500V Power MOSFET Integrated High Efficiency Constant Current LED Driver

General Description

The RT8468 integrates a 500V power MOSFET and a PWM controller. It is used for step-down converters by well controlling the internal MOSFET and regulating a constant output current. The output duty cycle of the RT8468 can be up to 100% for wider input voltage applications, such as E27 and PAR30 off-line LED lighting products.

The RT8468 also features a 47kHz fixed frequency oscillator, an internal 220mV precision reference, and a PWM comparator with latching logic. The accurate output LED current is achieved by an averaging current feedback loop and the LED current dimming can be easily controlled via the ACTL pin. The RT8468 also has multiple features to protect the controller from fault conditions, including Under Voltage Lockout (UVLO), Over Current Protection (OCP) and Over Voltage Protection (OVP). Additionally, to ensure the system reliability, the RT8468 is built with the thermal protection function.

The RT8468 is housed in a SOP-7 package. Thus, the components in the whole LED driver system can be made very compact.

Features

- **Built-In 500V/1A Power MOSFET**
- **Low Cost and Efficient Buck Converter Solution**
- **Universal Input Voltage Range with Off-Line Topology**
- **Adjustable Constant LED Current**
- **Dimmable LED Current by ACTL**
- **Output LED String Open Protection**
- **Output LED String Short Protection**
- **Output LED String Over Current Protection**
- **Built-in Thermal Protection**
- **SOP-7 Package**
- **RoHS Compliant and Halogen Free**

Applications

- E27, PAR30, Offline LED Lights

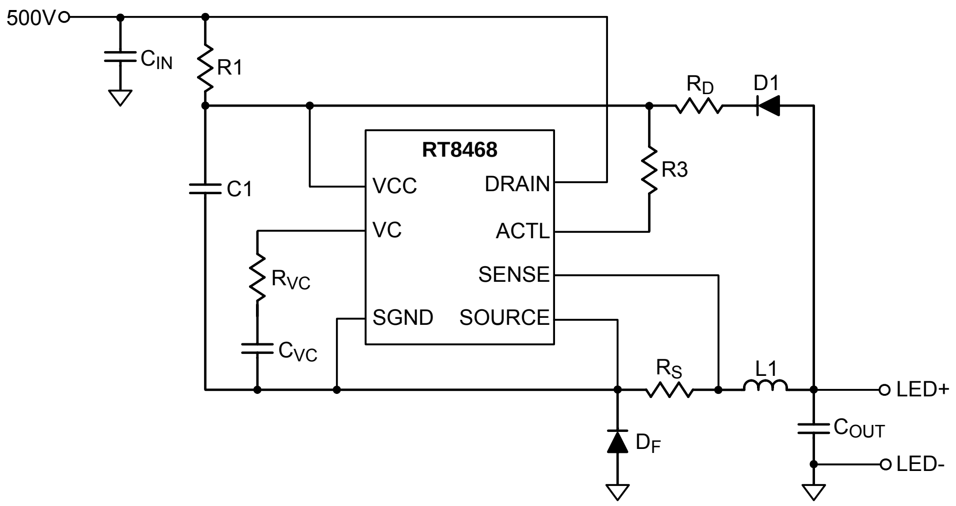
Marking Information

RT8468 GSYMDNN •

RT8468GS : Product Number

YMDNN : Date Code

Simplified Application Circuit



Ordering Information

RT8468□□

- Package Type
  S : SOP-7
- Lead Plating System
  G : Green (Halogen Free and Pb Free)

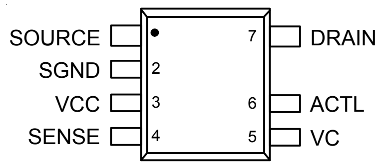
Note :

Richtek products are :

- RoHS compliant and compatible with the current requirements of IPC/JEDEC J-STD-020.
- Suitable for use in SnPb or Pb-free soldering processes.

Pin Configurations

(TOP VIEW)

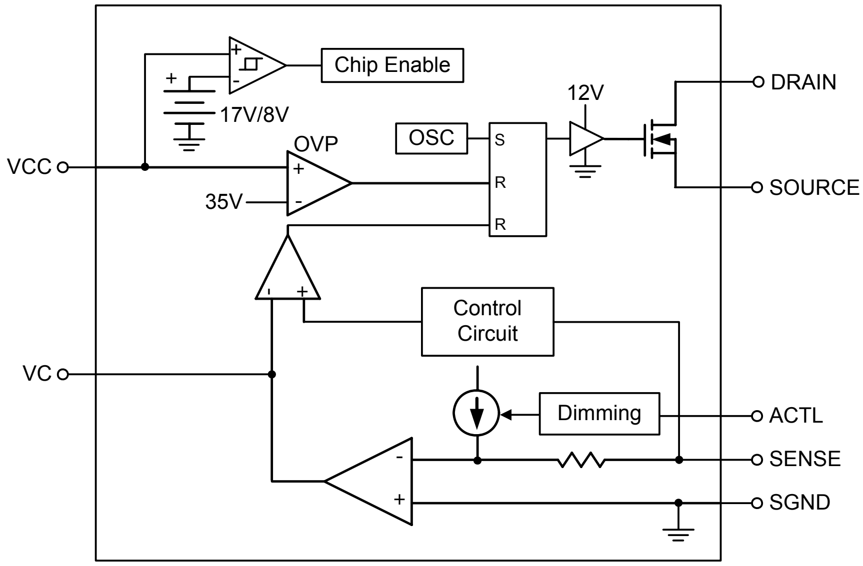


SOP-7

Functional Pin Description

Pin No.	Pin Name	Pin Function
1	SOURCE	Internal Power MOSFET Source Connection.
2	SGND	Ground.
3	VCC	Power Supply Input. For good bypass, a ceramic capacitor near the VCC pin is required.
4	SENSE	LED Current Sense Input. Typical sensing threshold is 220mV.
5	VC	PWM Loop Compensation Node.
6	ACTL	Analog Dimming Control. The typical effective dimming range is between 0.1V to 1.2V.
7	DRAIN	Internal Power MOSFET Drain Connection.

