市电供电的大功率LED驱动控制器

Large Power LED Driving Controller

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随着LED的材料、结构、工艺及封装技术的发展，LED的新品种不断增加，性能也逐年提高，应用领域越来越宽，从而使产量不断增加，价位也逐年下降。特别在大屏幕LCD的背光照明、建筑的外墙及轮廓照明（亮丽工程）和景点装饰照明、公共场所（广场、道路照明）、汽车及运输工具的内外照明上获得较大的发展，并且在很多地方采用大功率LED（主要是1~3W）来取代Φ5小功率LED，获得更好的效果。在这种形势下，大功率LED驱动器相应地发展很快，特别是采用市电供电的大功率LED驱动器发展更快。本文介绍一种通用的用市电供电的大功率LED驱动控制器SMD802及其应用电路。

特点及应用领域

SMD802是一种可采用220V市电直接供电的大功率LED驱动控制器集成电路，它是一种PWM控制器，可组成固定开关频率的非隔离型降压式、峰值电流控制的恒流LED驱动电路。该IC的主要特点：IC能直接接450V直流电压，无需降压电阻降压后供电，使电路更简单；外围元器件极少，有可能将整个驱动器装入E27灯头内；并且生产成本低；转换效率可大于90%；除输入国际通用的85~265V_{AC}电压外，还可采用8~450V直流电压供电；在低压直流供电时，该控制器还可以组成升压式或升降压式架构，满足不同负载（串联的LED数）的要求；输出的恒流驱动电流可设定，从几十毫安到1安培，适用于多个串联的大功率LED的应用，输出功率也达几十瓦；工作频率（开关频率）可由用户设定，频率范围为25kHz到300kHz；可采用模拟方式调光，也可采用输入低频PWM信号调光；内部有欠压锁存保护及过载保护；工作温度范围－40℃到＋80℃。

该控制器组成的大功率LED驱动电路主要应用于1W~3W大功率LED照明灯，如MR-16小筒灯、射灯；大屏幕LCD的背光照明、LED信号灯、警示灯、应急灯、矿灯及各种发光颜色的照明灯；公共场所的照明灯（路灯、投射灯、舞台灯、隧道灯等）；汽车内外照明及信号指示灯；也可应用于通用恒流源或充电器的应用。

引脚排列及功能

SMD802有两种引脚：8引脚及16引脚。8引脚有DIP封装及SOIC封装，16引脚为SOIC封装，各引脚的排列如图1所示，各引脚的功能如表1所示。

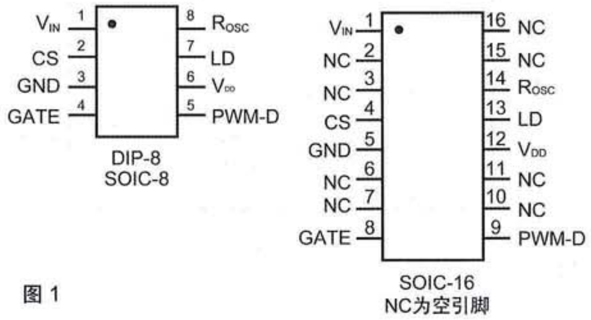


图1

8引脚	16引脚	符号	功能
1	1	V_{IN}	输入电压8~450VDC
2	4	CS	外接采样电阻R_{CS}到地，检测I_{LED}电流
3	5	GND	地
4	8	GATE	接外部MOSFET的栅极，驱动MOSFET
5	9	PWM_D	输入低频PWM信号可调光，也是使能端的输入端（高电平有效），低电平关闭驱动器
6	12	V_{DD}	内部7.5V线性稳压电源输出端（可输出1mA），需外接一个4.7μF的电容到地
7	13	LD	线性调光输入端（0~250mV）
8	14	R_{OSC}	外接R_{OSC}来设定开关频率（25kHz~30025kHz）

主要参数

SMD802的主要参数：直流输入电压V_{INDC} = 8V~450V；关机模式时(PWM_D引脚接地)耗电0.5mA ~ 1mA；内部线性电源电压 V_{DD} = 7.5V ± 0.5V；内部7.5V电源对外可提供1mA电流；欠压锁存阈值电压典型值为6.7V；PWM_D端输入高电平的最低电压是 > 2.4V、低电平是 < 1V；CS端最大输入电压阈值为250mV；GATE端输出的高电平约为7.5V，输出低电平时低于0.3V；内部振荡器的工作频率取决于外设电阻R_{OSC}，频率范围为25kHz~300 kHz；线性调光引脚LD的调光电压范围为0mV~250mV；内部有消除外接MOSFET导通瞬间产生的尖脉冲消隐电路，其时间间隔为215ns；从CS到GATE的传输延迟时间t_{DELAY} = 300ns(最大值)；GATE输出的上升及下降时间典型值为30ns。

