = \frac{V_{bridge}}{5 \times I_{bridge}} \qquad (3)$$

此例中我们选用 300ohm（25℃），电流额定不小于 0.2A 的热敏电阻。

第三步：输入电容的选择（C1 和 C2）

输入电容的选择是使电容在充放电的过程中能够保证后端电路需要的工作能量。要保证系统的正常工作，电容上的最小电压应该是最大输出 LED 电压的两倍以上，以保证系统的正常工作，所以：

$$V_{\min,dc} = 2 \times V_{o,\max} = 48V$$

输入电容应能够保证在最小的输入电压下，为电路正常工作提供足够的能量，所以电容的选择按下式计算：

$$C1 \geq \frac{2 \times V_{o,\max} \times I_{o,\max}}{\left(2 \times V_{\min,ac}^2 - V_{\min,dc}^2\right) \times \eta \times freq}$$

此例中我们选择 C≥6.26uF

输入电容的电压额定应该比最大峰值输入电压放大 10～12%的安全余量来选择的，请按下式选择：

$$V_{\max,cap} \geq (1.1\sim1.2)\sqrt{2} \times V_{\max,ac} \Rightarrow V_{\max,cap} \geq 410.6V$$

此例中我们选择 450V，10uF 的电解电容。

由于电解电容存在相当大的 ESR，所以不能吸收高频纹波，所以还要另外在电解电容上并联一个多层瓷片电容（MLCC）用来吸收高频纹波，对于高频电容请按下式选择：

$$C2 = \frac{I_{o,\max} \times 0.25}{f_s \times \left(0.05 \times V_{\min,dc}\right)}$$

此例中我们选择 1uF,450V 的瓷片电容。

第四步：输出电感的选择：

电感的大小决定了 LED 中的脉动电流，一个＋/－10%（总的 20%的峰峰值脉动）对于 LED 来说是比较合适的，如果更大的脉动电流会减小电感的尺寸和降低系统的成本，但同时也会降低 LED 的使用寿命，对于电感的选择请按下式计算：

$$L1=\frac{V_{o,\max}\times\left(1-\frac{V_{o,\max}}{\sqrt{2}\times V_{ac,nom}}\right)}{0.2\times I_{o,\max}\times f_s}$$

此例中我们选择 L1=6.5mH

电感的峰值额定按下式选择：

$$i_p=0.35\times1.1=0.39A$$

电感的平均电流就是 20%的脉动电流的平均电流，为系统输出的平均电流。

此例中我们选择 6.8mH、峰值电流为 0.5A、平均电流为 0.35A 的功率电感。

第五步：开关 mossfet 管（Q1）和续流二极管的选择：

开关管的峰值电压额定等于最大的输入电压，选择时我们放大 50%的安全余量：按下式选择：

$$V_{FET}=1.5\times\left(\sqrt{2}\times \mathrm{Vac,max}\right)$$

开关管的最大平均电流就是最小输入电压、最大占空比的情况下通过的电流，

$$I_{FET}\approx I_{o,\max}\times\sqrt{\mathrm{Dmax}}$$

实际选择开关管的额定电流的时候均放大两倍的余量，就是选择 3 倍的I_{FET}。

此例中我们选择 600V，<1A 的 MOSFET。对于 MOSFET 管的选择并不是越打越好，要综合考虑电压额定、电流额定、以及损耗等多方面的因素，以达到最小的能量损失为目的。

续流二极管的额定电压就等于 MOSFET 管的额定电压。

续流二极管的平均电流按下式选择：

$$I_{diode}=0.5\times I_{o,\max}=0.175A$$

此例中选择 600V，1A 的快恢复整流二极管。

第六步：LED 限流电阻的选择（R3）

LED 限流电阻阻值按下式选择：

$$R3=\frac{0.25}{1.1\times I_{o,max}}$$

电阻的功率额定按下式计算选择：

$$P_{R3}=I_{o\max}{}^2\times R3$$

此例中选择 0.62Ω0.1W 的限流电阻。

第七步：VDD 限流电阻（R1）和保持电容（C3）的选择

限流电阻 R1 的选择决定于芯片的工作电流和芯片驱动 MOSFET 所需的电流之和。具体选择请按下式选择：

$$R1 = \frac{\sqrt{2}\ \mathrm{Vac,nom} - \mathrm{VDD,nom}}{\mathrm{Iin}}$$

此例中我们选择 Iin 为 5mA，得出 R1 的数值为 60KΩ。电阻的功率按下式确定：

$$P_{R1} = I_{\mathrm{in,max}}{}^{2} \times R1$$

其中，Iin,max=(1.414×264)/(63.2×1000)=5.9mA,此例中 R1 的功率为 2W.

保持电容 C3 的选择和 C1 的选择一样,

$$C3 \geq \frac{2 \times V_{\mathrm{in,max}} \times I_{\mathrm{in,max}}}{\left(V_{\mathrm{min},dc}^{2} - V_{\mathrm{in,min}}^{2} \right) \times freq}$$

此例中选择 35V,1uF 的电解电容.

