Green Mode Buck Converter

General Description

The RT8409 integrates a power MOSFET controller. It is used for step down converters by well controlling the internal MOSFET and regulating a constant output voltage.

The RT8409 features few system component counts and simple system design. Especially, the RT8409 can use a cheap simple drum core inductor in the system instead of an EE core while maintaining the high efficiency.

The RT8409 is housed in a SOP-8 package. The components of the whole system can be made very compact.

Ordering Information

RT8409□□

- Package Type
  S : SOP-8
- 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.

Marking Information

RT8409 GSYMDNN •

RT8409GS : Product Number

YMDNN : Date Code

Features

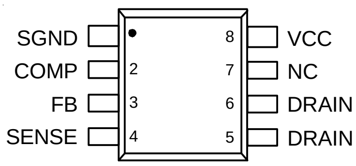
- **Built-In 600V Power MOSFET**
- **Programmable Constant Output Voltage**
- **Extremely Low Quiescent Current Consumption and 1μA Shutdown Current**
- **Low System BOM Cost for Economical Step Down Converter Solution**
- **Universal Off-Line Input Voltage operation Range**
- **Built-In Over-Temperature Protection**
- **Built-In Over-Voltage Protection**
- **Output Open Protection**
- **Output Short Protection**
- **Output Over-Current Protection**
- **SOP-8 Package**

Applications

- Home Appliance
- Standby Power

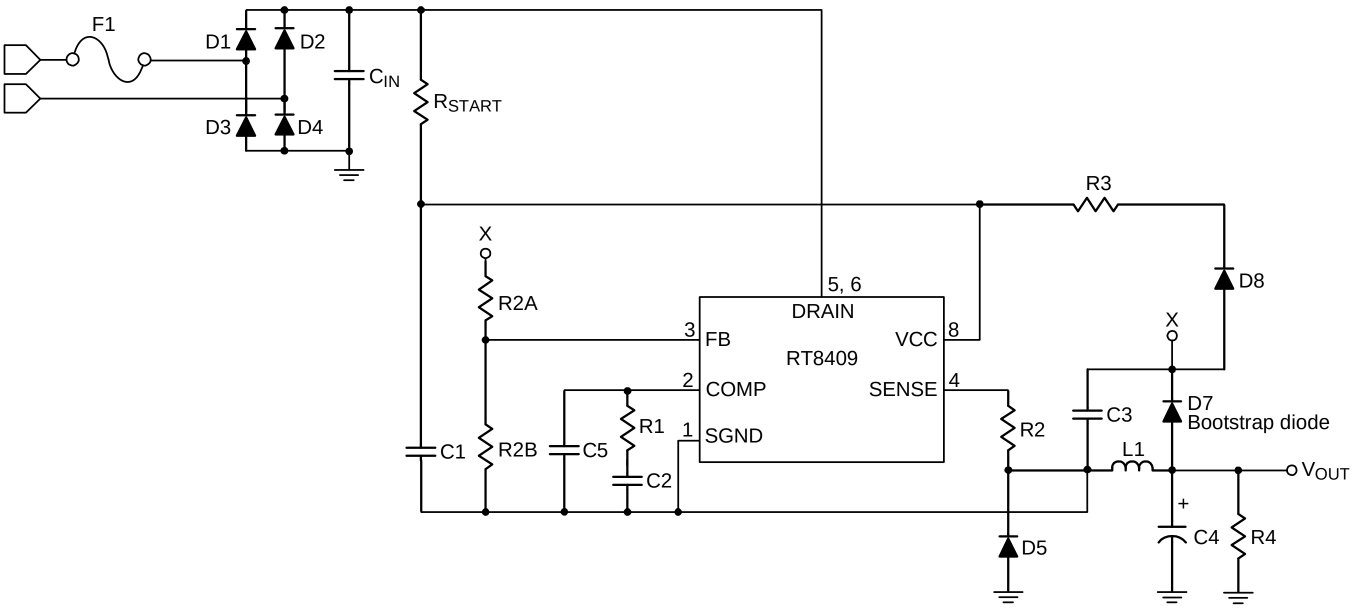
Pin Configuration

(TOP VIEW)