Function Block Diagram



Operation

The RT8468 is a high voltage Buck PWM current mode driver with an integrated 500V power MOSFET. The start up voltage of RT8468 is around 17V. Once VCC is above 17V, RT8468 will maintain operation until VCC drops below 8V.

The RT8468's main control loop consists of a 47kHz fixed frequency oscillator, an internal 220mV precision current sense threshold OPAMP (OP1), and a PWM comparator (CCOMP) with latching logic. In normal operation, the GATE turns high when the gate driver is set by the oscillator (OSC). The lower the average of the sensed current is below the loop-regulated 220mV threshold, the higher the VC pin voltage (OP1 output) will go high. Higher the VC voltage means longer the GATE turn-on period. The GATE of RT8468 can turn on more than 100% duty. It is not always that the GATE turns low in each OSC cycle. The GATE turns low until the current comparator (CCOMP) resets the gate driver. The GATE will be set high again by OSC and the next switching cycle repeats.

The ACTL voltage of RT8468 is internally biased to 0.6V. The adjustment of the regulated sense current threshold (dimming) can be achieved by varying ACTL pin voltage. The typical range of ACTL voltage adjustment is between 0.1V and 1.2V.

The RT8468 is equipped with protection from several fault conditions, including input voltage Under Voltage Lockout (UVLO), Over Current Protection (OCP) and VIN/VOUT Over Voltage Protection (OVP). Additionally, to ensure the system reliability, the RT8468 is built with internal thermal protection function.

Absolute Maximum Ratings (Note 1)

- Supply Input Voltage, VCC to SGND ---------- −0.3V to 40V
- ACTL Voltage to SGND ---------- −0.3V to 8V
- VC Voltage to SGND ---------- −0.3V to 6V
- SENSE Voltage to SGND ---------- −1V to 0.3V
- DRAIN to SOURCE Voltage, V_{DS} ---------- −0.3V to 550V
- DRAIN Current, I_D @ T_C = 25°C ---------- 1.4A
- DRAIN Current, I_D @ T_C = 100°C ---------- 0.9A
- Power Dissipation, P_D @ T_A = 25°C
  SOP-7 ---------- 0.5W
- Package Thermal Resistance (Note 2)
  SOP-7, θ_{JA} ---------- 200.2°C/W
- Junction Temperature ---------- 150°C
- Lead Temperature (Soldering, 10 sec.) ---------- 260°C
- Storage Temperature Range ---------- −65°C to 150°C
- ESD Susceptibility, Except DRAIN & SOURCE Pin (Note 3)
  HBM (Human Body Model) ---------- 2kV
  MM (Machine Model) ---------- 200V

Recommended Operating Conditions (Note 4)

- Supply Input Voltage, VCC ---------- 16V to 31V
- Junction Temperature Range ---------- −40°C to 125°C

Electrical Characteristics

(V_{CC} = 24V_{DC}, T_A = 25°C, unless otherwise specified)

Parameter	Symbol	Test Conditions	Min	Typ	Max	Unit
Supply Voltage						
Input Start-Up Voltage	V_{ST}		--	16	19	V
Under Voltage Lockout Threshold Hysteresis	ΔV_{UVLO}		--	8	9	V
Maximum Startup Current	$I_{ST(MAX)}$		--	250	300	μA
Input Supply Current	I_{CC}	After Start-Up, V_{CC} = 24V	--	2	5	mA
Input Quiescent Current	I_{QC}	Before Start-Up, V_{CC} = 15V	--	--	2	μA
Current Sense Amplifier						
Current Sense Voltage	V_{SENSE}		213	220	227	mV
Sense Input Current	I_{SENSE}	V_{SENSE} = 0.2V	--	20	--	μA
VC Sourcing Current	I_{VC_Sr}	V_{SENSE} = −150mV	--	18.5	--	μA
VC Sinking Current	I_{VC_Sk}	V_{SENSE} = −230mV, V_{VC} = 3.5V	--	165	--	μA
VC Threshold for PWM Switch Off	V_{VC}		1.15	1.25	1.35	V

Parameter	Symbol	Test Conditions	Min	Typ	Max	Unit
Oscillator						
Switching Frequency	f_{SW}		38	47	56	kHz
Oscillator Maximum Duty Cycle	D_{MAX}		--	--	100	%
Maximum Duty in Transient Operation	$D_{MAX(TR)}$	VC = 3V	--	--	100	%
Maximum Duty in Steady State Operation	D_{MAX}		--	97	--	%
Blanking Time	t_{BLANK}		--	300	--	ns
Minimum Off-Time (Note 5)			--	650	--	ns
LED Dimming						
Analog Dimming ACTL Pin Input Current	I_{ACTL}		--	1	20	μA
LED Current On Threshold at ACTL	V_{ACTL_ON}		--	1.2	--	V
LED Current Off Threshold at ACTL	V_{ACTL_OFF}		--	0.1	0.2	V
Internal MOSFET						
Static Drain-Source On-Resistance	$R_{DS(ON)}$	V_{VC} = 3V, I_D = 0.6A	--	12	--	Ω
Drain-Source Leakage Current	I_{DSS}	V_{VC} = 0V, V_{DS} = 500V	--	--	10	μA
Output Capacitance	C_{OSS}	V_{CC} = 0V, V_{DS} = 25V, f = 1MHz	--	14	40	pF
OVP and Soft-Start						
Over Voltage Protection	V_{OVP}	VCC pin	32	35	38	V
Thermal Protection						
Thermal Shutdown Temperature	T_{SD}		--	150	--	°C

