SamHop Microelectronics Corp.

SM8205

High-Power LED Driver with Integrated PWM Dimming MOSFET Driver

GENERAL DESCRIPTION

The SM8205 is a current mode control wide-input voltage (8V to 48V) LED driver IC specifically designed to power one or multi-strings of high power LEDs. The 10V gate driver allow the use of standard level MOSFET . The low voltage 5.0V V_{CC} is used to power the internal logic and also acts as a reference voltage to set the current level. An external resistor sets the adjustable switching frequency of the SM8205. The switching frequency can be between 100KHz and 1MHz to optimize efficiency, performance or external component size. This controller uses a peak-current control scheme (with programmable slope compensation), and includes an internal transconductance amplifier to control the output current in closed loop, enabling high output current accuracy. Programmable MOSFET current limit enables current limiting during input under-voltage and output overload conditions. An internal 8V～48V linear regulator powers the IC, elimination the need for a separate power supply for the IC. The SM8205 provides a TTL compatible PWM dimming input that can accept an external control signal with a duty ratio of 0～100% and frequency of up to a few kilohertz. The SM8205 also provides a FAULT output which can be used to disconnect the LEDs in case of a fault condition, using an external disconnect N-channel MOSFET. The SM8205 also offer the following protection functions: LED open protection (OVP), LED short-circuit protection (SCP), Junction over-temperature shutdown and input under voltage lockout (UVLO).

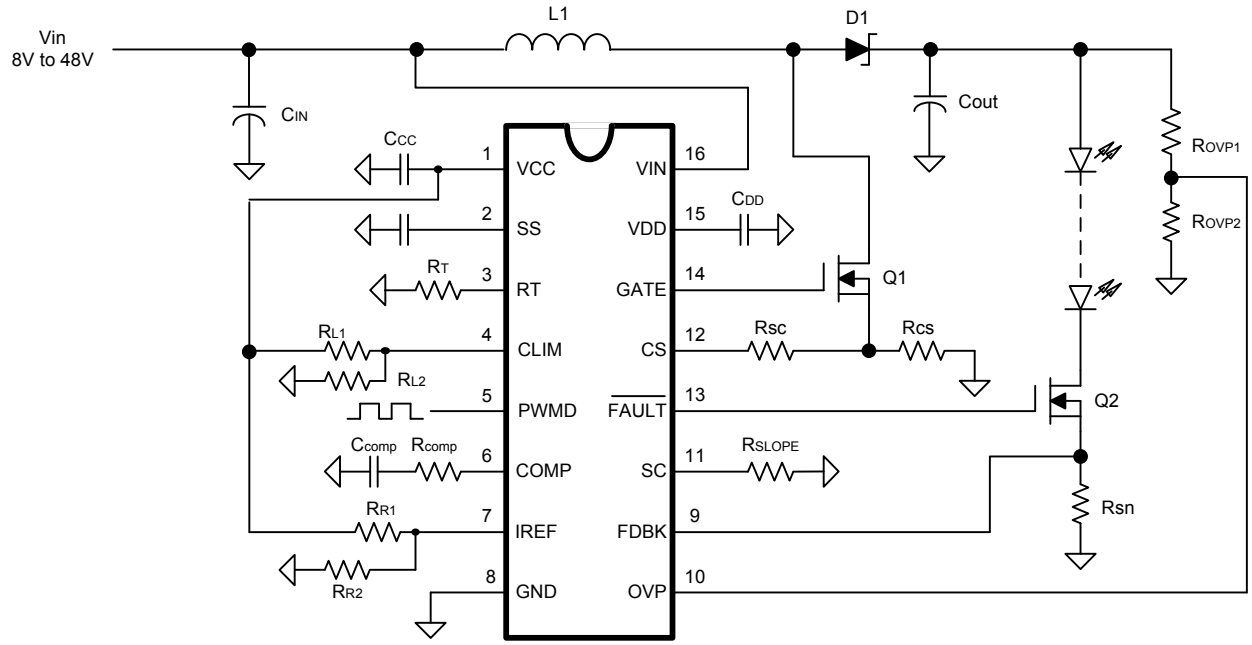
FEATURES

- Wide input operating voltage range from 8V to 48V
- Internal 2% reference voltage
- Integrated PWM dimming N-channel MOSFET driver
- Dimming ratio: 1000:1
- 100KHz to 1MHz programmable high-frequency operation
- Programmable slope compensation
- Input under-voltage protection
- LED short-circuit protection (SCP)
- LED open-voltage protection (OVP)
- Junction over-temperature shutdown protection
- Drivers LEDs in Boost, Buck-Boost, SEPIC Topology
- Cycle-by-cycle current limit
- Soft start
- Providing SOP-16 Package

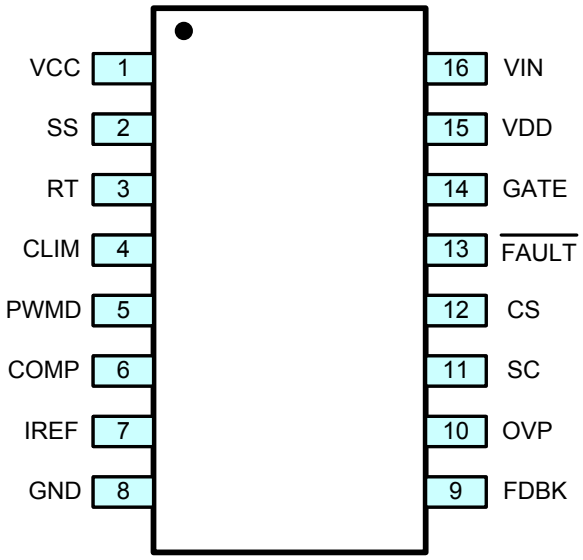
APPLICATIONS

- Single-string LED LCD backlighting
- High power LED drivers
- DC/DC Boost / Buck-Boost converter
- Automotive or Industrial

TYPICAL APPLICATION CIRCUIT



PIN ASSIGNMENTS



SOP-16 (Top View)

ORDERING INFORMATION

Part Number	Marking	Tube
SM8205SL	SM8205SL △xxxxxx	50

Note: The letter "S" is marked for SOP package, and Letter "L" is marked for Lead Free parts.