内部结构及工作原理

SMD802的内部结构框图（仅说明工作原理的）及外围元器件的电路如图2所示。图2输入的是直流电压，若是要用市电供电，则需要将220V交流经全波整流及滤波后再输入，如图3所示，即市电往全波整流后的直流电压V_{OUT}接在图2的V_{IN}端。

SMD802的内部结构部分由能输入高达450V的7.5V线性稳压器、250mV基准电压、振荡器、RS触发器、两个电压比较器、消隐电路、或门、与门及下拉100kΩ电阻组成。外接元器件有开关管Q1、续流二极管D1、电感L1、采样电阻R_{CS}、确定振荡器频率的R_{OSC}及7.5V稳压器的外接电容C_{DD}组成。串联的LED是驱动电路的负载。

可以把SMD802看作受输出电流峰值控制的PWM发生器，它的输出端(GATE)直接驱动外接N沟道MOSFET开关管Q1。在GATE端输出高电平时，Q1导通V_{IN}经电感L1、LED串、Q1、RCS形成电流回路，LED发光。由于电感L1的存在，电流是斜坡上升的，并且在电感L1中储存能量。当R_{CS}上的电压上升到 > 250mV时，此电压经消隐电路输入到比较器C1的同相端，C1的反相端接250mV基准电压，比较器输出高电平，此高电平输入或门，使或门输出高电平，使RS触发器复位，Q端输低电平，此低电平输入与门，使GATE输出低电平，则Q1截止。在Q1截止时，L1释放储存的能量，产生的电感电流经LED串、D1形成回路，LED亮，LED的电流是连续的。在开关管导通(ON)及截止(OFF)的周期(T)内，I_{LED}的电流如图4所示。输出的平均电流即恒定的LED电流。

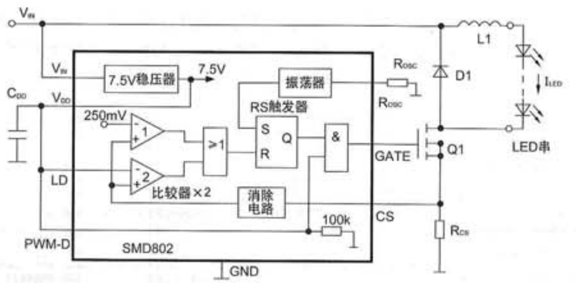


图2

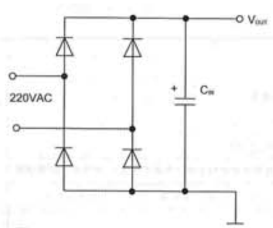


图3

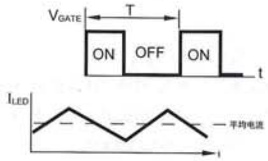


图4

在开关管Q1导通的瞬间，有一个脉冲电流，脉冲电流在R_{CS}上可能会产生一个高的脉冲电压(大于250mV)，使产生误动作，如图5所示。所以在IC内部有一个产生延迟时间的消隐电路(215ns)，消除这类脉冲产生的误动作。由于有延迟时间，在设计中要使开关管导通(ON)的时间大于消隐延迟电路的时间。

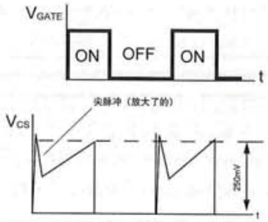


图5

在图2中，LD端及PWM_D端都是接V_{DD}的，即LD及PWM_D端都接高电平，这电路的LED是不调光的。

两种调光方法

SMD802有两种调光方法：

1. LD端加0mV~250mV直流电压，实现调光，如图6所示。R1及电位器W1组成分压器，调节W1，使V_{LD}=0mV~250mV，则可达到模拟调光的目的。R1及W1的电路中流过的电流要小于1mA。从图2中可看出：若V_{LD}=150mV，则CS端的电压略大于150mV时，比较器2输出高电平，使SR触发器复位，Q输出低电平，GATE输出低电平，Q1截止，流过LED串的平均电流就减小，亮度减小，达到调光的目的。

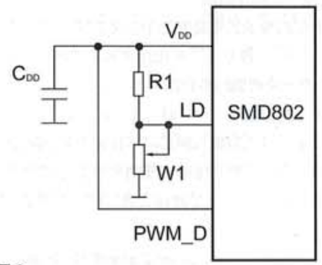


图6

2. PWM_D端加低频PWM信号调光(占空比0~100%)，可从灭到最亮的调节。如图7所示。

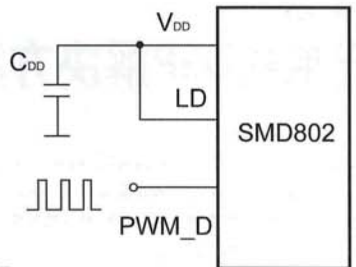


图7

PWM信号的频率为数kHz。PWM_D端也是使能端(不作调光用时)；加高电平时，电路正常工作；加低电平时，电路被关闭。

元器件参数的计算及选择

采用220V交流市电供电的LED驱动器电路计算时要已知串联的LED的正向压降V_F、LED的电流I_{LED}及串联的LED数，并要设定开关管的工作频率。现以串联12个1W白光LED，I_{LED}=320mA，LED的正向压降V_F=3.5V，开关管工作频率为204.92kHz为例进行计算。