第八步：热敏电阻 RT1 的选择

热敏电阻 RT1 的选择取决于系统的温度保护点。芯片的端口保护电压设置为 1V,芯片内部将有一个 30uA 的恒流源对 RT1 热敏电阻提供电流，当随着系统温度的升高，NTC 热敏电阻会变小，当 30uA 的电流源在热敏电阻上形成的压降小于等于 1V 的保护点时，系统降由于温度过高而停止工作。所以选择热敏电阻时要根据热敏电阻的温度特性，系统的合适保护点进行合理选择。

此例中我们选择 50K 的 NTC 热敏电阻。

PowTech

PT4107

Universal High Brightness LED Driver with Improved Current Regulation and EMI Performance

GENERAL DESCRIPTION

The PT4107 is a high voltage buck control IC for constant LED current regulation. It allows efficient operation of High Brightness (HB) LEDs from voltage sources ranging from 18VDC up to 450VDC or 110VAC/220VAC. The PT4107 controls an external MOSFET at fixed switching frequency from 25 kH_Z to 200 kH_Z. The frequency can be programmed using an external resistor. A proprietary peak current control method keeps constant average LED currents for wide input and output ranges. The output current can be programmed from a few milliamps up to more than 1A. The output current on one LED string also can be programmed to any value between zero and its maximum value by applying an external control voltage at the linear dimming control input of the PT4107. Moreover, PT4107 provides a low-frequency PWM dimming input that can accept an external control signal with duty ratio of 0-100% and a frequency of up to a few kilohertz.

Frequency jittering is used to reduce the EMI.

FEATURES

- Proprietary constant-current control.
- Wide input range from 18V to 450V or 110VAC/220VAC
- Applications from a few mA to more than 1A Output
- up to hundreds of LEDs
- PWM Low-Frequency Dimming via Enable pin
- Linear Dimming via LD pin
- Frequency jittering for better EMI performance
- Programmable Over temp Protection (OTP)

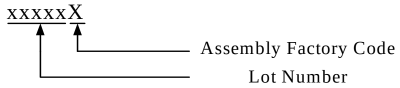
APPLICATION

- AC/DC LED Driver applications
- RGB Backlighting LED Driver
- Signal and Decorative LED lighting

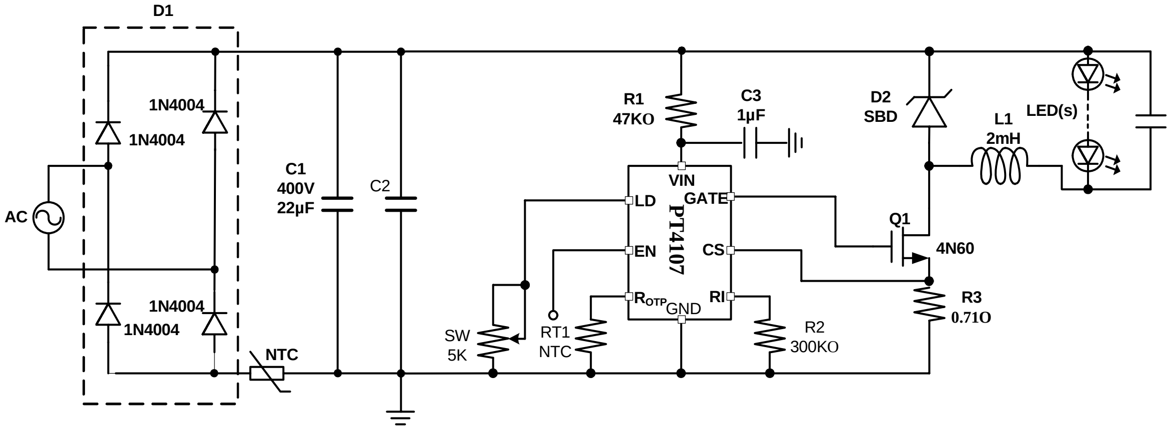
ORDERING INFORMATION

PACKAGE	TEMPERATURE RANGE	ORDERING PART NUMBER	TRANSPORT MEDIA	MARKING
SOP-8	-40℃ to 85℃	PT4107ESOP	Tape and Reel	PT4107 xxxxxX
DIP-8	-40℃ to 85℃	PT4107EDIP	Tape and Reel	PT4107 xxxxxX

Note:



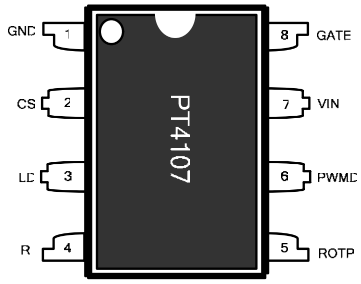
TYPICAL APPLICATION CIRCUIT



PT4107

Universal High Brightness LED Driver with Improved Current Regulation and EMI Performance