Note 1. Stresses beyond those listed "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 indicated in the operational sections of the specifications is not implied. Exposure to absolute maximum rating conditions may affect device reliability.

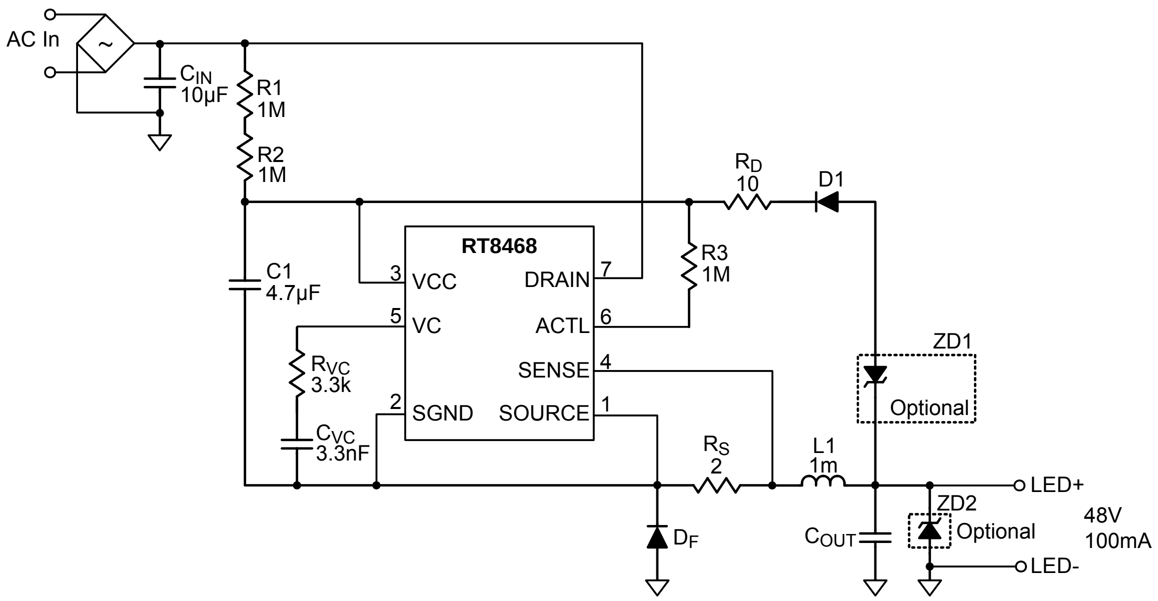
Note 2. θ_{JA} is measured at T_A = 25°C on a high effective thermal conductivity four-layer test board per JEDEC 51-7.

Note 3. Devices are ESD sensitive. Handling precaution is recommended.

Note 4. The device is not guaranteed to function outside its operating conditions.

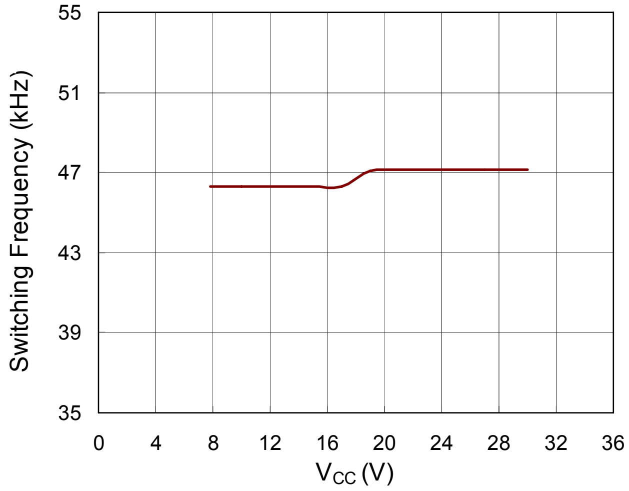
Note 5. Guaranteed by design, not subjected to production test.

