4.5A Step-Up DC/DC Converter

General Description

The RT8509A is a high performance switching Boost converter that provides a regulated supply voltage for active matrix thin film transistor (TFT) liquid crystal displays (LCDs).

The RT8509A incorporates current mode, fixed-frequency, pulse width modulation (PWM) circuitry with a built in N-MOSFET to achieve high efficiency and fast transient response.

The RT8509A has a wide input voltage range from 2.8V to 14V. In addition, the output voltage can be adjusted up to 24V via an external resistive voltage divider. The maximum peak current is limited to 4.5A (min.). Other features include adjustable soft-start, over-voltage protection, and over-temperature protection.

The RT8509A is available in the WDFN-12L 5x5 package.

Marking Information

RT8509A GQW YMDNN ●	RT8509AGQW : Product Number YMDNN : Date Code

Features

- **90% Efficiency**
- **Adjustable Output Up to 24V**
- **2.8V to 14V Input Supply Voltage**
- **Input Supply Under-Voltage Lockout**
- **Fixed 1.2MHz Switching Frequency**
- **Adjustable Soft-Start**
- **V_{OUT} Over-Voltage Protection**
- **Over-Temperature Protection**
- **Thin 12-Lead WDFN Package**
- **RoHS Compliant and Halogen Free**

Applications

- GIP TFT-LCD Panels

Ordering Information

RT8509A□□

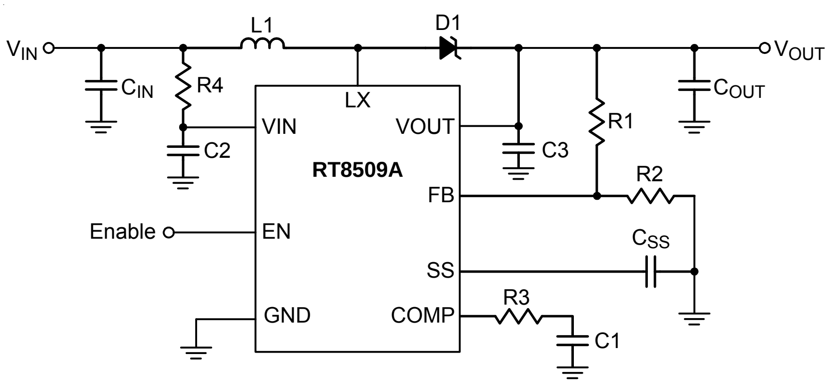
- Package Type
  QW : WDFN-12L 5x5 (W-Type)
- Lead Plating System
  G : Green (Halogen Free and Pb Free)

Note :

Richtek products are :

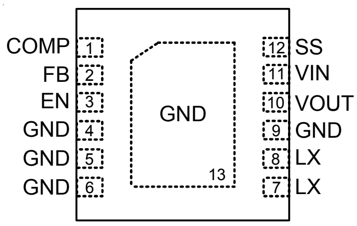
- RoHS compliant and compatible with the current requirements of IPC/JEDEC J-STD-020.
- Suitable for use in SnPb or Pb-free soldering processes.

Simplified Application Circuit



Pin Configurations

(TOP VIEW)