PIN DESCRIPTIONS

Pin No.	Name	Description
1	VCC	5V Low-dropout voltage regulator. Bypass to GND with at least a 4.7uF low-ESR ceramic capacitor. It provides 2% accurate reference voltage to external IREF and CLIM terminal use for setting control loop reference.
2	SS	Soft-start time programming pin. Connect capacitor from SS pin to GND to program converter soft-start time.
3	RT	Connect a resistor from RT to GND to program the switching frequency.
4	CLIM	This pin provides a programmable input current limit for the converter. The current limit can be set by using a resistor divider from the VCC pin, soft-start can also be provided using this pin.
5	PWMD	PWM dimming input. High level is normal operation, when is pulled to GND or left open, switching of the SM8205 is disabled.
6	COMP	Error-amplifier output. Connect an RC network from COMP to GND for stable operation.
7	IREF	The voltage at this pin sets the output current level. The current reference can be set using a resistor divider from VCC pin.
8	GND	Ground return for all circuit.
9	FDBK	LED current sense input. Connect a sense resistor from LED strings to GND to regulate LED output current.
10	OVP	Over-voltage protection sense input. When this pin voltage exceeds 1.2V, the GATE output of the SM8205 is turned off and FAULT goes low. The IC will turn on again until input power is recycled.
11	SC	Slope compensation for current sense. A resistor between SC and GND will program the slope compensation.
12	CS	Current sense positive input. Connected to external current sense resistor which in turn is connected to the source of the external power N-MOSFET as well as an external slope compensation resistor.
13	$\overline{\text{FAULT}}$	External dimming MOSFET gate driver. This pin is pulled to Ground when there is an output short circuit or output over voltage fault conditions, and then disconnect the load from voltage source.
14	GATE	Output gate driver pin to drive an external N-channel power MOSFET.
15	VDD	This pin is a regulated 10V supply for two gate driver (GATE and FAULT), It must be bypassed with a low-ESR ceramic capacitor at least 1.0uF to GND.
16	VIN	Power supply input pin. Voltage input range from 8V to 46V, place a bypass capacitor 1uF～10uF to ground as close to the device as possible in the circuit board layout.

ABSOLUTE MAXIMUM RATINGS

Parameter	Rating	Units
Vin to GND	50	V
V_{DD} to GND	11	V
V_{CC} to GND	5.5	V
GATE , FAULT to GND	11	V
All other pins to GND	5.5	V
Junction To Ambient Thermal Impedance (θ_{JA})	102	℃/W
Junction Temperature	150	℃
Operating Junction Temperature Range	-40 ～ +125	℃
Storage Temperature Range	-65 ～ +150	℃
Lead Temperature (Soldering,10sec)	260	℃

Stresses beyond those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicates in the operational sections of the specifications is not implied. Exposure to maximum rating conditions for extended periods may affect device reliability.

RECOMMENDED OPERATING CONDITIONS

Parameter	Symbol	Min	Max	Units
Input Voltage	VIN	8	48	V
Operating Frequency	F_{OSC}	100	1000	KHz
Operating Ambient Temperature	T_A	-20	85	℃

ELECTRICAL CHARACTERISTICS

The typically testing values are at V_{IN}=12V, T_A=25℃, Unless otherwise noted.

Symbol	Parameter	Min	Typ	Max	Units	Conditions
Input						
V_{IN}	Input DC supply voltage range	8	-	48	V	Input to V_{IN} pin voltage
I_Q	Quiescent current	-	1.9	2.2	mA	PWMD=0, No switching
Internal Regulator						
V_{DD}	Internally regulated voltage for Gate driver	9	10	11	V	12V ≤ V_{IN} ≤ 48V
		V_{IN}-1	-	-		8V ≤ V_{IN} ≤ 11V
UVLO	V_{DD} under-voltage Lockout threshold	6.8	-	7.4	V	V_{DD} rising
ΔUVLO	V_{DD} under-voltage Lockout hysteresis	-	500	-	mV	V_{DD} falling
Reference						
V_{CC}	V_{CC} pin voltage	4.90	5.00	5.10	V	V_{CC} pin connected a 10uF Capacitor to GND, I_{CC}=0, PWMD=0
$V_{CC(Line)}$	Line regulation of the V_{CC} voltage	0	-	20	mV	V_{IN}=8～48V, PWMD=0
$V_{CC(Load)}$	Load regulation of the V_{CC} voltage	0	-	15	mV	I_{CC}=0～3mA, PWMD=0

ELECTRICAL CHARACTERISTICS (continued)

The typically testing values are at V_{IN}=12V, T_A=25℃, Unless otherwise noted.

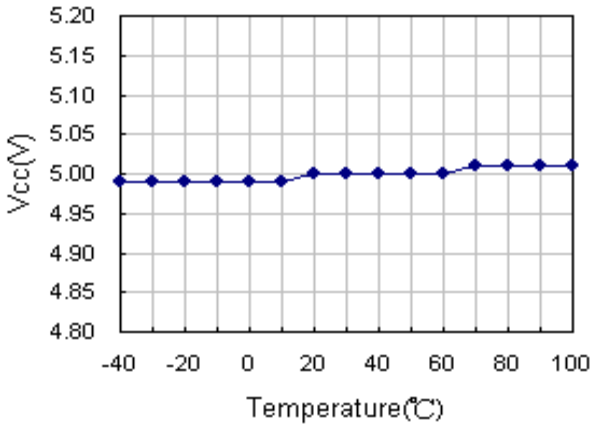
Symbol	Parameter	Min	Typ	Max	Units	Conditions
PWM Dimming						
$V_{PWMD(Lo)}$	PWM input Low voltage	-	-	0.8	V	
$V_{PWMD(Hi)}$	PWM input High voltage	2.0	-	-	V	
R_{PWMD}	PWM pin pull-down resistance	90	100	130	KΩ	
Over Voltage Protection						
V_{OVP}	Over-voltage threshold	1.15	1.20	1.25	V	OVP rising
T_{PD}	Propagation delay time	-	150	-	ns	OVP=0-2V step
Oscillator						
Fosc	Switching frequency	90	100	110	KHz	R_T=910KΩ
		270	300	330	KHz	R_T=300KΩ
D_{MAX}	Maximum duty cycle	-	92	-	%	
Error Amplifier (Note1)						
GB	Gain bandwidth product	-	2.5	-	MHz	75pF capacitance at COMP pin
A_V	Open loop gain	73	-	-	dB	Output open
V_O	Output voltage range	0.3	-	4.95	V	V_{CC}=5.0V
g_m	Transconductance	-	630	-	uA/V	
Gate Driver						
$I_{G-SOURCE}$	Gate short-circuit current	60	-	-	mA	V_{GATE}=0V, V_{DD}=10V
I_{G-SINK}	Gate sinking current	310	-	-	mA	V_{GATE}=10V, V_{DD}=10V
T_{G-RISE}	Gate driver output rise time	-	35	50	ns	C_L=1000pF, V_{DD}=10V
T_{G-FALL}	Gate driver output fall time	-	20	35	ns	C_L=1000pF, V_{DD}=10V
$I_{F-SOURCE}$	Fault pin short-circuit current	45	-	-	mA	V_{FAULT}=0V, V_{DD}=10V
I_{F-SINK}	Fault sinking current	60	-	-	mA	V_{FAULT}=10V, V_{DD}=10V
T_{F-RISE}	Fault driver output rise time	-	165	-	ns	C_L=1000pF, V_{DD}=10V
T_{F-FALL}	Fault driver output fall time	-	145	-	ns	C_L=1000pF, V_{DD}=10V
Slope Compensation						
$V_{SC\ (PEAK)}$	SC pin peak voltage	-	1.5	-	V	R_T=910KΩ, R_{SLOPE}=30KΩ
I_{SLOPE}	Current source out of SC pin	0	-	100	uA	
G_{SLOPE}	Internal current mirror ratio	1.8	2	2.2	-	R_{CS}=1KΩ, R_{SLOPE}=30KΩ
Output Short-Circuit						
$T_{OFF(S.C)}$	Propagation time for short-circuit detection	-	-	200	ns	I_{REF}=400mV, F_{DBK}=0-1V, Fault goes from high to low
G_{IREF}	Amplifier gain at IREF pin	1.7	2	2.1	-	I_{REF}=400mV
Current Sense						
T_{BLANK}	Leading edge blanking	-	100	-	ns	
T_{DELAY}	Delay to output of PWM comparator	-	150	-	ns	COMP=CLIM=V_{CC}, VCS=0-600mV Step
Thermal Protection						
T_{SD}	Thermal shutdown temperature	-	140	-	℃	
T_{HYS}	Thermal shutdown hysteresis	-	40	-	℃	