Typical Application Circuit

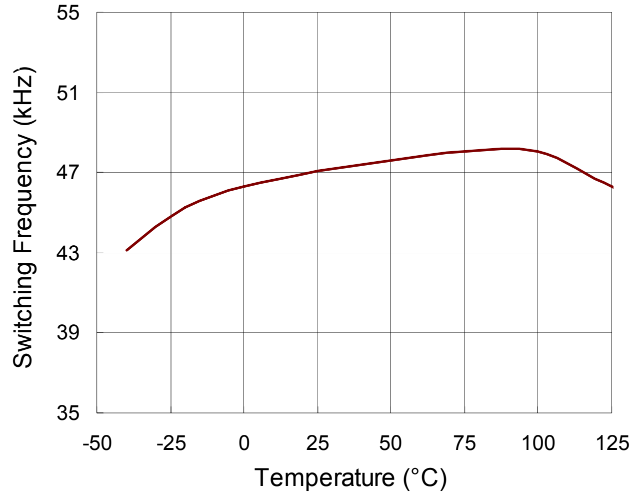


Typical Operating Characteristics

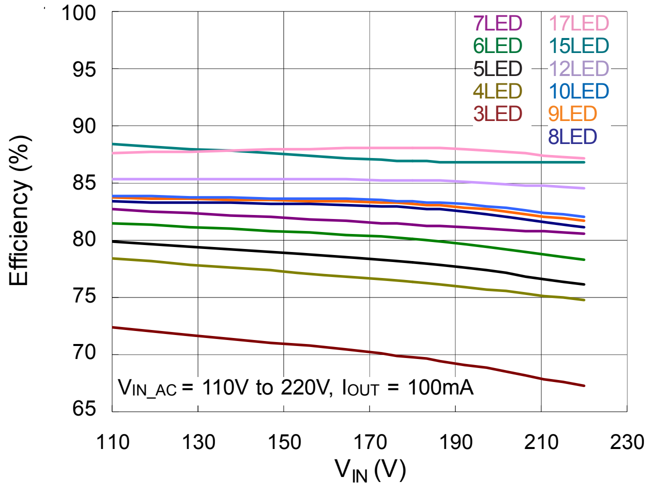
Switching Frequency vs. V_{CC}



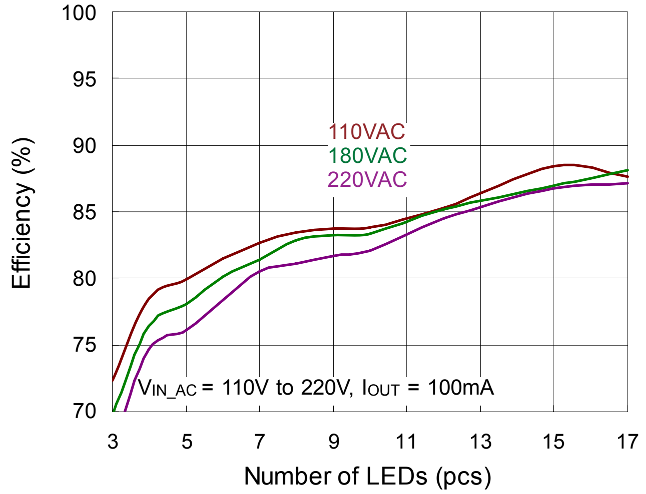
Switching Frequency vs. Temperature



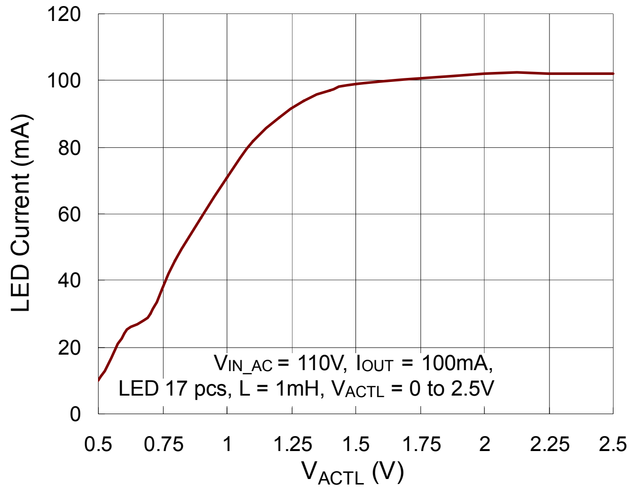
Efficiency vs. V_{IN}



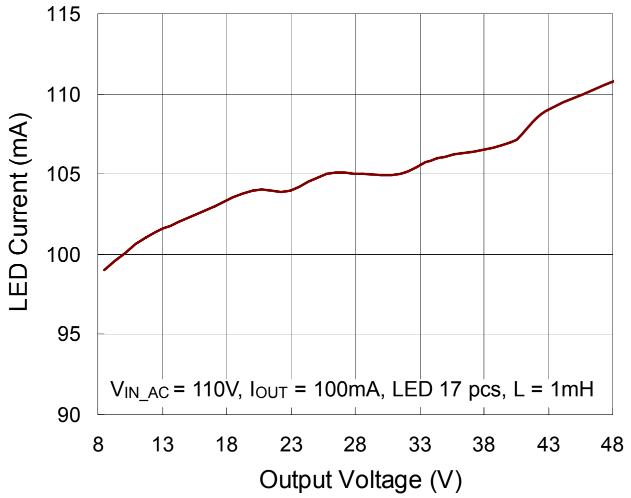
Efficiency vs. Number of LEDs



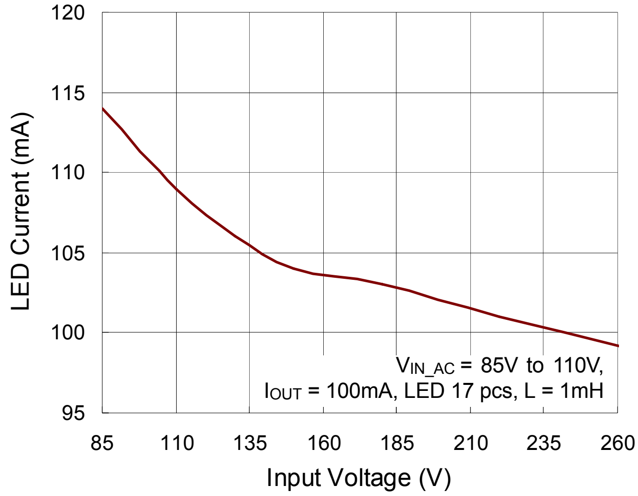
LED Current vs. V_{ACTL}



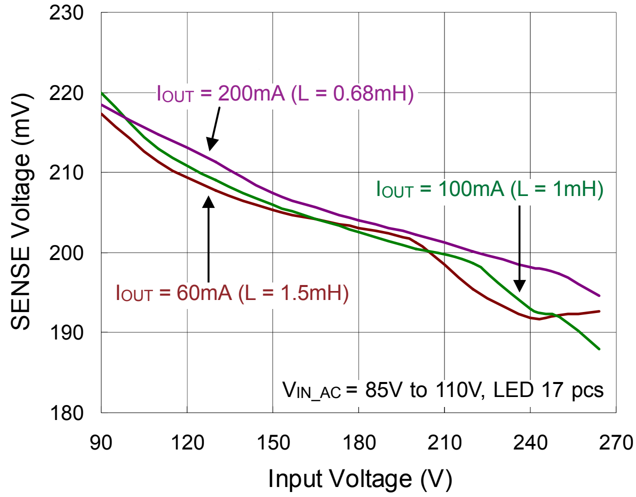
LED Current vs. Output Voltage



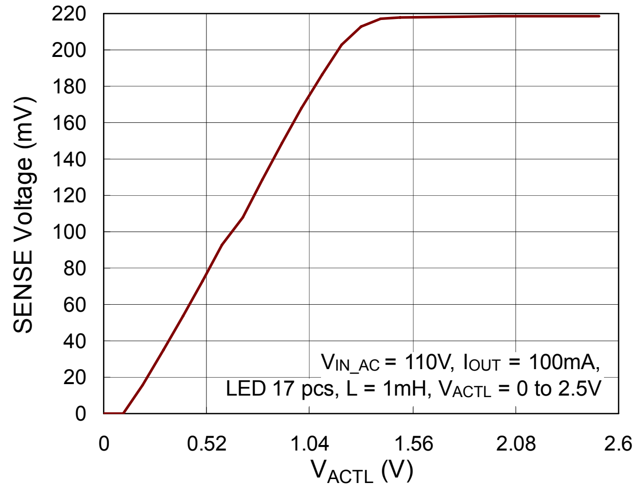
LED Current vs. Input Voltage



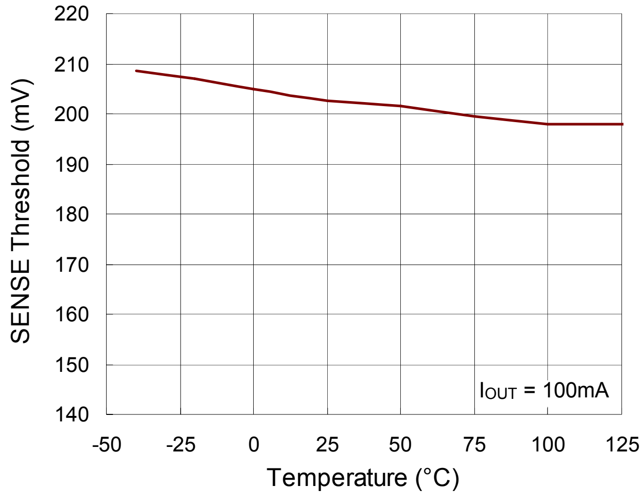
SENSE Voltage vs. Input Voltage



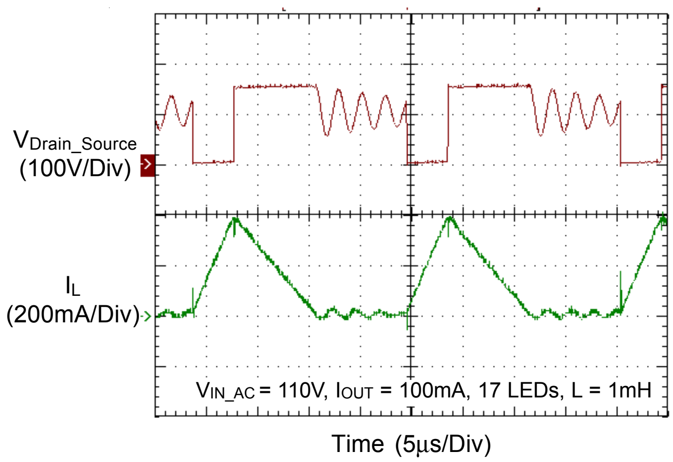
SENSE Voltage vs. V_{ACTL}



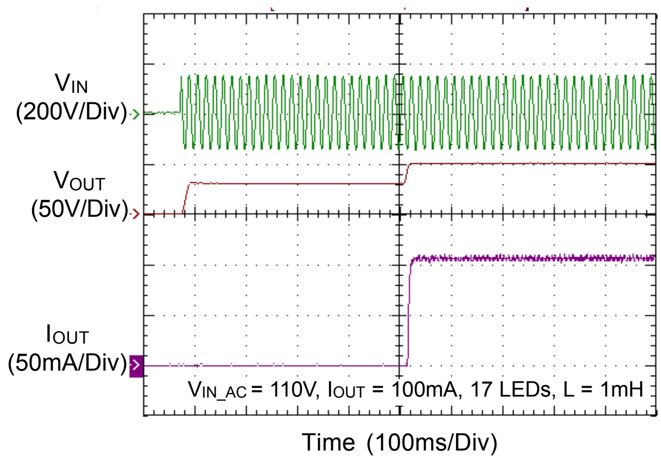
SENSE Threshold vs. Temperature

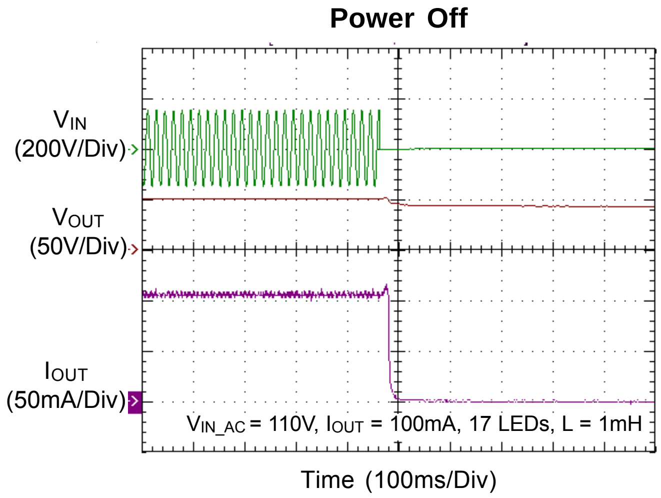


GATE Voltage and Inductor Current



Power On




Power Off
VIN (200V/Div)
VOUT (50V/Div)
IOUT (50mA/Div)
VIN_AC = 110V, IOUT = 100mA, 17 LEDs, L = 1mH
Time (100ms/Div)

Application Information

The RT8468 is a high efficiency PWM Buck LED driver for high brightness LED application. Its high side floating gate driver is used to control the Buck converter with internal MOSFET and regulate the constant output current.

The RT8468 can achieve high accuracy LED output current via the average current feedback loop control. The internal sense voltage (220mV typ.) is used to set the average output current. The oscillator frequency is fixed at 47kHz to get better switching performance. Once the average current is set by the external resistor, R_S, the output LED current can be dimmed by varying the ACTL voltage.