PIN ASSIGNMENT



SOP8/DIP8

PIN DESCRIPTIONS

SOP8/DIP-8 PIN No.	PIN NAMES	DESCRIPTION
1	GND	Device ground
2	CS	Senses LED string current
3	LD	Linear dimming by changing the current limit threshold at current sense comparator
4	RI	Oscillator frequency control. A resistor connected between this pin and ground sets the PWM frequency
5	ROTP	Temperature sensing input pin. Connected through an NTC resistor to GND. Once the voltage of the ROTP pin drops below a pre-defined value, PWM output will be disabled
6	PWMD	Low frequency PWM dimming pin, also Enable input. Internal 100kohm pull-up to 5 V
7	VIN	Input Voltage 18V to 450VDC connected by a resistor
8	GATE	Drives the gate of the external MOSFET

ABSOLUTE MAXIMUM RATINGS (Note1)

SYMBOL	ITEMS	VALUE	UNIT
V_{IN}	Supply Voltage	-0.3~25	V
GATE	Drives the gate of the external MOSFET	-0.3~20	V
	Other pins voltage	-0.3~6	V
$I_{VIN(MAX)}$	Max. Input Current	10	mA
P_{DMAX}	Power Dissipation (Note 2)	Internally Limited	W
P_{TR1}	Thermal Resistance, SOP-8 θ_{JA}	105	℃/W
P_{TR2}	Thermal Resistance, DIP-8 θ_{JA}	90	℃/W
T_J	Operation Junction Temperature Range	-40 to 125	℃
T_{STG}	Storage Temperature	-55 to 150	℃
	ESD Susceptibility (Note 3)	2	kV

RECOMMENDED OPERATING RANGE

SYMBOL	ITEMS	VALUE	UNIT
V_{IN}	V_{DD} Supply Voltage	0 ~ 20	V
	Other pins	0 ~ 5	V
T_{OPT}	Operating Temperature	-40 to +85	℃

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: The maximum power dissipation must be derated at elevated temperatures and is dictated by T_{JMAX}, θ_{JA}, and the ambient temperature T_A. The maximum allowable power dissipation is $P_{DMAX} = (T_{JMAX} - T_A)/ \theta_{JA}$ or the number given in Absolute Maximum Ratings, whichever is lower.

Note 3: Human body model, 100pF discharged through a 1.5kΩ resistor.

ELECTRICAL CHARACTERISTICS (Note 4, 5)

The following specifications apply for V_{IN}=16V, T_A=25℃, unless specified otherwise.

SYMBOL	ITEMS	CONDITIONS	MIN.	TYP.	MAX.	UNIT
I_{VIN_START}	V_{IN} start up current	V_{IN}=15V, RI=300k		3	10	µA
I_{VIN_OPER}	V_{IN} operation current	V_{IN}=15V, RI=300k, GATE floated			1	mA
V_{IN_clamp}	Maximal pin V_{IN} voltage			20		V
UVLO (H)	V_{IN} Under Voltage Lockout Exit	V_{IN} rising	15.5	16.5	17.5	V
UVLO (L)	V_{IN} Under Voltage Lockout Enter	V_{IN} falling	9.5	10.5	12	V
V_{EN}(lo)	PIN PWMD input low voltage				0.5	V
V_{EN}(hi)	PIN PWMD input high voltage		2.4			V
R_{EN}	PIN PWMD pull-up resistance			100		kΩ
V_{CS}	Current sense pull-in threshold voltage	V_{CS} Falling from 600mV	250	275	300	mV
V_{OL}	GATE Output Low Level	V_{IN}=16V, Io=-20mA			0.3	V
V_{OH}	GATE Output High Level	V_{IN} =16V, Io=20mA	11			V
V_{G_clamp}	Output Clamp			18		V
T_r	Output Rising Time	V_{IN} =16V, CL=1nF		120		ns

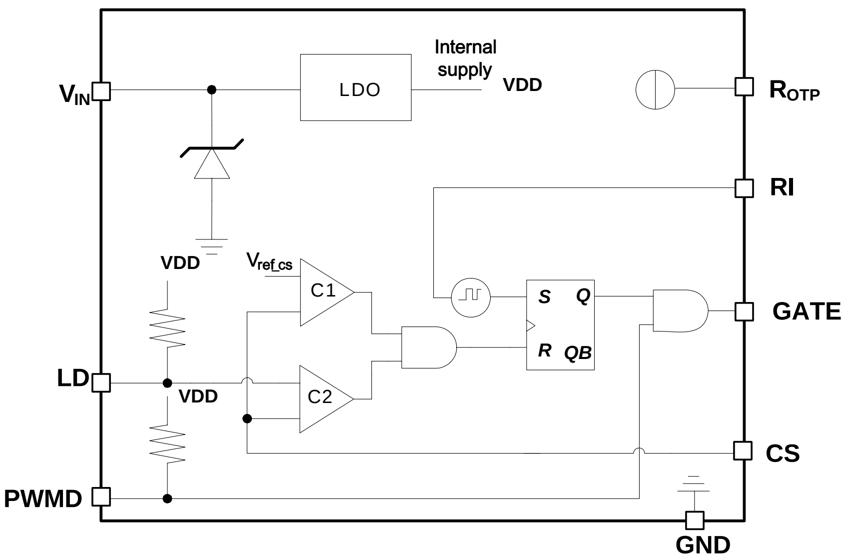
ELECTRICAL CHARACTERISTICS (Continued) (Note 4, 5)