Note1: Guaranteed by design

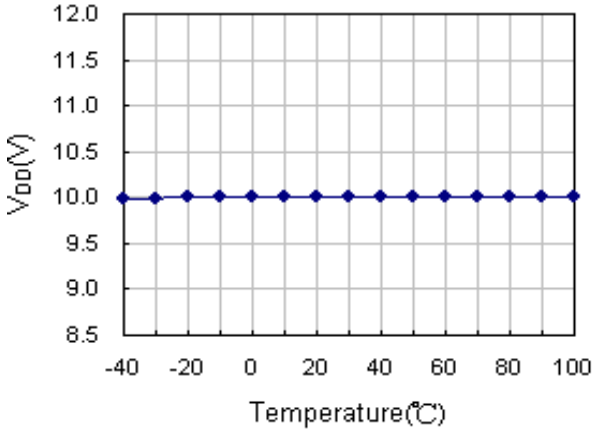
TYPICAL OPERATION CHARACTERISTIC

Test Conditions：V_{IN}=12V, C_{VCC}=10uF, C_{VDD}=1.0uF, R_T=910K, T_A=25℃, Unless otherwise noted.

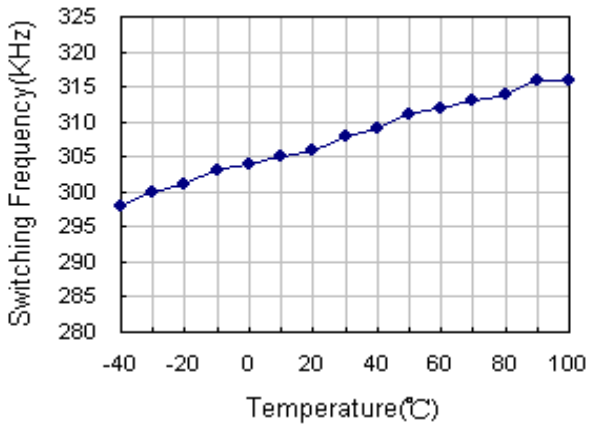
Vcc vs. Temperature



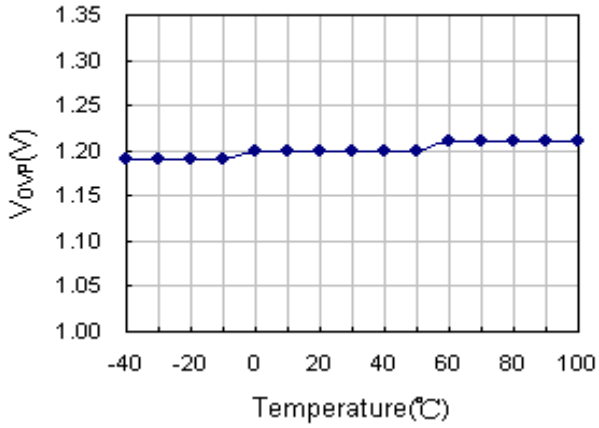
V_{DD} vs. Temperature



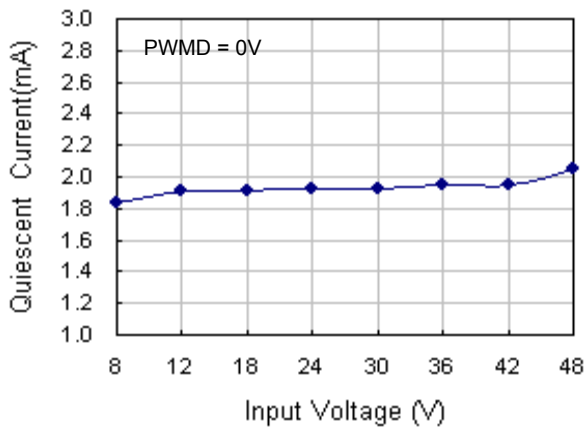
Switching Frequency vs. Temperature



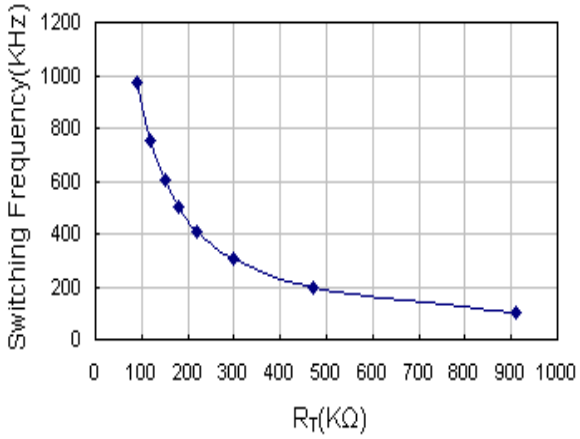