整流桥及滤波电容C_{IN}的计算

市电(V_{LINE})的额定值是220V_{AC}，它有±10%的允差即$V_{LINE_in}=198VAC$，$V_{LINE\_ax}=242VAC$，整流后的直流电压分别是280V_{DC}及342.2V_{DC}。选择整流二极管的耐压要比最大的直流电压大1.25倍(1.25为安全系数)，一般选1N4007 × 4或600V/1A的整流桥。全波整流后的直流电压波形为"馒头波"，需要用C_{IN}来作平滑滤波，使输出较平直的直流电压。

C_{IN}的计算公式为：

$$C_{IN}\geq\frac{P_{IN}(1-D_{ch})}{V_{DNmin}\times 2f_L\times V_{Dmin}\times 0.15}$$

式中P_{IN}为驱动器的输入功率，$P_{IN}=P_O/\eta$(P_O为驱动器的输出功率，$P_O=\Sigma V_F\times I_{LED}$，η为驱动器的效率，η可取0.85)；$VDC_{min}$为最小输入直流电压($VDC_{min}=280V$)；$f_L$为市电的频率($f_L=50Hz$)；$V_{Dmin}\times 0.15$为滤波后的纹波电压；$D_{ch}$为0.2~0.25，这里取$D_{ch}=0.225$。

已知：$\Sigma V_F=12\times 3.5V=42V$，$P_O=42V\times 0.32A=13.44W$，则$P_{IN}=13.44/0.85=15.8w$；$D_{ch}=0.225$，代入公式：

$$C_{IN}\geq\frac{15.8W(1-0.225)}{280V\times 100\times 280\times 0.15}=10.4\mu F$$

可取10μF/400V的铝电解电容。

R_{OSC}的计算

R_{OSC}与工作频率F_{OSC}的关系为：

$$F_{OSC}=\frac{25000}{R_{OSC}+22}(kHz)$$

现设定$F_{OSC}=204.92kHz$，$R_{OSC}=100k\Omega$。

电流采样电阻R_{CS}的计算

电流采样电阻R_{CS}与I_{LED}的关系式为：

$$R_{CS}=\frac{0.25}{I_{LED}+(0.5\times 0.2I_{LED})}$$

I_{LED}设为0.32A，代入上式

$$R_{CS}=\frac{0.25}{0.32+(0.5\times 0.2\times 0.32)}=0.71\Omega$$

可以取标准电阻值$R_{CS}=0.7\Omega(0.1W)$

电感L1的计算

电感L1的计算公式为：

$$L1\geq\frac{(VDC_{min}-V_{LED})\times t_{on}}{0.3\times I_{LED}}$$

式中ton是开关管导通时间。$T_{on}=D/F_{OSC}$(D是占空比，$D=V_{LED}/VDC_{min}$，$V_{LED}=\Sigma V_F$。$V_{LED}=42V$，则$D=42V/342.2V=0.1227$，$T_{on}=0.1227/2049=5.99E\_07$，代入上式

$$L1\geq\frac{(342.2-42)\times 5.99E\_07}{0.3\times 0.32}$$

$\geq 1.873mH$

可以取2mH电感，饱和电流取0.6A的。

Q1 及 D1 的选择

MOSFET (Q1) 的选择要考虑耐压、导通电阻、最大漏极电流及栅极电容 Q_G。为提高驱动器的效率，要选择导通电阻 $R_{DS(on)}$小的，Q_G 小的及有足够大的 V_{DSS} 及 I_D 的 MOSFET。

为了使MOSFET安全可靠，其耐压要取1.25倍的最大输入直流电压，即

$$V_{DSS}=1.25 \times VDC_{max}$$
$$=1.25 \times 342.2=428V$$

可取耐压 500V 的 MOSFET(或取 600V 的 MOSFET)。

MOSFET 的漏极电流 I_P 取 I_{IED} 的 3 倍以上。

这里可以选 ST 公司的 STBTN52K3 的 N-MOSFET。它的主要参数，V_{DSS}=525V，I_D=6.3A，$R_{DS(on)}$=0.98Ω，P_W=90W.(D^2PAK 或 T0-220 封装)。

D1的选择耐压与Q1相同，其额定正向电流 I_F 可大于 I_{LED} 两倍。可取耐压 600V/1A 的 1N4937 或 FR206 快速恢复二极管。1N4937 的耐压为 600V，额定电流 1A，正向不重复浪涌电流 30A，反向恢复时间 0.2μs。FR206 的耐压 800V、正向电压 1.2V、正向电流 2A。