SOP-8

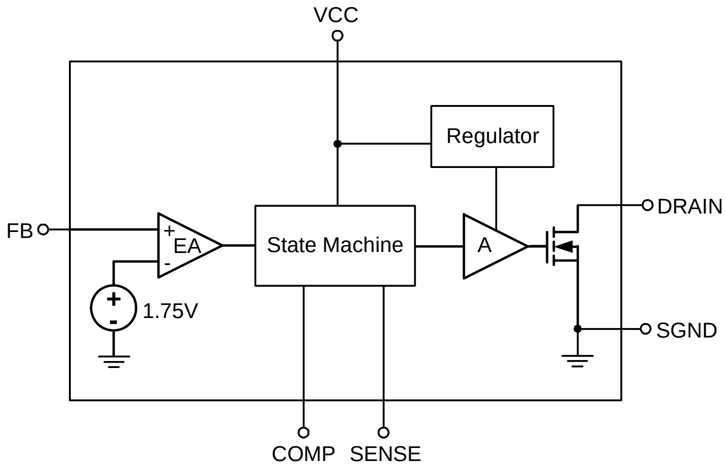
Typical Application Circuit



Functional Pin Description

Pin No.	Pin Name	Pin Function
1	SGND	Signal ground of the chip.
2	COMP	Close loop compensation node.
3	FB	Error amplifier input.
4	SENSE	Current sense input.
5, 6	DRAIN	Internal MOSFET drain.
7	NC	No internal connection.
8	VCC	Supply voltage input of the chip. For good bypass, a ceramic capacitor near the VCC pin is required.

Functional Block Diagram



Operation

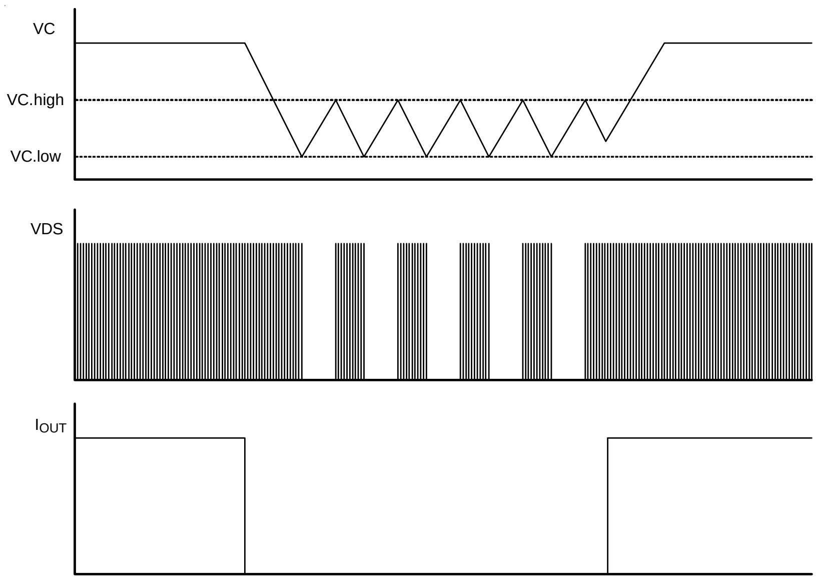
The RT8409 senses the output voltage via the bootstrap loop. The output voltage feedback signal is compared to an internal reference voltage for the output voltage regulation. The COMP pin, which is the operational amplifier output node, is used for the control loop compensation to obtain stable response. To stabilize the system properly select the compensation network is required.

The FB pin is the voltage loop input for the system regulation. The above COMP pin related compensation will be determined by specified system demand and be adapted to various applications.

Burst Mode

For the no load power saving demand, burst mode is a way to save power and maintain output regulation. High efficiency is achieved at light loads when Burst Mode operation is entered. The typical burst mode trigger levels are defined as follows. The MOSFET will stop switching when VC voltage goes lower than 200mV (typ.). The MOSFET will resume switching again once the VC voltage goes higher than 300mV (typ.).

In this mode the output ripple has a variable frequency component that depends upon load current. Burst Mode operation ripple can be reduced slightly by using more output capacitance.