Under Voltage Lockout (UVLO)

The RT8468 includes a UVLO feature with 9V hysteresis. The GATE terminal turns on when V_{IN} rises over 17V (typ.). The GATE terminal turns off when V_{IN} falls below 8V (typ.).

Setting Average Output Current

The output current that flows through the LED string is set by an external resistor, R_S, which is connected between the GND and SENSE terminal. The relationship between output current, I_{OUT}, and R_S is shown below :

$$I_{OUT} = \frac{0.22}{R_S} \quad (A)$$

Analog Dimming Control

The ACTL terminal is driven by an external voltage, V_{ACTL}, to adjust the output current to an average value set by R_S. The voltage range for V_{ACTL} to adjust the output current is from 0.2V to 1.3V. If V_{ACTL} becomes larger than 1.3V, the output current value will just be determined by the external resistor, R_S.

$$I_{OUTavg} = (0.22V/R_S) \times \frac{V_{ACTL} - 0.2}{1.1}$$

Component Selection

For component selection, an example is shown below for a typical RT8468 application, where V_{IN} = 110 to 90VAC/60Hz, LED output voltage = 30V, and output current = 200mA. The user can follow this procedure to design applications with wider AC voltage input and DC output voltage as well.

Start-up Resistor

Start-up resistor should be chosen not to exceed the maximum start-up current. Otherwise, the RT8468 may latch low and will never start. Start-up current = 130V/R1 for 110VAC regions, 260V/R1 for 220VAC regions. The typical start-up current is 250μA.

Input Diode Bridge Rectifier Selection