SYMBOL	ITEMS	CONDITIONS	MIN.	TYP.	MAX.	UNIT
T_f	Output Falling Time	V_{IN} =16V, CL=1nF		50		ns
F_{OSC}	Oscillator frequency	RI=1.2M RI=300k	20 80	25 100	30 120	kHz
D_{MAX}	Maximum PWM duty cycle			90		%
V_{LD}	Linear Dimming pin voltage range		0		500	mV
R_{LD}	Linear Dimming pin pull-up resistance			100		kΩ
T_{BLK}	Current sense blanking interval			400		ns
T_{DLY}	Delay from CS trip to GATE low				450	ns
Δf_{OSC}	Frequency Modulation range over Base Frequency		-3		+3	%
$f_{jittering}$	Modulation Freq.	RI=300k		32		Hz
I_{ROTP}	Output current of pin R_{OTP}	RI=300k		80		μA
V_{OTP}	Threshold voltage for OTP		0.8	1.0	1.2	V

Note 4: Typical parameters are measured at 25℃ and represent the parametric norm.

Note 5: Datasheet min/max specification limits are guaranteed by design, test, or statistical analysis.

SIMPLIFIED BLOCK DIAGRAM



PT4107

Universal High Brightness LED Driver with Improved Current Regulation and EMI Performance

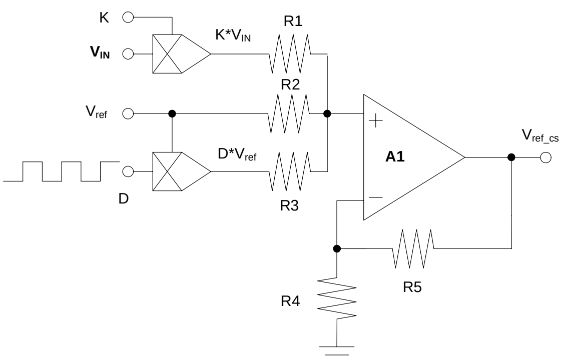
OPERATION DESCRIPTION

PT4107 is a high voltage buck controller for LED driver. The high input voltage from the rectified 110VAC or 220VAC is clamped to about 20V by an external resistor and an internal Zener. When the voltage at the VIN pin exceeds the UVLO threshold the gate drive is enabled. The output current is controlled by means of limiting peak current in the external power MOSFET. A current sense resistor is connected in series with the source terminal of the MOSFET. The voltage from the sense resistor is applied to the CS pin of the PT4107. When the voltage at CS pin exceeds a peak current sense voltage threshold, the gate drive signal terminates, and the power MOSFET turns off. The threshold is internally set, or it can be programmed externally by applying voltage to the LD pin. When soft start is required, a capacitor can be connected to the LD pin to allow this voltage to ramp at a desired rate, therefore, assuring that output current of the LED ramps gradually.

LED Current Control

The peak current of the LED is programmed by an external resistor connected to CS pin. And the peak current is changed adaptively at different input and output to get the constant average LED current. The peak current Ip*

$$Ip^* = \frac{Vref\_cs}{Rcs} + Ipd = \frac{Vref \times (1 + 0.8 \times D) + [(V_{IN} - V_{DD})/R1 - I_{DD}]}{Rcs} + Ipd \qquad (1)$$



Where V_{ref} = 275mV, $D=V_{OUT}/V_{IN}$ is the duty cycle of the controller, V_{IN} is the rectified voltage from the AC, V_{DD} = 20V, $R1$ is the start up resistor connected between V_{IN} and V_{DD}, I_{DD} is the operating current dependent on the operating frequency and the MOSFET connected to GATE. It increases with operating frequency and gate capacitance of the MOSFET. It is about 2mA when 4N60 is used at 100 kH_Z operating frequency.

And *Ipd* is the additional current due to the system delay. Normally the system delay is about 400 ns.

$$I_{pd} = \frac{(V_{IN} - n \times V_{led}) \times T_d}{L} \qquad (2)$$

The changed peak current is used to compensate the different inductor ripple current at different application to make sure the average LED current is constant at a wide range of input and output voltage.

After the peak current compensation, the LED current is programming easily when the inductor, operating frequency, and startup resistor is determined.

$$I_{LED} = \frac{Vref}{Rcs} = \frac{275mV}{Rcs} \qquad (3)$$

The application note provides more information how to choose them.

Dimming

The PT4107 can drive up to tens of High-Brightness (HB) LEDs or multiple strings of HB LEDs. The LED arrays can be configured as a series or series/parallel connection. The PT4107 regulates constant current that ensures controlled brightness and spectrum of the LEDs, and extends their lifetime. The PT4107 features an enable pin (PWMD) that allows PWM control of brightness. To keep the user from seeing the LED turn on and off, the switching speed must be greater than 100 Hz. Above 100 Hz, the human eye averages the on and off times, seeing only an effective brightness that is proportional to the LED's on-time duty cycle. The dimming frequency of PT4107 is up to 20 kHz.