Absolute Maximum Ratings (Note 1)

- Supply Input Voltage, VCC ---------- 40V
- Power Dissipation, P_D @ T_A = 25°C
  SOP-8 ---------- 0.48W
- Package Thermal Resistance (Note 2)
  SOP-8, θ_{JA} ---------- 206.9°C/W
- Lead Temperature (Soldering, 10 sec.) ---------- 260°C
- Junction Temperature ---------- 150°C
- Storage Temperature Range ---------- –65°C to 150°C
- ESD Susceptibility (Note 3)
  HBM (Human Body Model) ---------- 2kV

Recommended Operating Conditions (Note 4)

- Supply Input Voltage Range, VCC ---------- 11V to 22V
- Junction Temperature Range ---------- –40°C to 125°C
- Ambient Temperature Range ---------- –40°C to 85°C

Electrical Characteristics

(V_{CC} = 15V, T_A = 25°C, unless otherwise specified)

Parameter	Symbol	Test Conditions	Min	Typ	Max	Unit
VCC UVLO ON	V_{UVLO_ON}		17	18	19	V
VCC UVLO OFF	V_{UVLO_OFF}		6.5	7	8	V
VCC Shutdown Current	I_{SD}	$V_{CC} = V_{UVLO\_ON} - 3V$	--	1.5	3	μA
VCC Quiescent Current	I_{QC}	Gate stands still	--	0.5	2	mA
VCC Operating Current	I_{CC}	By C_{GATE} = 1nF, Freq.= 20kHz	--	1	2	mA
VCC OVP Level	V_{CC_OVP}		23.75	25	26.25	V
Current Sense Threshold	V_{SENSE}		0.97	1.04	1.11	V
Sense Pin Leakage Current	I_{SENSE}	V_{SENSE} = 3V	--	1	5	μA
FB Pin Threshold	V_{FB}		1.7	1.75	1.8	V
FB Over Voltage Protection	V_{FB_OVP}		1.82	1.96	2.1	V
FB Pin Leakage Current	I_{FB}	V_{FB} = 5V	--	1	3	μA
Switch Off Time	t_{OFF}		18	25	32	μs
Static Drain-Source On-Resistance	$R_{DS(ON)}$	V_{GD} = 12V, I_D = 50mA	--	6	--	Ω
Drain-Source Leakage Current	I_{DSS}	V_{DS} = 600V	--	--	10	μA

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.

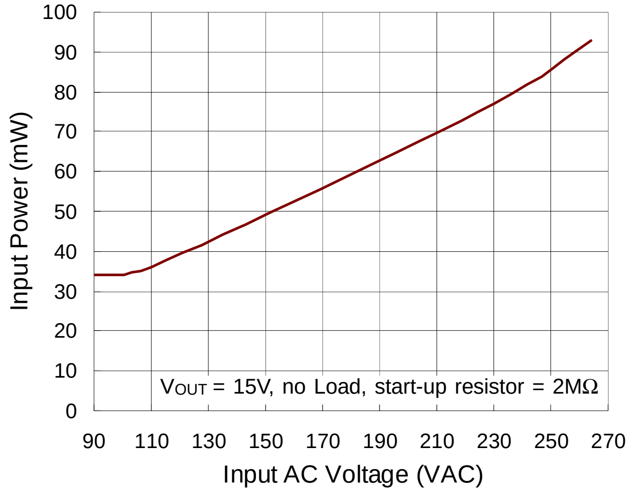
Note 2. θ_{JA} is measured under natural convection (still air) at T_A = 25°C with the component mounted on a low effective-thermal-conductivity two-layer test board on a JEDEC thermal measurement standard.

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

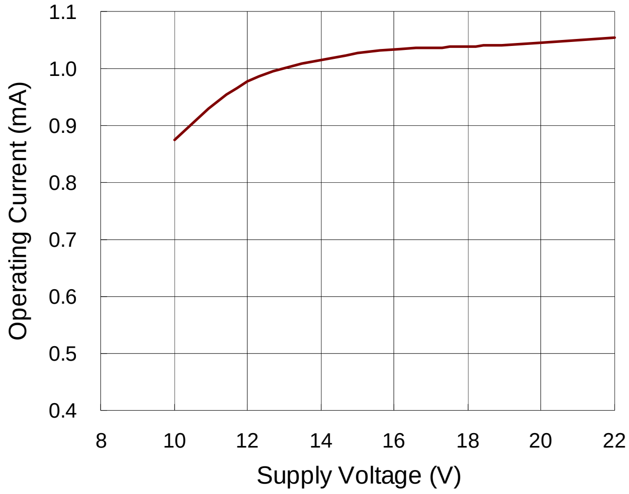
Note 4. The device is not guaranteed to function outside its operating conditions.