C_{DD} 一般取 2.2~4.7μF/16V

结束语

本文介绍的电路在结构上是十分简单的，在设计、计算上也是十分方便的。但在开关管 Q1 及快速恢复二极管(续流二极管)D1的选择上要求较高，特别在开关频率取得较高时，质量较差的 Q1 及 D1 会造成很大的损耗，这不仅使效率大大地降低，甚至于会产生故障。

本文介绍的驱动器电路在使用上必需满足 D < 0.5 (即 VLED/Vin < 0.5)。若 D > 0.5，电路进入亚谐振状态，会造成 I_{LED} 下降，纹波电流增加的不稳定状态。

LED驱动器电路是一种特殊电源，输出功率大于 25W驱动器除驱动电路外还有输入瞬态高压保护电路，输入电源滤波器电路及功率因数校正电路，使功率因数达到 95%以上，并且要满足 EMI 的要求及总滤波失真(THD)的要求。本文未包括这些电路。

另外要特别指出的是此电源是非隔离型，在调试、测量时要注意安全。GEC

Universal High Brightness LED Driver

SMD802

FEATURES

- > 90% Efficiency
- Universal rectified 85 – 265V_{AC} input range
- Constant-current LED driver
- Applications from a few mA to more than 1A Output
- LED string from one to hundreds of diodes
- PWM Low-Frequency Dimming via Enable pin
- Input Voltage Surge ratings up to 500V
- Internal thermal overload protection

DESCRIPTION

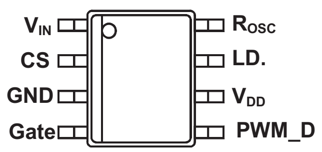
The SMD802 is a PWM high-efficiency LED driver control IC. It allows efficient operation of High Brightness (HB) LEDs from voltage sources ranging from 85V_{AC} up to 265V_{AC}. The SMD802 controls an external MOSFET at fixed switching frequency up to 300kHz. The frequency can be programmed using a single external resistor. The LED string is driven at constant current rather than constant voltage, thus providing constant light output and enhanced reliability. The output current can be programmed between a few milliamps and up to more than 1.0A.

SMD802 uses a rugged high voltage junction isolated process that can withstand an input voltage surge of up to 500V. Output current to an LED string 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 SMD802. The SMD802 provides a low-frequency PWM dimming input that can accept an external control signal with a duty ratio of 0-100% and a frequency of up to a few kilohertz.

APPLICATIONS

- AC/DC LED Driver applications
- RGB Backlighting LED Driver
- Back Lighting of Flat Panel Displays
- General purpose constant current source
- Signage and Decorative LED Lighting
- Chargers

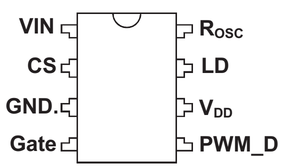
PACKAGE/ORDER INFORMATION



8-Pin Plastic S.O.I.C.
(Top View)

Order Part Number

SMD802MST



8-Pin Plastic DIP
(Top View)

SMD802M

PIN FUNCTIONS

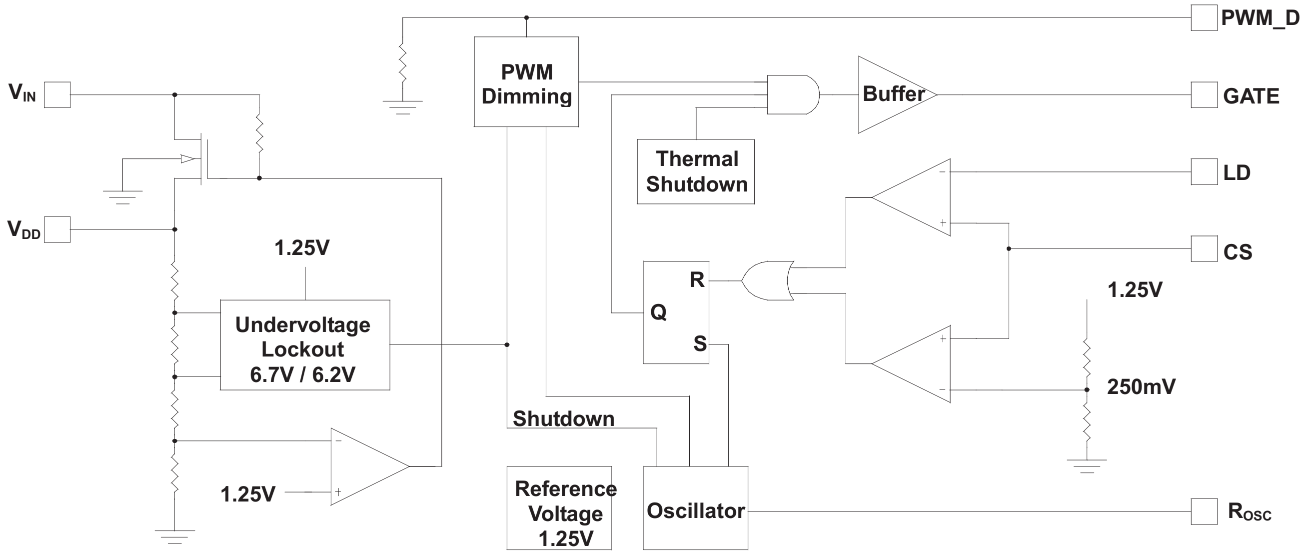
Pin No.	Pin Name	Function
1	V_{IN}	Input voltage
2	CS	Senses LED string current
3	GND	Device ground
4	GATE	Drives the gate of the external MOSFET
5	PWM_D	Low Frequency PWM Dimming pin, also Enable input. Internal 100kΩ pull-down to GND
6	V_{DD}	Internally regulated supply voltage. 7.5V nominal. Can supply up to 1 mA for external circuitry. A sufficient storage capacitor is used to provide storage when the rectified AC input is near the zero crossings.
7	LD	Linear Dimming by changing the current limit threshold at current sense comparator
8	R_{OSC}	Oscillator control. A resistor connected between this pin and ground sets the PWM frequency.