The PT4107 can also control brightness of LEDs by programming continuous output current of the LED driver (so-called linear dimming) when a control voltage is applied to the LD pin.

Thermal Protection

A thermistor (NTC) connected to R_{OTP} pin can prevent the LED from overheating. An internal current I_{ROTP} = 24000/ (RI [kΩ]) [μA] is sourcing from the R_{OTP} pin. The current is about 80μA when RI is equal to 300k Ohm. And the controller will shut down the system when the voltage of R_{OTP} pin is less than 1V. When the overheating situation is released, the system recovers to normal operation.

Frequency shuffling for EMI improvement

The frequency jittering (switching frequency modulation) is implemented in PT4107. The oscillator frequency is modulated with a random source so that the tone energy is spread out. The spread spectrum minimizes the conduction band EMI and therefore reduces system design challenge.

Enable

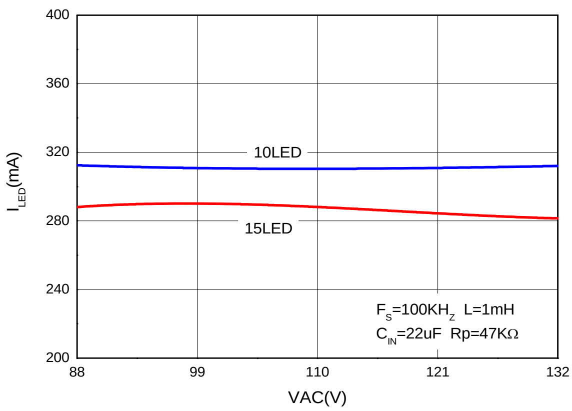
The PT4107 can be turned off by pulling the PWM_D pin to ground. When disabled, the PT4107 draws quiescent current of less than 1mA.

Leading Edge Blanking

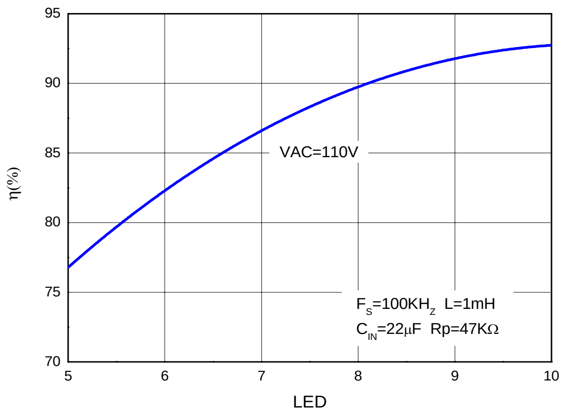
Each time when the power MOSFET is switched on, a turn-on spike will inevitably occur on the sense-resistor. To avoid premature termination of the switching pulse, a 400 ns leading-edge blanking time is built in. Conventional RC filtering can therefore be omitted. During this blanking period, the current-limit comparator is disabled and it cannot switch off the gate drive