V_{OVP} vs. Temperature



Quiescent Current vs. Input Voltage

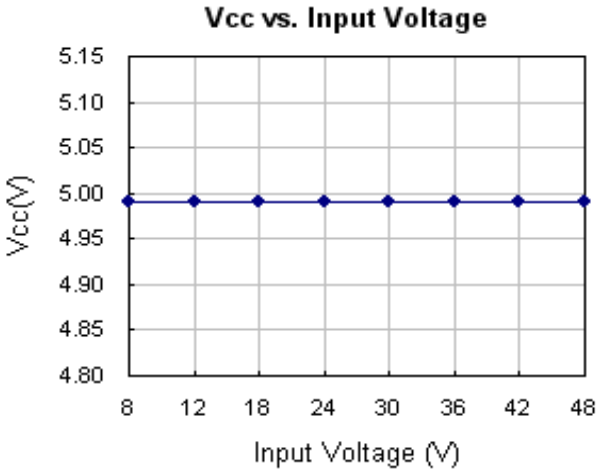


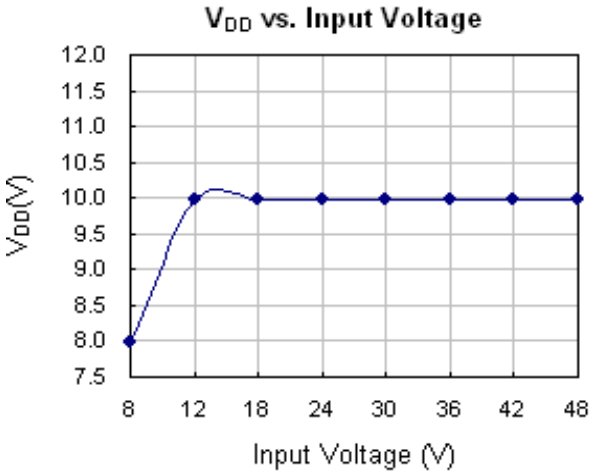
Switching Frequency vs. R_T

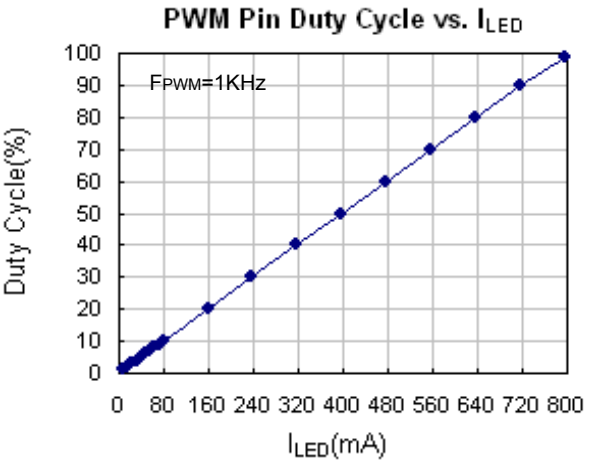


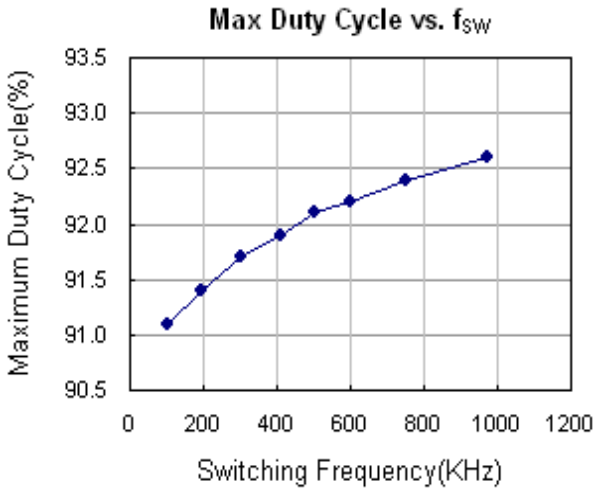
TYPICAL OPERATION CHARACTERISTIC

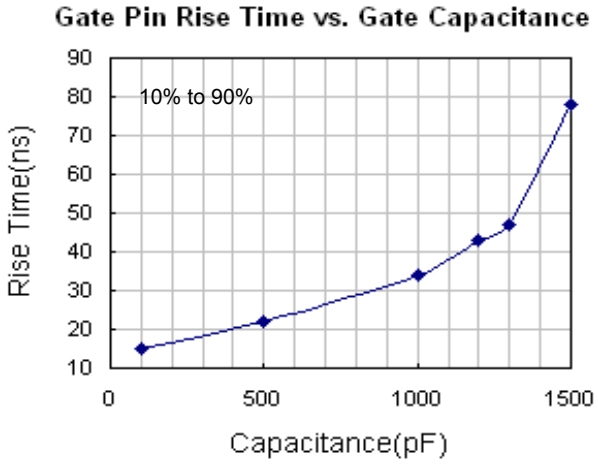
Test Conditions：V_{IN}=12V, C_{VCC}=10uF, C_{VDD}=1.0uF, R_T=910K, T_A=25℃, Unless otherwise noted.