Typical Operating Characteristics

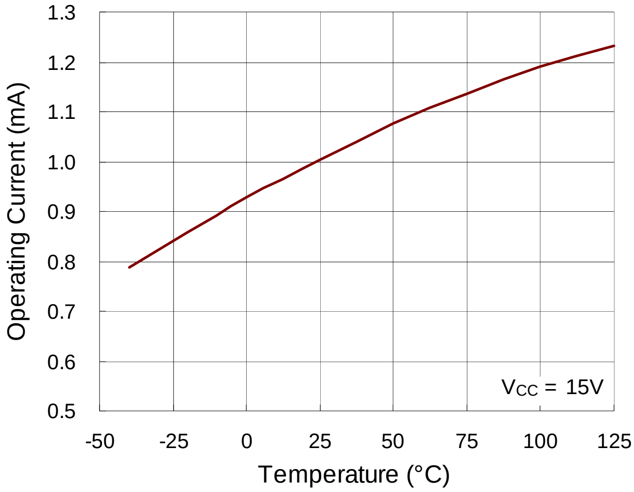
Standby Power



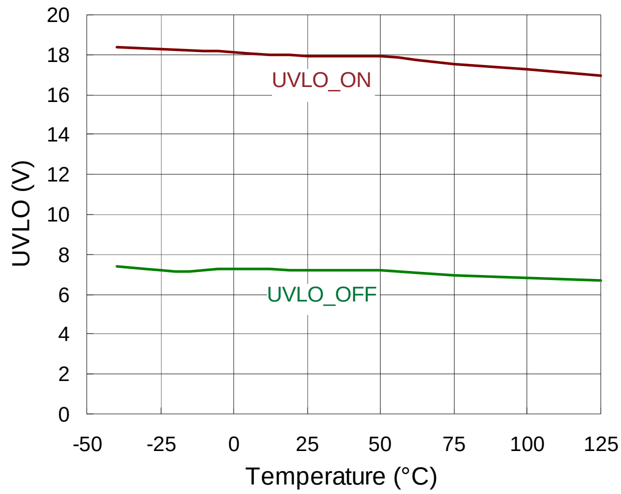
Operating Current vs. Supply Voltage



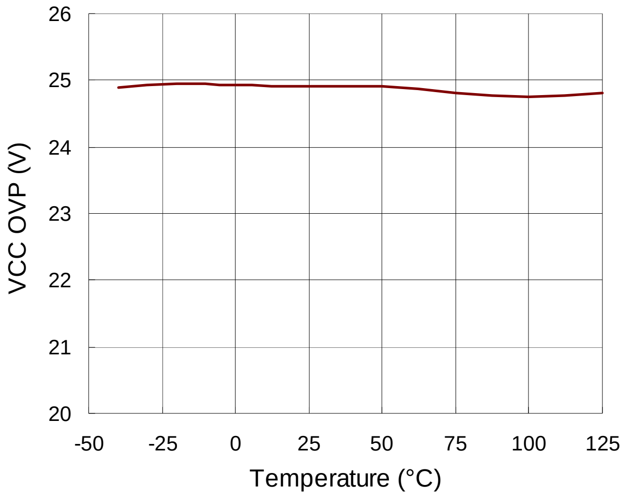
Operating Current vs. Temperature



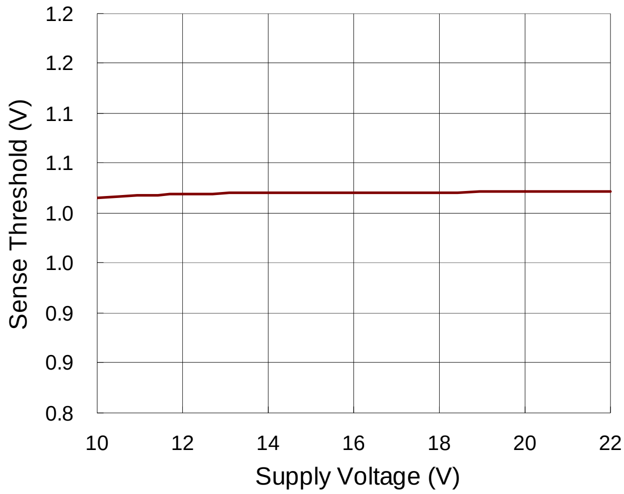
UVLO vs. Temperature



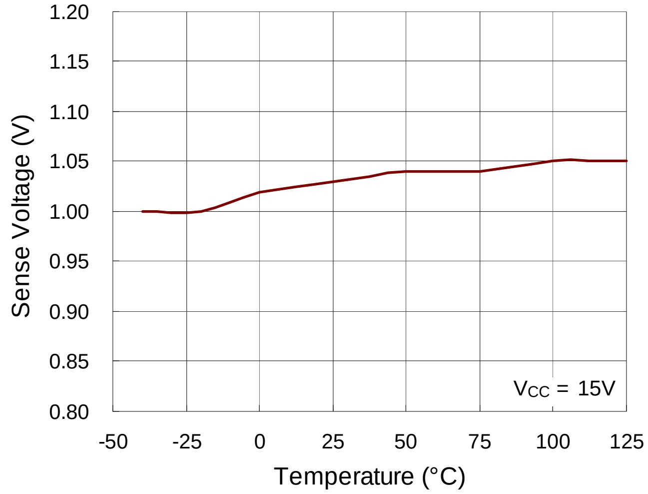
VCC OVP vs. Temperature



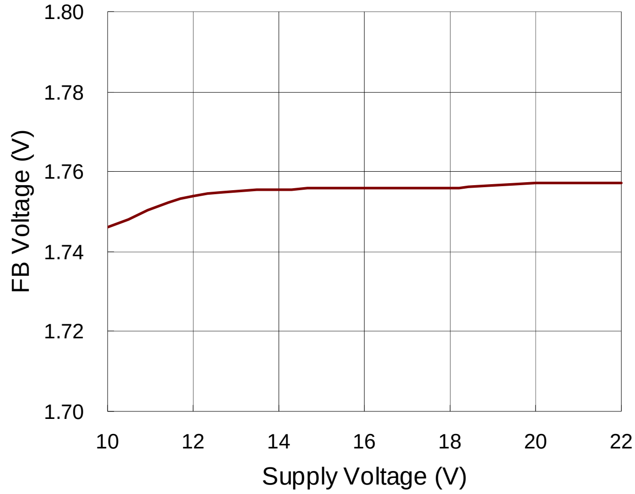
Sense Threshold vs. Supply Votatge



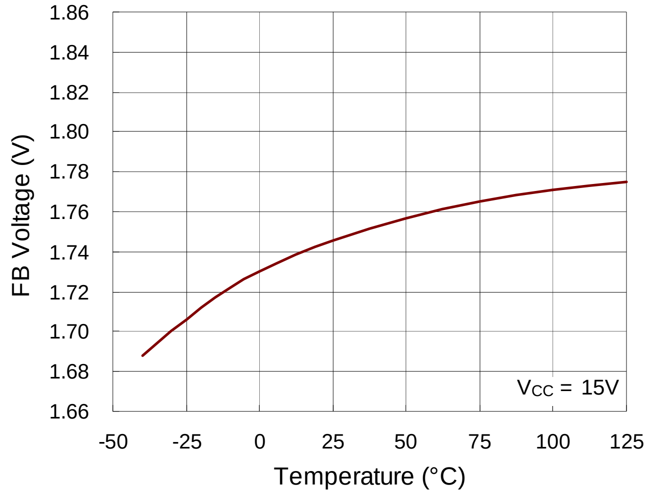
Sense Threshold vs. Temperature



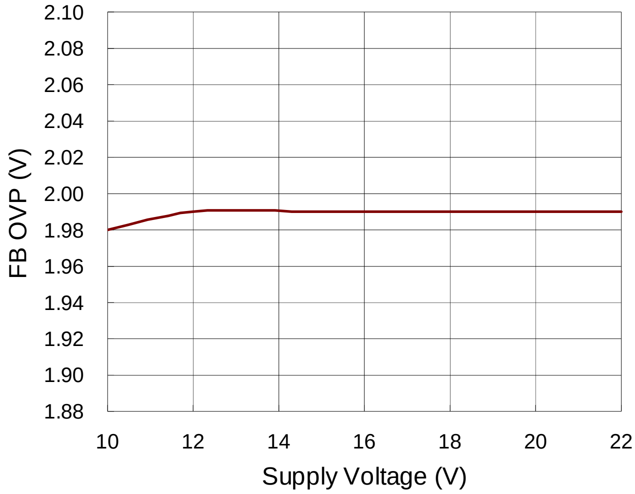
FB Voltage vs. Supply Voltage



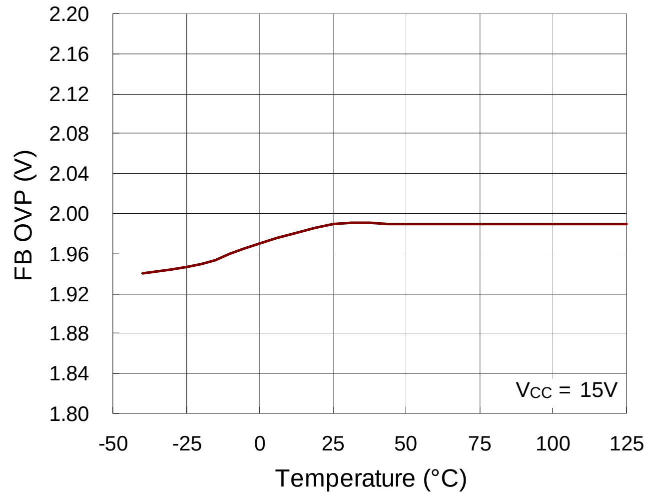
FB Voltage vs. Temperature



FB OVP vs. Supply Voltage



FB OVP vs. Temperature



Applications Information

The RT8409 is a constant off time control, high efficiency constant voltage high side converter with internal MOSFET. It can be used in buck down solution, to provide a constant output voltage to the load. It contains high side bootstrap voltage sense circuitry, while minimizing external component count. The SOP8 package keeps application footprint small, and makes the RT8409 a cost effective solution for off-line buck converter.

The RT8409 can achieve high accuracy output voltage via FB pin, which is the average output voltage sense feedback loop control pin. The internal FB reference voltage (1.75V typ.) is used to set the average output voltage by the external resistor, R2A, R2B. The sense voltage from sense pin is used for Over Current Protection (OCP) function.