ABSOLUTE MAXIMUM RATINGS (Note 1)

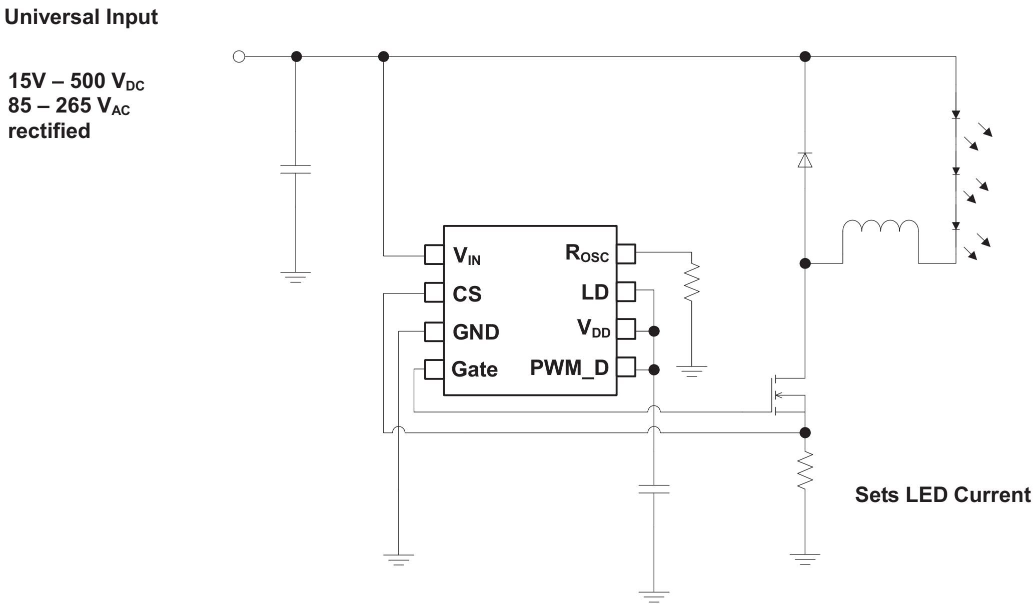
V_{IN} to GND	-0.5V to +520V
CS	-0.3V to (Vdd + 0.3V)
LD, PWM_D to GND	-0.3V to (Vdd – 0.3V)
GATE to GND	-0.3V to (Vdd + 0.3V)
V_{DDMAX}	13.5V
Continuous Power Dissipation (TA = 25°C) (Note 1)	
8 Pin DIP (derate 9mW/°C above +25°C	900mW
8 Pin SO (derate 6.3mW/°C above +25°C	630mW
Operating Temperature Range	-40°C to +85°C
Junction Termperature	+125°C
Storage Temperature Range	-65°C to +150°C

Note 1: Exceeding these ratings could cause permanent damage to the device. All voltages are with respect to ground. Currents are positive into, negative out of the specified terminal.