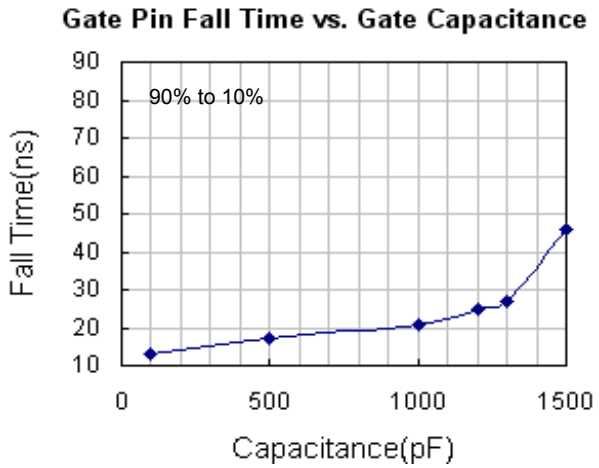




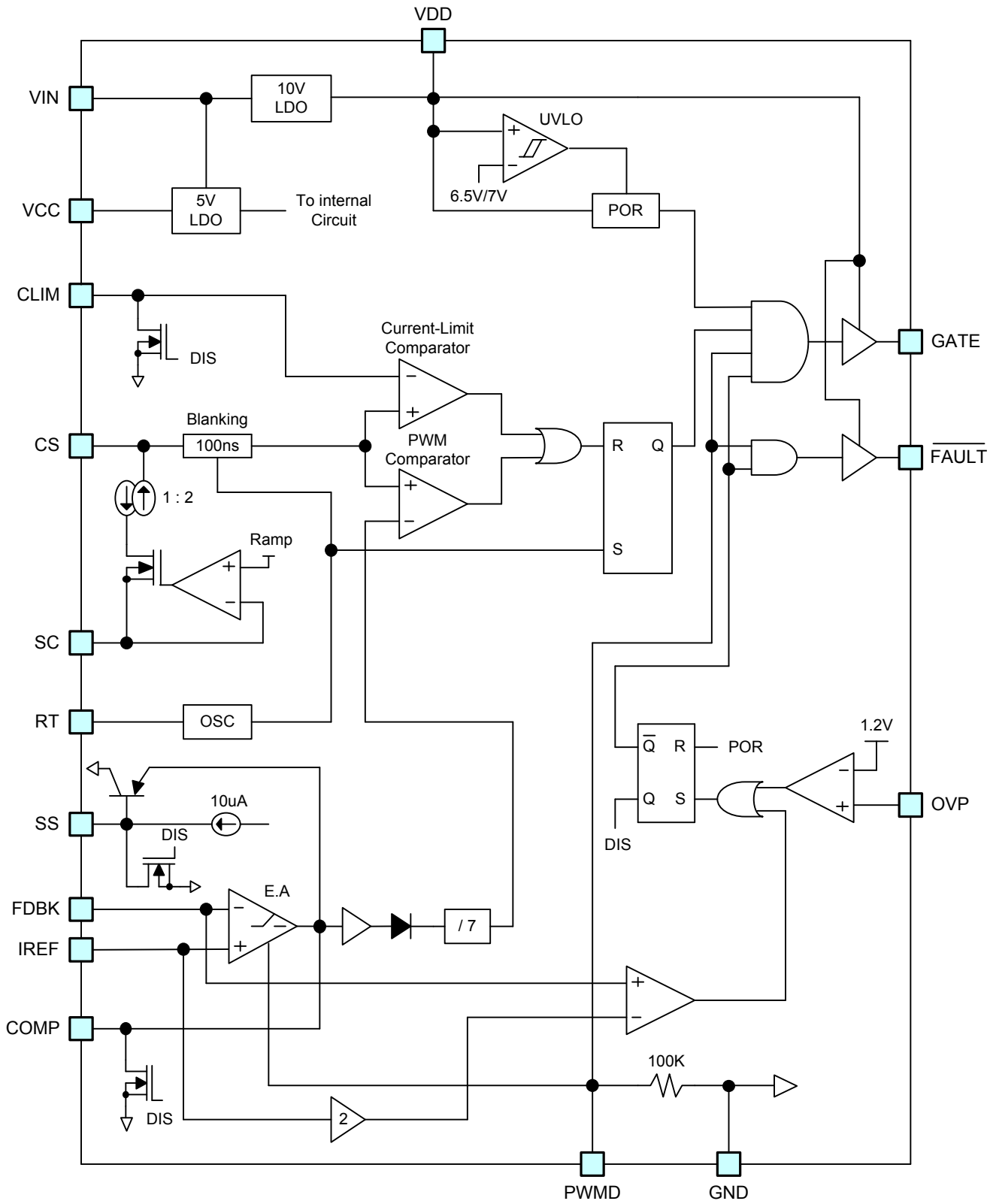








BLOCK DIAGRAM



BASIC OPERATION

Overview

The SM8205 is a current-mode, high-brightness LED driver designed to control a single-string LED current regulator with two external N-channel MOSFETs. It integrates all the building blocks necessary to implement a fixed-frequency, peak-current-mode control with programmable slope compensation to control the duty cycle of the PWM controller. The SM8205 allows implementation of different converter topologies such as SEPIC, Boost, Buck-Boost, Buck regulator. Basic operating discussion that follows it will be helpful to refer to the block diagram of the IC.

In normal operation with the PWMD pin low level, the GATE and FAULT pins are driven to GND, the COMP pin is high impedance to store the previous switching state on the external compensation capacitor, and the FDBK pin bias current is reduced to leakage levels. When the PWM pin transitions high level, the GATE pin transition high after a short-delay. At the same time, the internal oscillator generates a pulse to set the SR latch, turning on the external power MOSFET switch(GATE goes high), A voltage input proportional to the switch current, sensed by an external current sense resistor connected from CS and GND. This voltage is added to a stabilizing slope compensation ramp and the resulting is fed into the positive terminal of the PWM comparator. The current in the external inductor increases steadily during the time the switch is on. When this non-inversion input voltage exceeds inversion input voltage of the error amplifier E.A, the SR latch is reset and the external power switch is turned off. During the switch off phase, the inductor current decreases. At the completion of each oscillator cycle, internal signals such as slope compensation return to their starting point and a new cycle begins with the set pulse from the oscillator.

Minimum Input Voltage at Vin Pin

The SM8205 contains two internal high-voltage startup regulator that allows the VIN pin to be connected directly to line voltage as high as 46V. The 5V low dropout linear regulator V_{CC}, is used to power internal PWM controller, control logic, error amplifier and as the reference for the LED output current as well as to set switch current limit. In application, connect a bypass capacitor from this pin to GND, The recommended capacitance range is from 4.7uF to 10uF. Another 10V LDO regulator V_{DD}, is for external power MOSFETs driver, on the condition that $V_{IN} \geq 12V$, the regulator generates a 10V supply. If $7V \leq V_{IN} \leq 11V$, the V_{DD} is equal to V_{IN} minus drop voltage across bypass switch. When the voltage on the VDD pin reaches the rising threshold of 7V, the GATE driver is enabled. The GATE driver will remain enables until V_{DD} falls below 6.5V. Connect a bypass capacitor from this pin to GND, The recommended capacitance range is from 1.0uF to 10uF.

Gate Driver Voltage (V_{DD})

The SM8205's 10V LDO regulator powers up the switching MOSFET driver. Use at least a 1uF low-ESR ceramic capacitor from V_{DD} to GND for best performance. Careful choice of a lower Qg FET will allow higher switching frequency, leading to smaller magnetics. The VDD pin has it own undervoltage disable (UVLO) set to 6.5V (typical value) to protect the external MOSFET from excessive power dissipation caused by not being fully enhanced.

Control and Reference Voltage (V_{CC})

The SM8205 has a 2% accurate, 5V reference, V_{CC}. It provides power to most of the internal circuit blocks except for the gate drivers. It also can be used as the reference for the LED output current as well as to set the switch current limit through a resistor divider. Connect a at least 4.7uF ceramic capacitor from V_{CC} to GND.

Oscillator and Switching Frequency (R_T)

The internal oscillator of the SM8205 is programmable from 100KHz to 1MHz using a single resistor at R_T, Do not leave this pin open. Use the following formula to calculate the R_T value (1% resistors) :

$$R_T \approx \frac{1}{F_{OSC}(KHz) * 11 * 10^{-9}}$$

Table 1. Operating Frequency Selection

F_{OSC} (KHz)	R_T (KΩ)
100	910
200	455
300	303
500	182
600	152
1000	91

Note: Higher frequency operation yields smaller component size but increases switching losses and gate driving current, and may not allow sufficiently high or low duty cycle operation. Lower frequency operation gives better performance and efficiency but has larger external component size.

Soft-start (SS)

The soft-start feature allows the LED output current to gradually reach the LED current's rate, thereby reducing start-up stresses and input surge current. At power up, after the V_{CC} and input under-voltage lockout thresholds are satisfied, an internal 10uA current source charges an external capacitor connected to the SS pin. The capacitor voltage will ramp up slowly and will limit the COMP pin voltage and the switch current.