Under-Voltage Lockout (UVLO)

The RT8409 includes a UVLO function with 11V hysteresis.

For system start up, the VCC must rise over 18V (typ.) to turn on the internal MOSFET.

The internal MOSFET will be turned off if VCC falls below 7V (typ.)

Setting Average Output Voltage

The output voltage that provides to the output load is set by external resistors, R2A, R2B, which is connected between the cathode of D7 and SGND pins. The relationship between output voltage, and R2A, R2B is shown below :

$$V_{OUT} = \frac{R_{2A} + R_{2B}}{R_{2B}} \times 1.75V + V_{F\_D7} - V_{F\_D5}$$

Start-Up Resistor

The start-up resistor should be chosen to set the start up current exceeds certain minimum value. Otherwise, the RT8409 may latch off and the system will never start. The start-up current equals

$$\frac{\left(\sqrt{2} \times 90V\right)}{R_{START}}$$

where 90V is assumed the minimum line input voltage.

The typical required minimum start-up current is 60μA. The recommended total start-up resistance R_{START} for universal inputs should be no more than 2MΩ.

Input Diode Bridge Rectifier Selection

The voltage rating of the input bridge rectifier, VBR, dependent on the input voltage. Thus, the VBR rating is calculated as below :

$$VBR = 1.2 \times \left(\sqrt{2} \times VAC\ (MAX)\right)$$