BLOCK DIAGRAM



TYPICAL APPLICATIONS

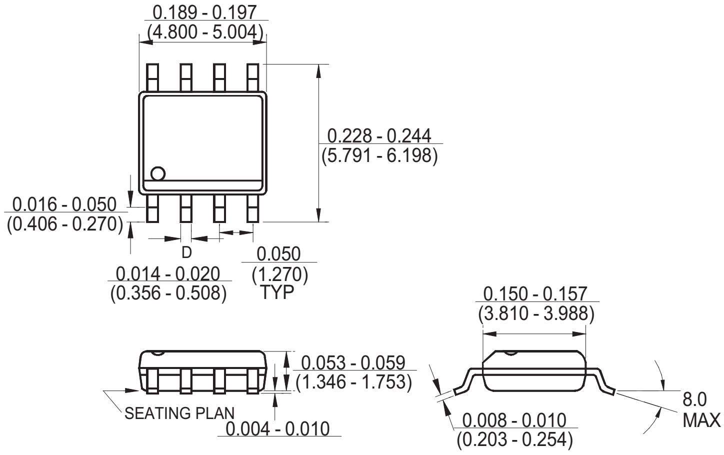


ELECTRICAL CHARACTERISTICS Unless otherwise specified, T_A = 25°C.

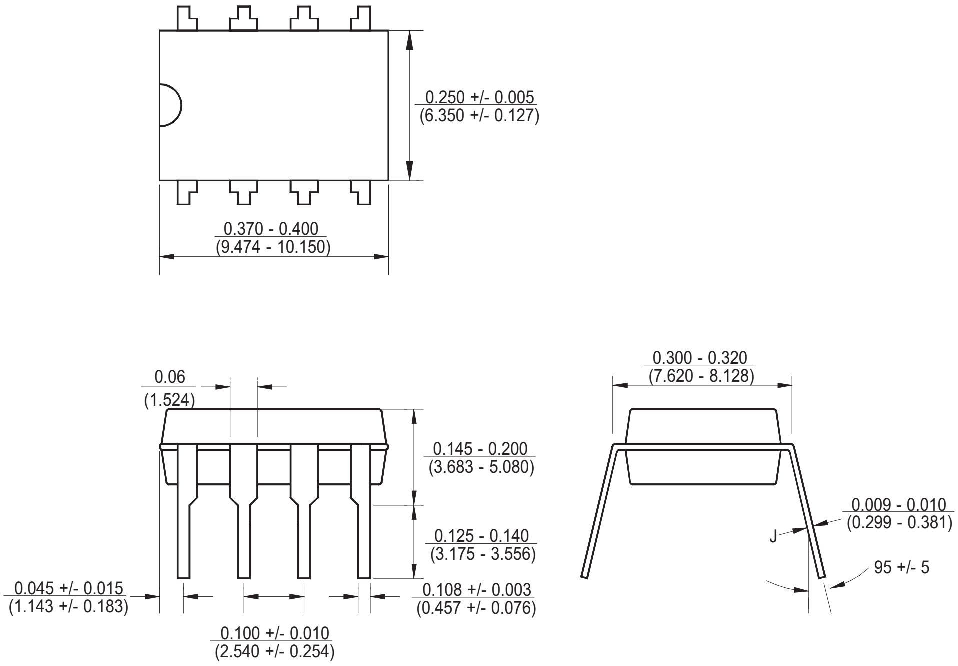
Parameter	Test Conditions	Symbol	Min	Typ	Max	Units
Input DC supply voltage range	DC input voltage	V_{INDC}	15.0		500	V
Shut-Down mode supply current	Pin PWM_D to GND, V_{IN} = 15V	I_{INsd}		0.4	1	mA
Internally regulated voltage	V_{IN} = 15-500V, $I_{DD(ext)}$=0, pin Gate open	V_{DD}	7.0	7.5	8.0	V
Maximal pin Vdd voltage	When an external voltage applied to pin Vdd	V_{DDmax}			13.5	V
V_{DD} current available for external circuitry [1]	V_{IN} = 15-100V	$I_{DD(ext)}$			1.0	mA
VDD under voltage lockout threshold	Vin rising	UVLO	6.45	6.7	6.95	V
VDD under voltage lockout hysteresis	Vin falling	ΔUVLO		520		mV
Pin PWM_D input low voltage	V_{IN} = 15-500V	$V_{EN(lo)}$			1.0	V
Pin PWM_D input high voltage	V_{IN} = 15-500V	$V_{EN(hi)}$	2.4			V
Pin PWM_D pull-down resistance	V_{EN} = 5V	R_{EN}	50	100	150	kΩ
Current sense pull-in threshold voltage	@TA = -40°C to +85°C	$V_{CS(hi)}$	225	250	275	mV
GATE high output voltage	I_{OUT} = 10mA	$V_{GATE(hi)}$	V_{DD} -0.3		V_{DD}	V
GATE low output voltage	I_{OUT} = -10mA	$V_{GATE(lo)}$	0		0.3	V
Oscillator frequency	R_{OSC} = 1.00MΩ	f_{OSC}	20	24	30	kHz
	R_{OSC} = 226kΩ		80	96	120	
Maximum Oscillator PWM Duty Cycle	F_{PWMhf} = 25kHz, at GATE, CS to GND.	D_{MAXhf}			100	%
Linear Dimming pin voltage range	@TA = <85°C, Vin = 20V	V_{LD}	0		$V_{CS(hi)}$	mV
Current sense blanking interval	V_{CS} = 0.55V_{LD}, V_{LD} = V_{DD}	T_{BLANK}	200	280	360	ns
Delay from CS trip to GATE lo	Vin = 20V, V_{LD} = 0.15, V_{CS} = 0 to 0.22V after T_{BLANK}	t_{DELAY}			300	ns
GATE output rise time	C_{GATE} = 500pF	t_{RISE}		25	50	ns
GATE output fall time	C_{GATE} = 500pF	t_{FALL}		20	50	ns
Thermal shut down		T_{SD}		150		°C