Over-Voltage Protection (OVP)

Over voltage protection is achieved by connecting the output voltage to the OVP pin through a resistor divider. The voltage at the OVP pin is constantly compared to the internal 1.2V. When the output voltage at LED load terminal is exceeded 1.2V, the IC is turned off, immediately, at the same time the GATE and FAULT pins goes low. Power on again to resume this situation. The output voltage can be set by selecting the values of R1 and R2 (see figure 1) according to the following equation:

$$V_{OUT} = 1.2 \bullet \frac{R1+R2}{R2}$$

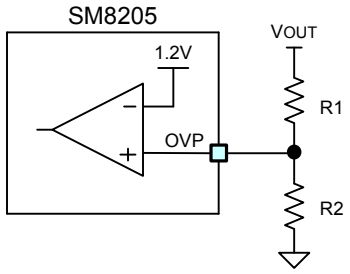


Figure 1. Over-voltage protection resistor connection

PWM Dimming (PWMD)

PWM dimming can be achieved by driving the PWMD pin with a TTL compatible source. The PWM signal is connected internally to the three different node – the transconductance amplifier, the $\overline{\text{FAULT}}$ output, and the GATE output.

When the PWMD signal is high, the GATE and $\overline{\text{FAULT}}$ pins are enabled, and the output of the EA amplifier is connected to the external compensation network. Thus, the internal amplifier controls the LED current. When the PWMD signal goes low, the output of the EA amplifier is disconnected from the compensation network. So, the integrating capacitor maintains the voltage across it. The GATE is disabled, the converter stops switching and the $\overline{\text{FAULT}}$ pin goes low, turning off the disconnect switch. By turning off the disconnect switch action, the output capacitor is prevented from being discharged, and thus the PWM dimming response of the boost converter improvs dramatically.

When the voltage at PWMD is greater than 2.0V, the PWM dimming MOSFET turns on and when the voltage on PWMD is below 0.8V, the PWM dimming MOSFET turns off.

LED Current Reference (IREF)

The LED current is propotional to the voltage at IREF. Applying an external DC voltage at IREF or using a potentionmeter from IREF to GND allow analog dimming of the LED current.

Gate driver (GATE)

External MOSFETs are driven by the SM8205's internal low impedance gate driver. These driver are biased from the V_{DD} and have a source current of 150mA and a sink current of 300mA, to switch a ground-referenced N-channel MOSFET in high-power applications. The average current demanded from the supply to drive the external MOSFET depends on the total gate charge (Qg) and the operating frequency of the converter, F_{SW}. Use the following equation to calculate the driver supply current I_{GATE} required for the switching MOSFET:

$$I_{GATE} = Qg \times F_{SW}$$

Dimming MOSFET Driver ($\overline{\text{FAULT}}$)

The SM8205 requires an external N-channel MOSFET for PWM dimming. Connect the gate of the MOSFET to the output of the dimming driver, $\overline{\text{FAULT}}$, for normal operation. The dimming driver is capable of sourcing or sinking up to 50mA of current.

LED Current-Sense Input (FDBK)

The current through the LED string is set via the value chosen for the current sense resistor, RSN. This value can be calculated using equation of below:

$$I_{LED} = \frac{V_{IREF}}{R_{SN}}$$

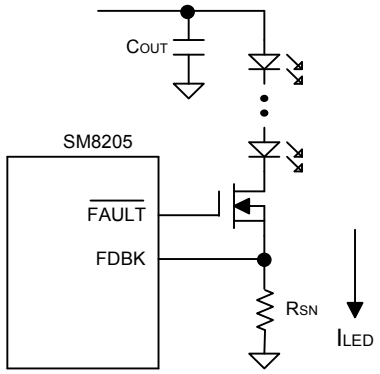


Figure 2. LED Forward Current Controls Path

Another important parameter to be aware of in the boost controller design, is the ripple current. The amount of ripple current through the LED string is equal to the output ripple voltage divided by LED AC resistance (R_{LED} is provided by the LED manufacturer) plus the current sense and R_{ON} of the MOSFET resistor. The amount of allowable ripple current through the LED string is dependent upon the application and design's discretion. The equation is shown as below:

$$\Delta I_{LED} = \frac{V_{OUT(RIPPLE)}}{R_{LED} + R_{ON} + R_{SN}}$$

Slope Compensation (SC)

The SM8205 uses an internal ramp voltage generator (typically at 1.5V_{PEAK}) for slope compensation, by an external resistor connects SC pin to GND to generate a respective ramp current source for slope compensation use. In a fixed operating frequency, slope compensation is necessary, Particularly, the operating duty cycle greater than 0.5. choosing a slope compensation which is one-half of the down slope of the inductor current to ensure the stability operation.

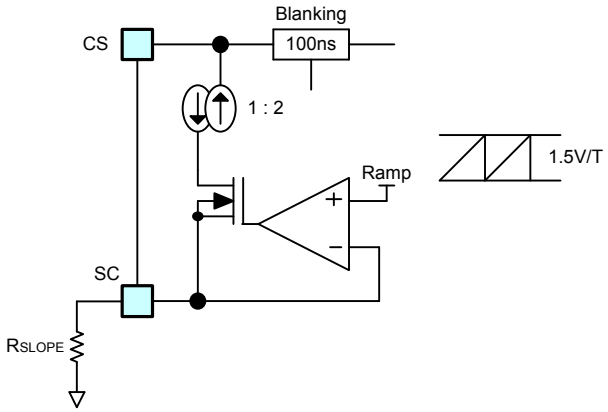


Figure 3. The Functional Block of the Ramp Current

Slope compensation can be programmed by two resistors RSLOPE and RSC. Assuming a down slope of DS (A/uA) for the inductor current, the slope compensation resistors can be computed as:

$$R_{SLOPE} = \frac{10 \cdot R_{SC}}{DS \cdot 10^{6} \cdot T_S \cdot R_{CS}}$$

- A typical value for R_{SC} is 620Ω.

Current Sense (CS)

The current sense input of the SM8205 built-in a 100ns (typical, see figure 3.) blanking time to prevent spurious turn off due to the initial current spike when the external power MOSFET turns on. SM8205 includes two high-speed comparator – one is used during normal operation, namely is PWM comparator, another one is used to limit the maximum input current during input under-voltage or overload conditions, which namely is current-limit comparator.

The SM8205 integrates an internal resistor divider network, which steps down the voltage at the COMP pin by a factor of 7 (see IC's block diagram). This steps down voltage is fed to one of the PWM comparator as the current reference. The reference to the other comparators (current-limit comparator), which acts to limit the maximum inductor current, is given externally.

It is recommended that the sense resistor RCS be chosen so as to provide about 250mV current sense signal.