where VAC(MAX) is the maximum input voltage (RMS) and the parameter 1.2 is used for safety margin.

For this example :

$$VBR = 1.2 \times \left(\sqrt{2} \times VAC(MAX)\right) = \left(1.2 \times \sqrt{2} \times 264\right) = 448V$$

If the input source is universal, VBR will reach 448V. In this case, a 600V, 0.5A bridge rectifier can be chosen.

Inductor Selection

For best efficiency, the RT8409 should be operated near boundary conduction mode. Based on this recommendation, the required inductor value is related to the input voltage, output voltages, the min. on-time and the max. off time. The inductor saturation current will be related to the over current limit set by the sense resistor between the sense pin and ground pin. The over current limit design information can be found in the later section.

The peak current of inductor is showed as below :

$$I_{PEAK} = \frac{V_{IN} - V_{OUT}}{L} \times t_{ON}$$

$$L \le \frac{\left(V_{IN} - V_{OUT}\right) \times \left(V_{OUT} + V_{F\_D5}\right)}{2 \times f_{SW} \times I_{OUT} \times V_{IN}}$$

$$t_{ON} = \frac{V_{OUT}}{V_{IN} - V_{OUT}} \times t_{OFF\_1}$$

$$t_{OFF\_1} = \frac{K_b + \sqrt{K_b^2 + 4 \times K_a \times K_c}}{2 \times K_a}$$

$$K_a = \frac{V_{OUT} \times V_{IN}}{L \times \left(V_{IN} - V_{OUT}\right)}$$

$$K_b = \frac{V_{OUT} \times I_{OUT}}{V_{IN} - V_{OUT}}$$

$$K_c = I_{OUT} \times t_{OFF}$$

Where

V_{OUT} is output voltage.