PACKAGE DESCRIPTION Dimensions in inches (millimeters) unless otherwise specified

SO 8

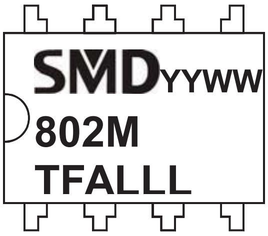


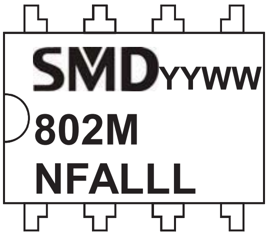
DIP 8



MARKING DIAGRAM

DIP 8





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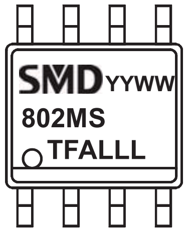
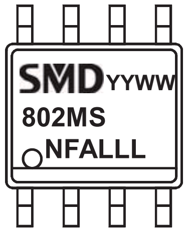




YY = Year, WW = Working Week, T = OTP, N = non OTP, F = Wafer side, A = AT side, LLL = Lot number

IMPORTANT NOTICE

Shamrock Micro Devices (SMD) reserves the right to make changes to its products or to discontinue any integrated circuit product or service without notice, and advises its customers to obtain the latest version of relevant information to verify, before placing orders, that the information being relied on is current.

A few applications using integrated circuit products may involve potential risks of death, personal injury, or severe property or environmental damage. SMD integrated circuit products are not designed, intended, authorized, or warranted to be suitable for use in life-support applications, devices or systems or other critical applications. Use of SMD products in such applications is understood to be fully at the risk of the customer. In order to minimize risks associated with the customer's applications, the customer should provide adequate design and operating safeguards.