TYPICAL PERFORMANCE CHARACTERISTICS

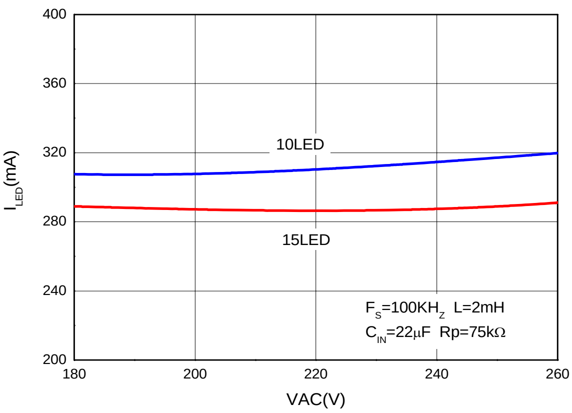
Input Voltage vs. LED Current



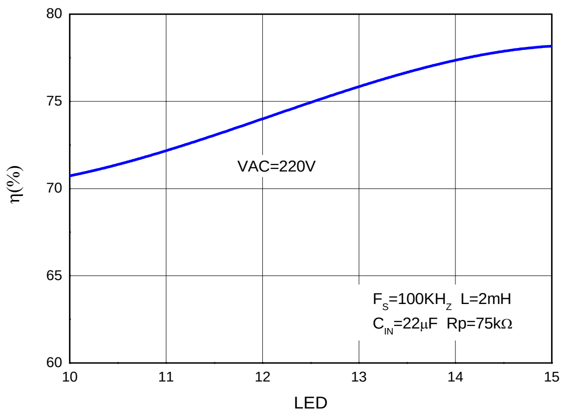
Efficiency



Input Voltage vs. LED Current

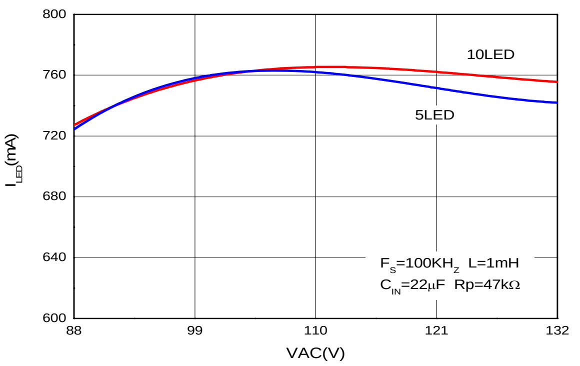


Efficiency

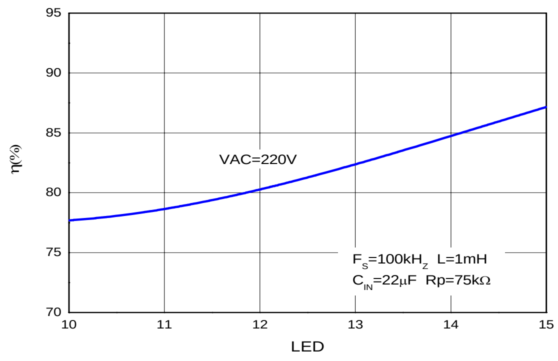


TYPICAL PERFORMANCE CHARACTERISTICS (Continued)

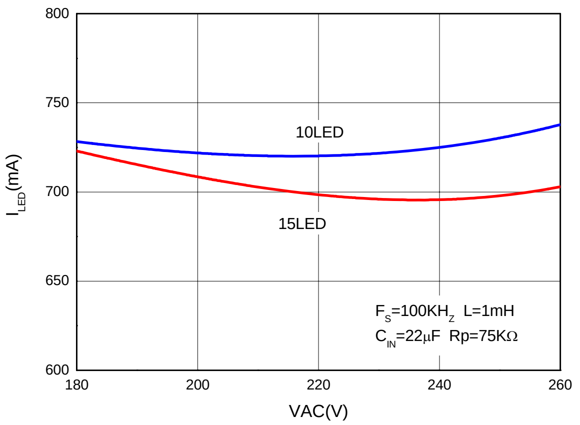
Input Voltage vs. LED Current



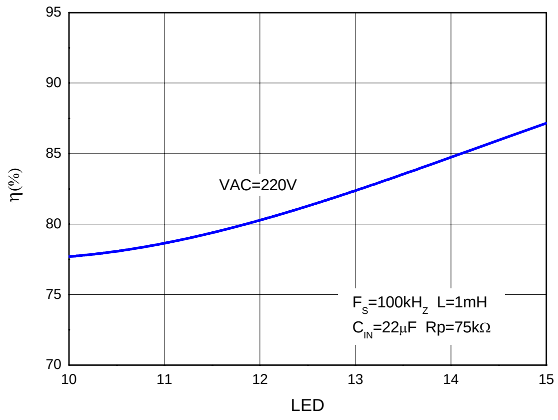
Efficiency



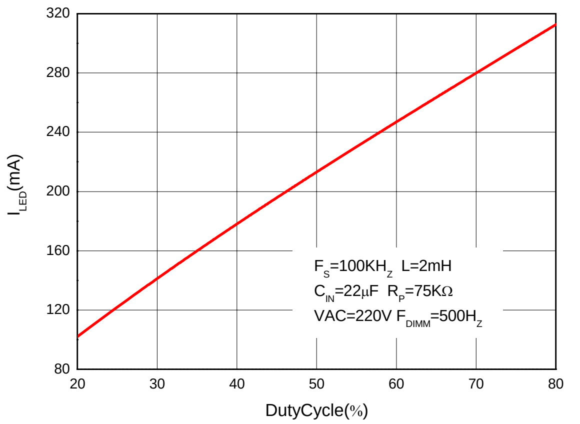
Input Voltage vs. LED Current



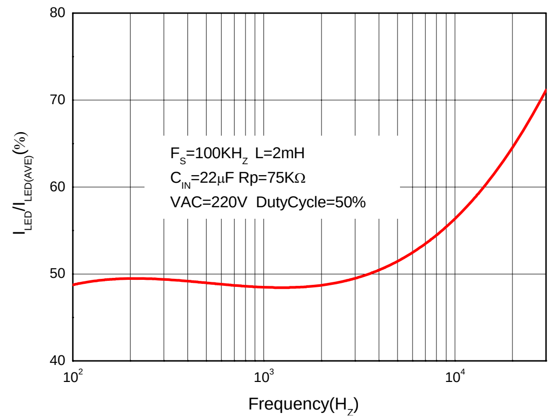
Efficiency



PWM Dimming



PWM Dimming



APPLICATION INFORMATION

This section discusses the design of a buck-based LED driver using the PT4107 with the help of an off-line application example.
For example:
AC Input Voltage Range： Vnom,ac＝220V rms Vmin,ac=176V rms Vmax,ac=264V rms freq=50Hz
Expected LED string voltage: Vo,min ＝ 30V Vo,max=70V
Stabilized LED CURRENT: Io,max＝350mA
Expected Efficiency：η＝90％

Switching Frequency and resistor (RI)

The operating frequency of the oscillator is programmed between 25 and 200 kHz using an external resistor connected to the RI pin:
F_{OSC} = 30000/ (RI [kΩ]) [kHz]
Normally, setting the operating frequency to 100 kHz and the resistor is 300 kΩ.
When the output LED strings are less than 5, lower operating frequency is used.