V_{IN} is input voltage.

I_{OUT} is full load current.

f_{SW} is switching frequency from 30kHz to 55kHz.

t_{OFF} is constant off time (25μs, Typ.).

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.

The peak voltage stress of diode is :

$$VD = 1.2\times\left(\sqrt{2}\times VAC(MAX)\right) = \left(1.2\times\sqrt{2}\times 264\right) = 448V$$

The input source is universal (V_{IN} = 90V to 264V), VD will reach 448V.

Bootstrap Diode Selection

The bootstrap diode is connected the switch output to provide supply voltage for VCC, and output voltage for FB divided resistors. The reverse voltage rating of the diode should be greater than maximum input voltage. A fast diode can be used, such as ES1J or FR107.

Sense Resistor Selection

The resistor, R5, between the Source of the external N-MOSFET and SGND should be selected to provide adequate switch current to drive the application without exceeding the current limit threshold set by the SENSE pin sense threshold of the RT8409. The Sense resistor value can be calculated according to the formula below :

$$R2 = \frac{V_{CLT}}{I_{OCP}}$$

where V_{CTL} is the current limit threshold (0.97V, min.).

I_{OCP} is about 1.2 to 1.5 times of the peak inductor current.

Thermal Protection (OTP)

A thermal protection feature is included to protect the RT8409 from excessive heat damage. When the junction temperature exceeds a threshold of 150°C, the thermal protection OTP will be triggered and the RT8409 will be turned off.

Thermal Considerations

The junction temperature should never exceed the absolute maximum junction temperature $T_{J(MAX)}$, listed under Absolute Maximum Ratings, to avoid permanent damage to the device. The maximum allowable power dissipation depends on the thermal resistance of the IC package, the PCB layout, the rate of surrounding airflow, and the difference between the junction and ambient temperatures. The maximum power dissipation can be calculated using 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 continuous operation, the maximum operating junction temperature indicated under Recommended Operating Conditions is 125°C. The junction-to-ambient thermal resistance, θ_{JA}, is highly package dependent. For a SOP-8 package, the thermal resistance, θ_{JA}, is 206.9°C/W on a standard JEDEC low effective-thermal-conductivity two-layer test board. The maximum power dissipation at T_A = 25°C can be calculated as below :

$P_{D(MAX)}$ = (125°C − 25°C) / (206.9°C/W) = 0.48W for a SOP-8 package.

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

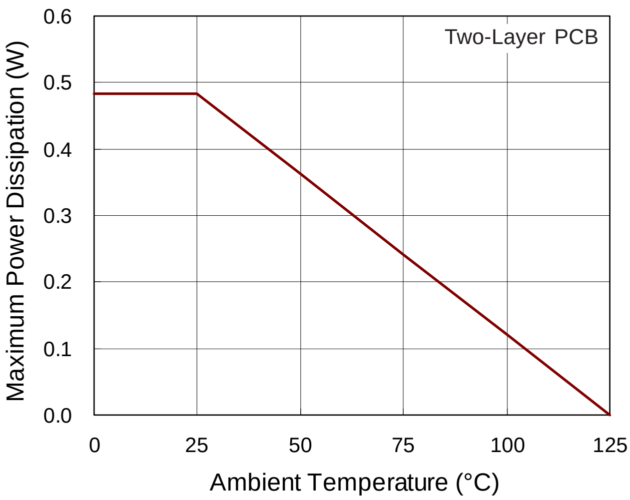


Figure 1. Derating Curve of Maximum Power Dissipation

Layout Consideration

For best performance of the RT8409, 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 compensation component C2 and R1, must be placed as close as possible to the COMP pin.
- The IC SOURCE pin are high frequency switching nodes. The traces must be as wide and short as possible.
- Keep the main traces with switching current as short and wide as possible.
- Place C_{IN}, L1, R2, C_{OUT}, and D5 as close to each other as possible.