The current rating of the input bridge rectifier is dependent on the V_{OUT}/V_{IN} transformation ratio. The voltage rating of the input bridge rectifier, V_{BR}, on the other hand, is only dependent on the input voltage. Thus, the V_{BR} rating is calculated as below :

$$V_{BR} = 1.2 \times (\sqrt{2} \times V_{AC(MAX)})$$

where $V_{AC(MAX)}$ is the maximum input voltage (RMS) and the parameter 1.2 is used for safety margin.

For this example :

$$V_{BR} = 1.2 \times (\sqrt{2} \times V_{AC(MAX)}) = (1.2 \times \sqrt{2} \times 110) = 187V$$

If the input source is universal, V_{BR} will reach 466V. In this case, a 500V, 0.5A bridge rectifier can be chosen.

Input Capacitor Selection

The input capacitor supplies the peak current to the inductor and flattens the current ripple on the input. The low ESR condition is required to avoid increasing power loss. The ceramic capacitor is recommended due to its excellent high frequency characteristic and low ESR. For maximum stability over the entire operating temperature range, capacitors with better dielectric are suggested. The minimum capacitor is given by :

$$C_{IN} \geq \frac{V_{OUT(MAX)} \times I_{OUT(MAX)}}{\left[(\sqrt{2} \times V_{AC(MIN)})^2 - V^2_{DC(MIN)}\right] \times \eta \times f_{AC}}$$

where f_{AC} is the AC input source frequency and η is the efficiency of whole system.

Notice that $V_{DC(MIN)}$ is the minimum voltage at bridge rectifier, output and $V_{DC(MIN)}$ should be larger than 2 x $V_{OUT(MAX)}$.

For a 90 to 264V_{AC} universal input range, the $V_{DC(MIN)}$ is 90V, therefore the LED string voltage $V_{OUT(MAX)}$ should be less than 45V.