Input Diode Bridge (D1) and the thermistor (NTC)

The voltage rating of the diode bridge will depend on the maximum value of the input voltage. The current rating will depend on the maximum average current drawn by the converter.

$$V_{bridge} = 1.5 \times \left(\sqrt{2} \times V_{\max,ac}\right) \quad (4)$$

$$I_{bridge} = \frac{V_{o,\max} \times I_{o,\max}}{V_{\min} \times \eta} \quad (5)$$

The 1.5 factor in equation (4) is a 50% safety margin. For this design, choose a 400V, 1A diode bridges. Placing a thermistor (or resistor) in series with input bridge rectifier will effectively limit the inrush charging current to input bulk capacitor C1 during the initial start-up of the converter. Except this useful action during very short time interval, such a series element creates unnecessary power loss dissipation during normal operation of the converter, and must be minimized. A good rule of thumb is that the thermistor should limit the inrush current to not more than five times the steady state current as given by equation (5), assuming maximum voltage is applied. The required cold resistance is:

$$R_{cold} = \frac{V_{bridge}}{5 \times I_{bridge}} \quad (6)$$

Choose a thermistor with a resistance around 300Ω and rms current greater than 0.2A for the application.

Input Capacitors (C1 and C2)

The first design criterion to meet is that the maximum LED string voltage is should be less than half the minimum input voltage to avoid having to implement a special loop compensation technique
For this example, the minimum rectified voltage should be:

$$V_{\min,dc} = 2 \times V_{o,\max} = 140V \quad (7)$$

The hold-up and input filter capacitor required at the diode bridge output have to be calculated at the minimum AC input voltage. The minimum capacitor value can be calculated as:

$$C1 \geq \frac{V_{o,\max} \times I_{o,\max}}{\left(2 \times V_{\min,ac}^2 - V_{\min,ac}^2\right) \times \eta \times freq} \quad (8)$$

In this example, C1>12.8μF
The voltage rating of the capacitor should be more than the peak input voltage with 10-12% safety margin.

$$V_{\max,cap} \geq \sqrt{2} \times V_{\max,dc} = 371V \quad (9)$$

Choose a 22μF, 400V electrolytic capacitor.

FET (Q1) and Diode (D2)

The peak voltage seen by the FET is equal to the maximum input voltage. Using a 50% safety rating,

$$V_{FET} = 1.5 \times \left(\sqrt{2} \times V_{ac,nom}\right) \quad (10)$$

The maximum RMS current through the FET depends on the maximum duty cycle, which is 50% by design. Hence, the current rating of the FET is

$$I_{FET} \approx I_{o,\max} \times \sqrt{2} \quad (11)$$

For this application, chose a MOSFET 600V, 2A. 2N60 is good choice.
The peak voltage rating of the diode is the same as the FET. The average current through the diode is:

$$I_{diode} = I_{o,\max} = 350mA \quad (12)$$

For this example, 600V/1A is ok. Fast recovery diode is recommended.

The Startup Resistor (R1) and Hold Capacitor (C3)

$$R1 = \frac{\sqrt{2}V_{ac,nom} - V_{DD,nom}}{I_{IN}} \quad (13)$$

Calculate resistor R1 power dissipation:

$$P_{R1} = I_{in,\max}^{2} \times R1 \quad (14)$$

Typically, the range of the startup resistor is 56k to 100k with 2W for 220V AC and 33k to 56k with 1W for 110V AC.
For this example, 75k/2W power resistor is used. A 1uF 30V hold capacitor is ok for PT4107.

The thermal protection resistance (RT1)

An NTC thermistor RT1 can be connected from pin ROTP to ground. A constant current I_{ROTP} is output from pin ROTP. The voltage on ROTP pin can be expressed as $V_{OTP} = I_{ROTP} \times RT1$, The system will be shut down when the voltage of the pin ROTP as low as 1V.
I_{ROTP} = 24000/ (RI [kΩ]) [µA]

Choose the Inductor (L1)

The inductor value depends on the ripple current in the LEDs. The LED current decreases with the ripple current without compensation. However, a proprietary current compensation technique is used in PT4107 to overcome this problem. The average LED current doesn't change with the ripple current at a wide range of output voltage. The inductor can be smaller and the total cost can be lower. A bypass capacitor is used to reduce ripple current if necessary.
If the operating frequency is set to 100 kHz, the value of inductor is shown in table 1. It's valid at a wide range of output voltage from 10 LEDs to 20 LEDs if the input voltage is 220V AC.

Table1

I_{OUT}	220V AC	110V AC
350mA	2000uH	1000uH
750mA	1000uH	560uH
1000mA	680uH	390uH

Normally, the value of inductor decreases with the LED current and operating frequency. It's not recommended the higher operating frequency is used due to higher switching loss.
For this example, 2mH/500mA inductor is ok.