Application Note of SMD802

Universal High Brightness LED Driver

FEATURES

_ > 90% Efficiency

_ Universal rectified 85 – 265V_{AC} input range

_ Constant-current LED driver

_ Applications from a few mA to more than 1A Output

_ LED string from one to hundreds of diodes

_ PWM Low-Frequency Dimming via Enable pin

_ Input Voltage Surge ratings up to 500V

_ Internal thermal overload protection

APPLICATIONS

_ AC/DC LED Driver applications

_ RGB Backlighting LED Driver

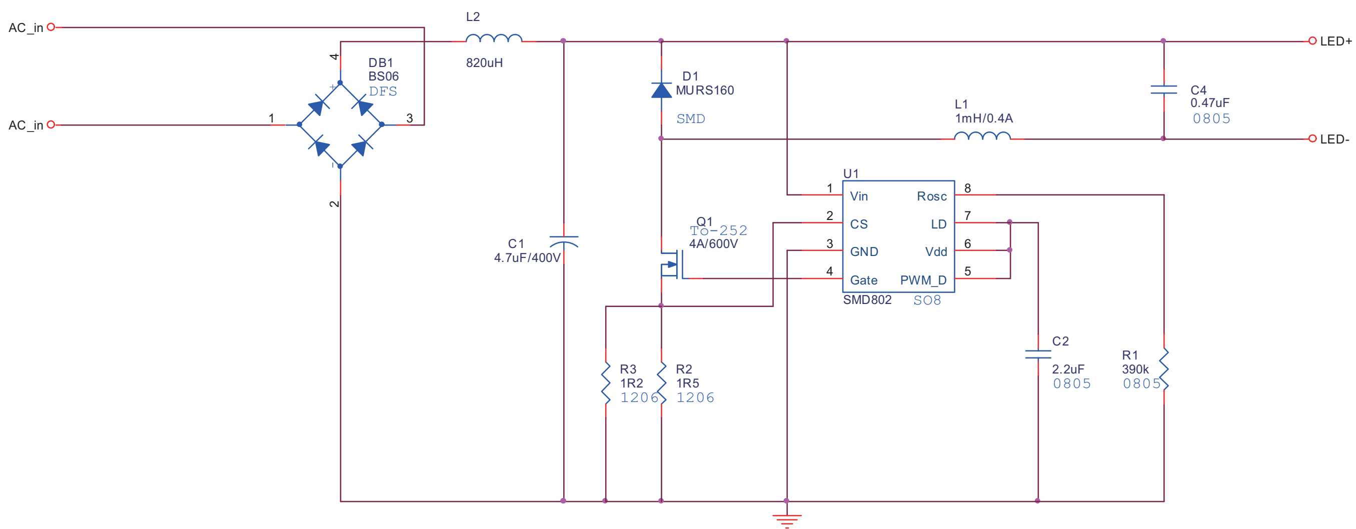
_ Back Lighting of Flat Panel Displays

_ General purpose constant current source

_ Signage and Decorative LED Lighting

_ Chargers

1. Demo board circuit for E-27：



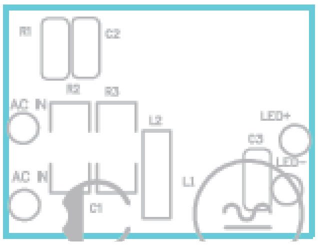
Note：R1 shall be 820KΩ~1MΩ for the case of V_{out}＜7V because it has to satisfy the condition of T_{on}＞T_{BLANK}. The efficiency can be improved as well.

2. BOM：

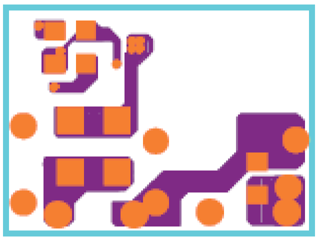
Item	Quantity	Reference	Part
1	1	C1	4.7uF/400V
2	1	C2	2.2uF
3	1	C4	0.47uF
4	1	DB1	BS06
5	1	D1	MURS160
6	1	L1	4.7mH/0.4A
7	1	L2	820uH
8	1	Q1	4A/600V
9	1	R1	390K
10	1	R2	1R5
11	1	R3	1R2
12	1	U1	SMD802

3. PCB Layout：

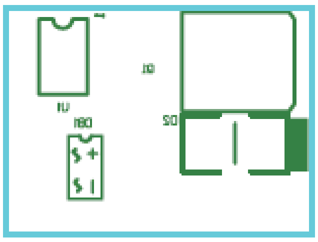
Top-Silkscreen



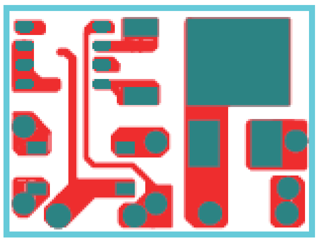
Top-side



Bottom-Silkscreen



Bottom-side



4. Critical Inductance：

The buck power stages have been for continuous and discontinuous conduction modes of steady-state operation. The conduction mode of a power stage is a function of input voltage, output voltage, output current, and the value of the inductor. A buck power stage can be designed to operate in continuous mode for load currents above a certain level usually 15% to 30% of full load. Usually, the input voltage range, the output voltage and load current are defined by the power stage specification. This leaves the inductor value as the design parameter to maintain continuous conduction mode.

The minimum value of inductor to maintain continuous conduction mode can be determined by the following procedure.

Equation：

$$D = \frac{V_{LEDs(VF)}}{V_{in}}$$

$$T_{on} = \frac{D}{F_{osc}}$$

$$L \geq \frac{(V_{in} - V_{LEDs(VF)}) \times T_{on}}{0.3 \times I_{LED}}$$

$$R_{sense} = \frac{0.25}{I_{LED} + (0.5 \times (I_{LED} \times 0.2))}$$

$$F_{osc} = \frac{25000}{R_{osc} + 22}$$

5. **Input** Capacitance：

An input filter capacitor should be designed to hold the rectified AC voltage above twice the LED string voltage throughout the AC line cycle. Assuming 15% relative voltage ripple across the capacitor, a simplified formula for the minimum value of the bulk input capacitor is given by：

Equation：

$$C_{in} \geq \frac{P_{in} \times (1 - D_{ch})}{\sqrt{2V_{Line\_min}} \times 2 f_L \times \Delta V_{DC\_max}}$$

Among them D_{ch} is that C_{in} capacity charges work period, it is generally about 0.2~0.25, f_L is input frequency, at input the full range voltage(85~265 V_{rms}), ΔV_{DC_max} should be set 10~15% of $\sqrt{2V_{Line\_min}}$.

6. Dimming control：

This terminal can be used to either enable/disable the converter or to apply a PWM dimming signal.

To just enable the converter, connect the PWMD pin to the V_{DD} pin.

Disconnecting the PWMD pin will cause the circuit to stop.

PWM dimming of the LED light can be achieved by turning on and off the converter with low frequency 50Hz to 1000Hz TTL logic level signal.

Changing the Duty Ratio of the signal changes the effective average current via the LEDs, changing the light emission.

Note：In the case of PWM dimming, the PWM_D pin should not be connected to the V_{DD} pin!

Also, the signal generator or the device applying the signal to PWM_D pin must be isolated from the input mains.