For this particular example :

$$C_{IN} \geq \frac{30 \times 0.2}{\left[(\sqrt{2} \times 90)^2 - 90^2\right] \times 0.9 \times 60} = 13.7\mu F$$

In addition, the voltage rating of the input filter capacitor, V_{CIN}, should be large enough to handle the input voltage.

$$V_{CIN} \geq (1.2 \times \sqrt{2} \times V_{AC(MAX)}) = (1.2 \times \sqrt{2} \times 110) = 187V$$

Thus, a 22µF / 250V electrolytic capacitor can be chosen in this case. Due to its large ESR, the electrolytic capacitor is not suggested for high current ripple applications.

Inductor Selection

The inductor value and operating frequency determine the ripple current according to a specific input and output voltage. The ripple current, ΔI_L, increases with higher V_{IN} and decreases with higher inductance, as shown in equation below :

$$\Delta I_L = \left[\frac{V_{OUT}}{f \times L}\right] \times \left[1 - \frac{V_{OUT}}{V_{IN}}\right]$$

To optimize the ripple current, the RT8468 operates the Buck converter in BCM (Boundary-Condition Mode). The largest ripple current will occur at the highest V_{IN}. To guarantee that the ripple current stays below the specified value, the inductor value should be chosen according to the following equation :

$$L = \frac{V_{OUT} \times T_S \times (1 - D)}{2 \times I_{OUT}}$$

$$= \frac{30 \times 20.83\mu s \times (1 - 0.333)}{2 \times 0.2} = 1.04mH$$

where D is the duty cycle and T_S is the switching period.

Forward Diode Selection

When the power switch turns off, the path for the current is through the diode connected between the switch output and ground. This forward biased diode must have minimum voltage drop and recovery time. The reverse voltage rating of the diode should be greater than the maximum input voltage and the current rating should be greater than the maximum load current.

In reality, the peak current through the diode is more than the maximum output current. This component current rating should be greater than 1.2 times the maximum load current and the diode reverse voltage rating should be greater than 1.2 times the maximum input voltage, assuming a ± 20% output current ripple.

The peak voltage stress of diode is :

$$V_D = 1.2 \times (\sqrt{2} \times V_{AC(MAX)}) = 1.2 \times (\sqrt{2} \times 110) = 187V$$

The current rating of diode is :

$$I_D = 1.2 \times I_{OUT,PK} = 1.2 \times 1.2 \times 0.2 = 0.288A$$

If the input source is universal (V_{IN} = 90V to 264V), V_D will reach 466V. A 500V, 2A ultra-fast diode can be used in this example.

Output Capacitor Selection

The selection of C_{OUT} is determined by the required ESR to minimize output voltage ripple. Moreover, the amount of bulk capacitance is also a key for C_{OUT} selection to ensure that the control loop is stable. Loop stability can be checked by viewing the load transient response. The output voltage ripple, ΔV_{OUT}, is determined by :

$$\Delta V_{OUT} = \frac{V_O \times (1 - D)}{8 \times L \times C_{OUT} \times f_{OSC}{}^2}$$

where f_{OSC} is the switching frequency. Multiple capacitors placed in parallel may be needed to meet the ESR and RMS current handling requirement. Dry tantalum, special polymer, aluminum electrolytic and ceramic capacitors are all common selections and available in surface mount packages. Tantalum capacitors have the highest capacitance density, but it is important to only use ones that pass the surge test for use in switching power supplies. Special polymer capacitors offer very low ESR value, but with the trade-off of lower capacitance density. Aluminum electrolytic capacitors have significantly higher ESR, but still can be used in cost-sensitive applications for ripple current rating and long term reliability considerations.

Thermal Protection

A thermal protection feature is included to protect the RT8468 from excessive heat damage. When the junction temperature exceeds a threshold of 150°C, the thermal protection will turn off the GATE terminal.

Soldering Process of Pb-free Package Plating

To meet the current RoHS requirements, pure tin is selected to provide forward and backward compatibility with both the current industry standard SnPb-based soldering processes and higher temperature Pb-free processes. In the whole Pb-free soldering processes pure tin is required with a maximum 260°C (<10s) for proper soldering on board, referring to J-STD-020 for more information.

Thermal Considerations

For continuous operation, do not exceed absolute maximum junction temperature. The maximum power dissipation depends on the thermal resistance of the IC package, PCB layout, rate of surrounding airflow, and difference between junction and ambient temperature. The maximum power dissipation can be calculated by the following formula :

$P_{D(MAX)} = (T_{J(MAX)} - T_A) / \theta_{JA}$

where $T_{J(MAX)}$ is the maximum junction temperature, T_A is the ambient temperature, and θ_{JA} is the junction to ambient thermal resistance.

For recommended operating condition specifications, the maximum junction temperature is 125°C. The junction to ambient thermal resistance, θ_{JA}, is layout dependent. For SOP-7 package, the thermal resistance, θ_{JA}, is 200.2°C/W on a standard JEDEC 51-7 four-layer thermal test board. The maximum power dissipation at T_A = 25°C can be calculated by the following formula :

$P_{D(MAX)}$ = (125°C − 25°C) / (200.2°C/W) = 0.5W for SOP-7 package

The maximum power dissipation depends on the operating ambient temperature for fixed $T_{J(MAX)}$ and thermal resistance, θ_{JA}. The derating curve in Figure 1 allows the designer to see the effect of rising ambient temperature on the maximum power dissipation.