Current Limit (CLIM)

The SM8205 features a current limit protection feature to prevent any current runaway conditions. Current limit has to be set by a resistor divider from the V_{CC} (5V) reference available on the IC. Assuming a maximum operating inductor current I_{PK} (including the ripple current), the voltage at the CLIM pin can set as:

$$V_{CLIM} \geq 1.2 \cdot I_{PK} \cdot R_{CS} + \left(\frac{5 \cdot R_{SC}}{R_{SLOPE}}\right) \cdot D_{MAX}$$

Note that this equation assumes a current limit at 120% of the maximum input current. Also, if V_{CLIM} is greater than 450mV, the saturation of the internal E.A amplifier will determine the limit on the input current rather than the CLIM pin. In such a case, the sense resistor R_{CS} should be reduced till V_{CLIM} reduces below 450mV.

Internal Transconductance Error Amplifier

The SM8205 has a built-in transconductance amplifier used to amplify the error signal inside the feedback loop. The amplified current-sense signal is connected to the negative input of the g_m amplifier with the current reference connected to IREF. The output of the op-amp is controlled by the input at PWMD. When the signal at PWMD is high, the output of the op-amp connects to COMP; when the signal at PWMD is low, the output of the op-amp disconnects from COMP to keep the charge on the compensation capacitor. When the voltage at PWMD goes high, the voltage on the compensation capacitor forces the converter into a steady state. COMP is connected to the negative input of the PWM comparator with CMOS input through a buffer, forward diode and 7:1 resistor divider, which draw a small current from the compensation capacitor at COMP and thus prevent discharge of the compensation capacitor when the PWMD input is low.

FAULT Protection

The SM8205 includes a output over-voltage and LED short-circuit protections. Both protection features are latched, which means that the power to the IC must be recycled to reset the IC. The IC also built-in a $\overline{FAULT}$ pin which goes low during any fault conditions. At start-up, a monoshot circuit (trigger by POR the circuit), reset an internal SR filp-flop which causes $\overline{FAULT}$ to go high, and remains high during normal operation. This also allows the GATE drive to function normally. This pin can be used to drive an external switch Q2 (see typical application on page 1), which will disconnect the load during a fault condition. This disconnect switch is very important in a boost converter, as turning off the switching MSOFET (Q1) during an output short-circuit condition will not remove the fault (Q1 is not in the path of the fault current), the disconnect switch will help to disconnect the shorted load from the input.

LED Short-Circuit Protection

The LED short-circuit condition is indicated by $\overline{\text{FAULT}}$. At start-up, a monoshot circuit (triggered by the POR circuit), reset an internal SR flip-flop, which causes $\overline{\text{FAULT}}$ to go high, and remains high during normal operation. This also allows the GATE driver to function normally. The steady state current is reflected in the reference voltage connected to the transconductance amplifier. The instantaneous output current is sensed from FDBK terminal of the op-amp. The short-circuit threshold current is internally set to 200% of the steady state current. During short-circuit condition, when the current exceeds the internally set threshold, the SR flip-flop is set and $\overline{\text{FAULT}}$ goes low. Meanwhile, the GATE driver of the power MOSFET is inhibited, providing a latching protection. The converter can be reset by cycling the input voltage for operating again.

Current Sense Filter

Parasitic circuit capacitance, inductance and gate driver current create a spike in the current sense voltage at the point where Q1 turns on. In order to prevent this spike from terminal the on-time prematurely, every circuit should have a low-pass filter that consists of R_F and C_F, shown in figure 4. The time constant of this filter should be long enough to reduce the parasitic spike without significantly affecting the shape of the actual current sense voltage. The recommended range for R_F is between 10Ω and 500Ω, and C_F is between 100pF and 2.2nF.

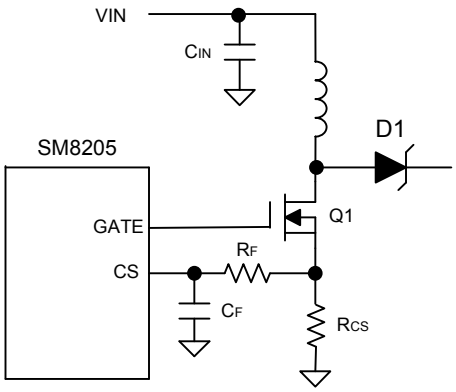
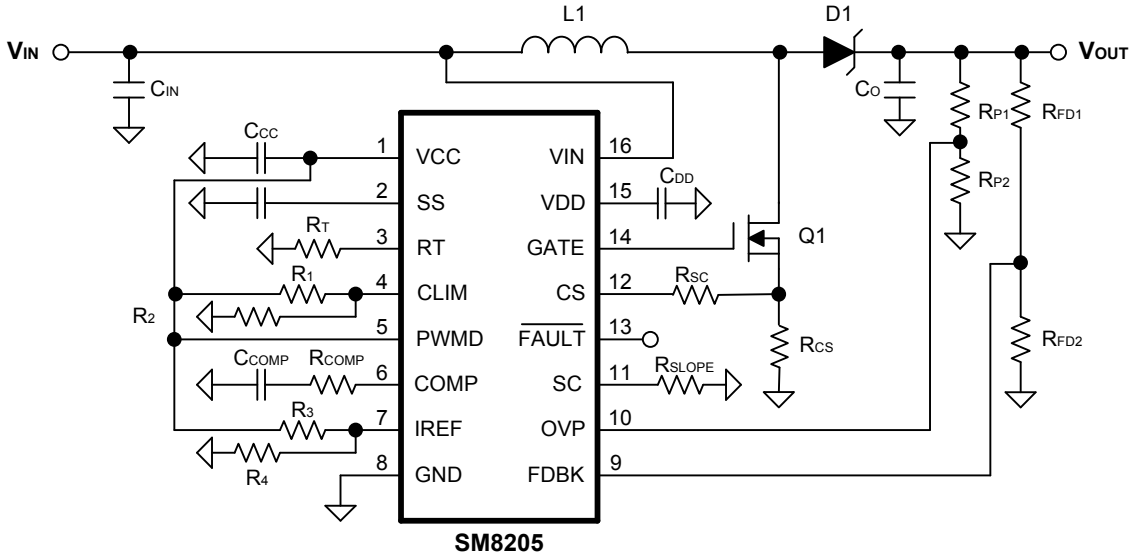