Choose the Current Sense Resistor (R3)

The sense resistor value is given by:

$$R3 = \frac{0.275}{I_{LED}} = 0.786\Omega \quad (15)$$

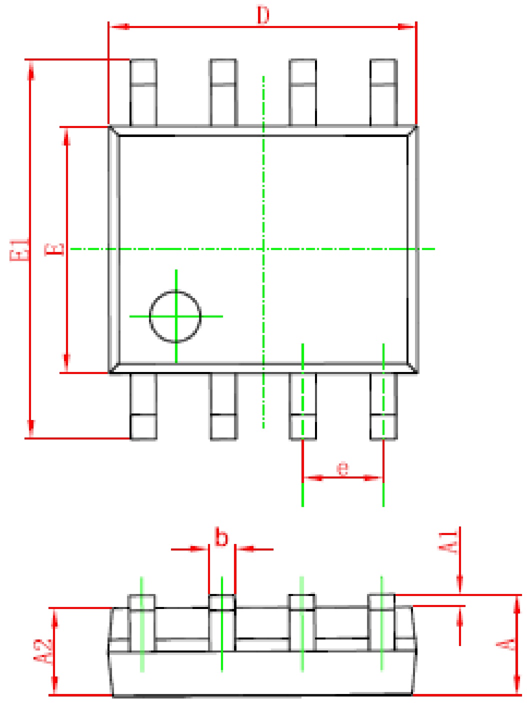
Calculate also resistor power dissipation:

$$P_{R3} = I_{LED}^{2} \times R3 = 0.096W \quad (16)$$

A 0.125W 0.786Ω resistor is good for this application.

PACKAGE INFORMATION

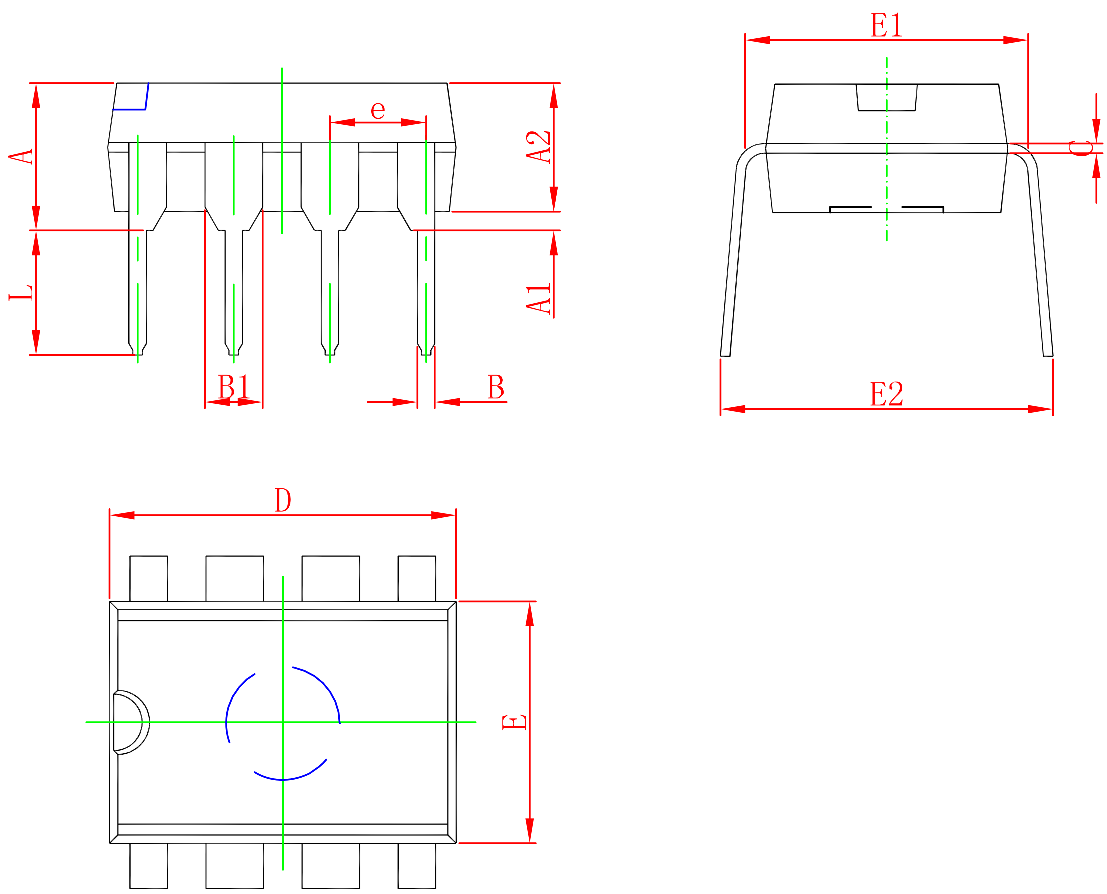
SOP-8 Package



Symbol	Dimension in Millimeters		Dimension in Inches	
	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	0.060
θ	0°	8°	0°	8°

PACKAGE INFORMATION

DIP8 Package



Symbol	Dimension in Millimeters		Dimension 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