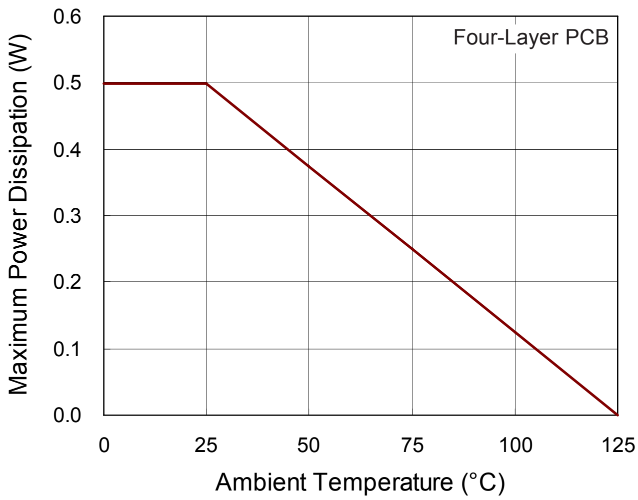


Figure 1. Derating Curve of Maximum Power Dissipation

Layout Considerations

For best performance of the RT8468, the following layout guidelines should be strictly followed.

- The hold up capacitor, C1, must be placed as close as possible to the VCC pin.
- The output capacitor, C_{OUT}, must be placed as close as possible to the LED terminal.
- The power ground (PGND) should be connected to a strong ground plane.
- Place the sense resistor R_S as close to the SOURCE pin as possible.
- Keep the main current traces as short and wide as possible.
- Place L1, R_S, and D_F as close to each other as possible.

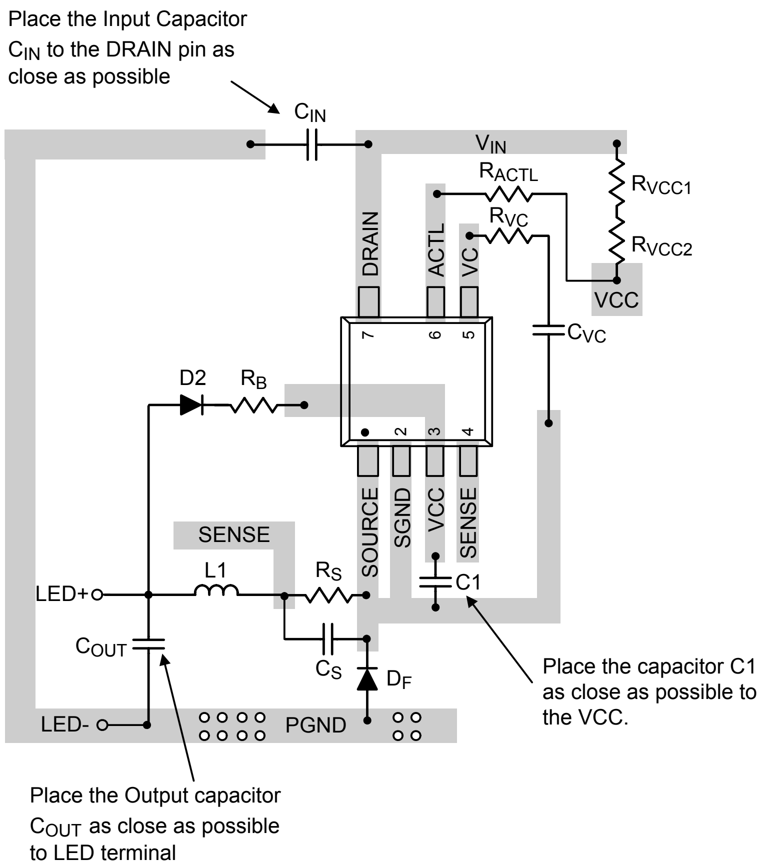
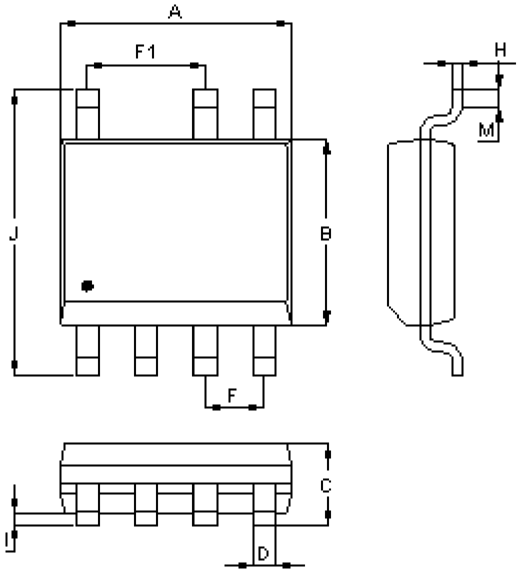


Figure 2. PCB Layout Guide

Outline Dimension



Symbol	Dimensions In Millimeters		Dimensions In Inches	
	Min.	Max.	Min.	Max.
A	4.801	5.004	0.189	0.197
B	3.810	3.988	0.150	0.157
C	1.346	1.753	0.053	0.069
D	0.330	0.510	0.013	0.020
F	1.194	1.346	0.047	0.053
F1	2.464	2.616	0.097	0.103
H	0.100	0.254	0.004	0.010
I	0.050	0.254	0.002	0.010
J	5.791	6.200	0.228	0.244
M	0.400	1.270	0.016	0.050

7-Lead SOP Plastic Package

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