Figure 4. Adding a low-pass filter to prevent premature triggering

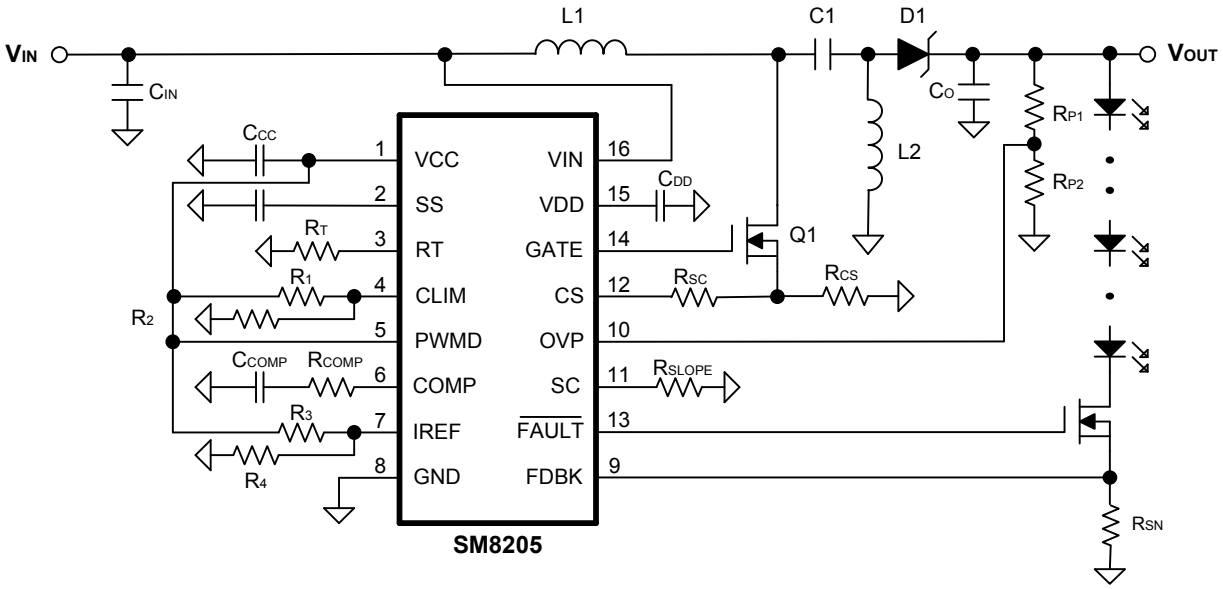
Thermal Shutdown

Internal thermal shutdown circuitry is provided to protect the SM8205 in the event that the maximum junction temperature is exceeded. When activated, typically at 140℃, the controller is forced to disable the output GATE and $\overline{\text{FAULT}}$ drivers in low-state. After the temperature is reduced (typical hysteresis is 25℃) the gate driver will be re-enabled.

Application Circuit 1 – For a Boost DC to DC Converter

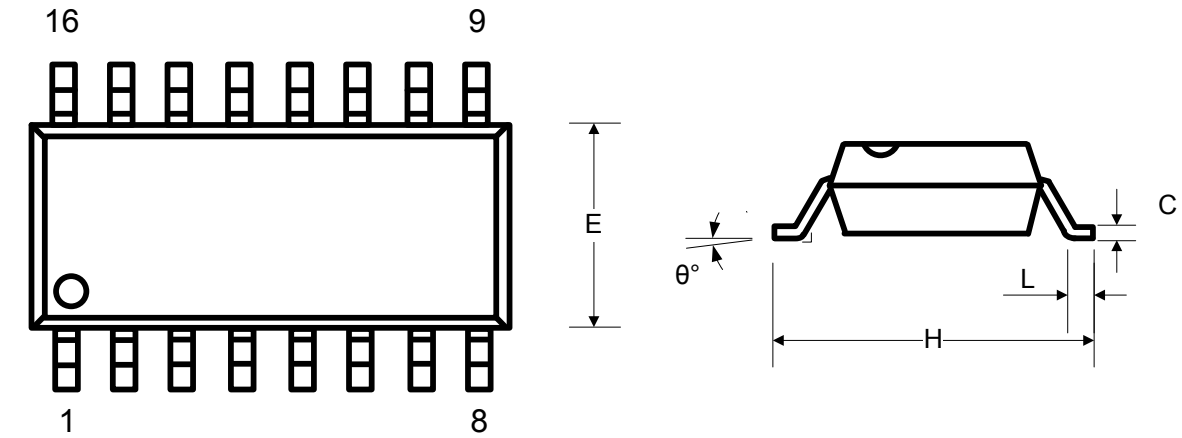


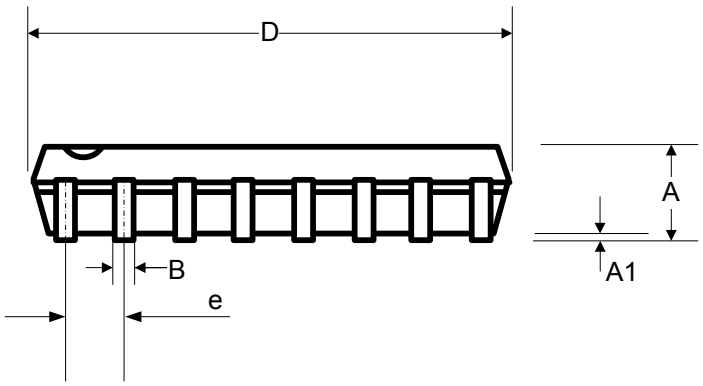
Application Circuit 2 – For a SPEIC LED Driver

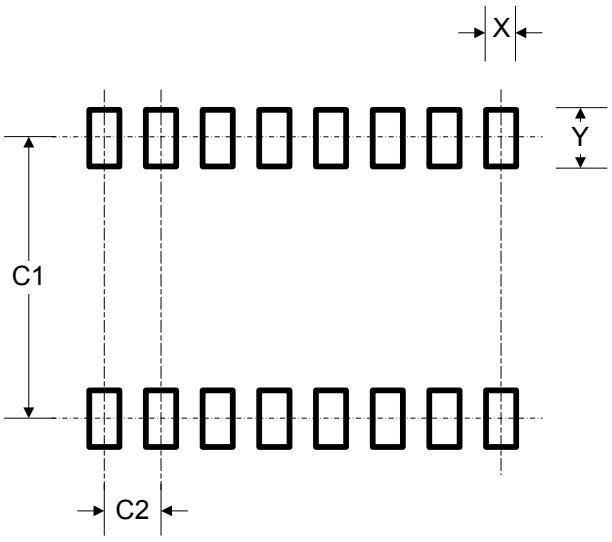


PACKAGE DIMENSIONS

SM8205 16 PIN SOP







RECOMMENDED LAND PATTERN

DIM	INCHES		MILLIMETERS	
	MIN	MAX	MIN	MAX
A	0.0532	0.0688	1.35	1.75
A1	0.0040	0.0096	0.10	0.25
B	0.013	0.020	0.33	0.51
C	0.0075	0.0096	0.19	0.25
D	0.3859	0.3937	9.80	10.00
E	0.1497	0.1574	3.80	4.00
e	0.050 BSC.		1.27 BSC.	
H	0.2284	0.2440	5.80	6.20
L	0.016	0.050	0.40	1.27
θ°	0°	8°	0°	8°
X	0.0236		0.60	
Y	0.0590		1.50	
C1	0.2125		5.4	
C2	0.0499		1.27	