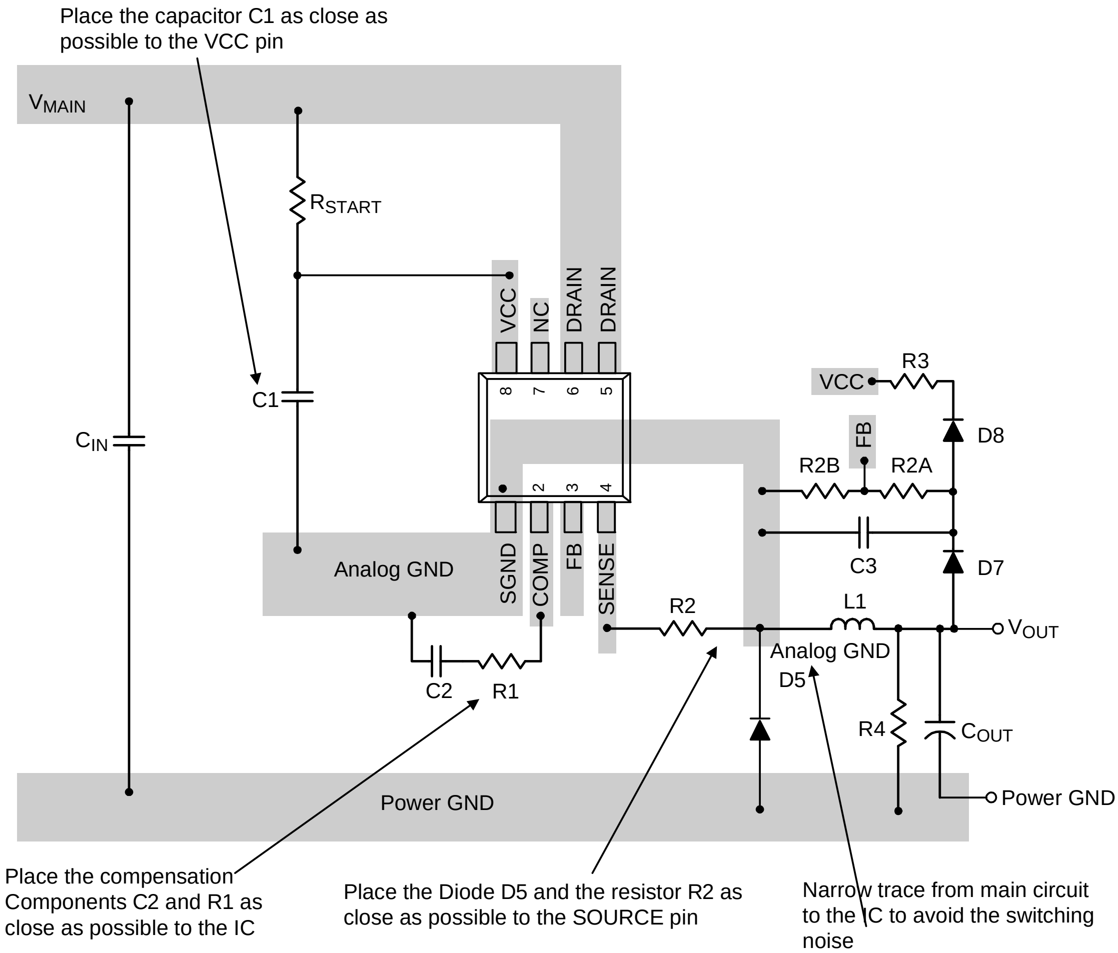
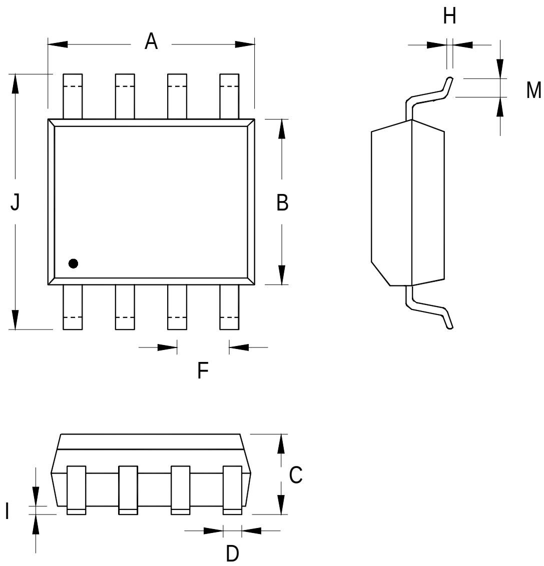


Figure 2. PCB Layout Guide

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	0.508	0.013	0.020
F	1.194	1.346	0.047	0.053
H	0.170	0.254	0.007	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

8-Lead SOP Plastic Package

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