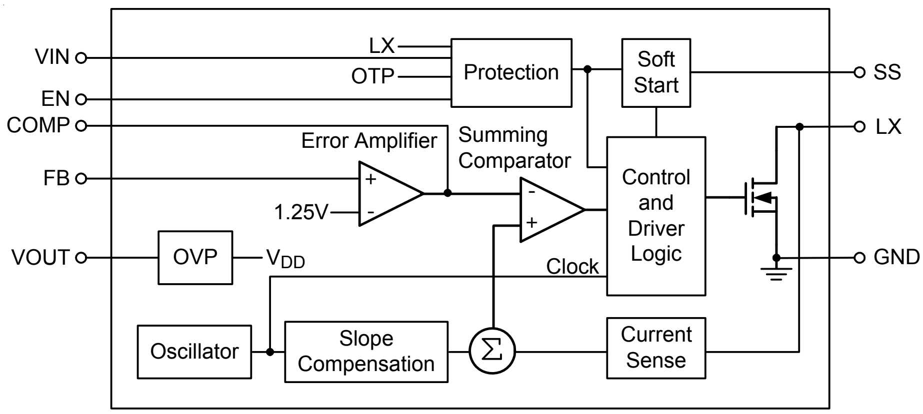


WDFN-12L 5x5

Functional Pin Description

Pin No.	Pin Name	Pin Function
1	COMP	Compensation Node for Error Amplifier. Connect a series RC from COMP to ground.
2	FB	Feedback Voltage Input. The FB regulation voltage is 1.25V nominal. Connect an external resistive voltage divider between the step-up regulator's output (V_{OUT}) and GND, with the center tap connected to FB. Place the divider close to the IC and minimize the trace area to reduce noise coupling.
3	EN	Enable Control Input. Drive EN low to turn off the Boost.
4, 5, 6, 9, 13 (Exposed Pad)	GND	Ground. The Exposed Pad must be soldered to a large PCB and connected to GND for maximum power dissipation.
7, 8	LX	Switch Node. LX is the Drain of the internal MOSFET. Connect the inductor/rectifier diode junction to LX and minimize the trace area for lower EMI.
10	VOUT	Over-Voltage Protection Input for Boost Converter. Bypass VOUT with a minimum 1μF ceramic capacitor directly to GND.
11	VIN	Supply Voltage Input. Bypass VIN with a minimum 1μF ceramic capacitor directly to GND.
12	SS	Soft-Start Time Setting. Connect a soft-start capacitor (C_{SS}) to this pin. The soft-start capacitor is charged with a constant current of 5μA. The soft-start capacitor is discharged to ground when EN is low.

Function Block Diagram



Operation

The RT8509A is a high-performance step-up DC/DC converter that provides a regulated and high precision supply voltage. It incorporates current mode, fixed-frequency, pulse-width modulation (PWM) circuitry with a built-in N-Channel power MOSFET to achieve high efficiency and fast transient response. The device features an adjustable soft start time using an external soft-start capacitor to reduce in-rush current.

Absolute Maximum Ratings (Note 1)

- LX to GND ---------- –0.3V to 28V
- VIN, EN to GND ---------- –0.3V to 16.5V
- Other Pins ---------- –0.3V to 6.5V
- Power Dissipation, P_D @ T_A = 25°C
  WDFN-12L 5x5 ---------- 3.38W
- Package Thermal Resistance (Note 2)
  WDFN-12L 5x5, θ_{JA} ---------- 29.5°C/W
  WDFN-12L 5x5, θ_{JC} ---------- 7.5°C/W
- Junction Temperature ---------- 150°C
- Storage Temperature Range ---------- –65°C to 150°C
- Lead Temperature (Soldering, 10sec.) ---------- 260°C
- ESD Susceptibility (Note 3)
  HBM (Human Body Model) ---------- 2kV
  MM (Machine Model) ---------- 200V

Recommended Operating Conditions (Note 4)

- Ambient Temperature Range ---------- –40°C to 85°C
- Junction Temperature Range ---------- –40°C to 125°C

Electrical Characteristics

(V_{IN} = 3.3V, V_{OUT} = 10V, T_A =25°C unless otherwise specified)

Parameter	Symbol	Test Conditions	Min	Typ	Max	Unit
Supply Current						
Input Voltage Range	V_{IN}		2.8	--	14	V
Output Voltage Range	V_{OUT}		--	--	24	V
Under Voltage Lockout Threshold	V_{UVLO}	V_{IN} Rising	--	2.5	3	V
UVLO Hysteresis	ΔV_{UVLO}		--	200	--	mV
VIN Quiescent Current	I_Q	V_{FB} = 1.3V, LX Not Switching	--	1	--	mA
		V_{FB} = 1V, LX Switching	--	5	--	
Thermal Shutdown Threshold	T_{SD}	Temperature Rising	--	155	--	°C
Thermal Shutdown Hysteresis	ΔT_{SD}		--	10	--	°C
VOUT Over Voltage Threshold		V_{OUT} Rising	--	26	--	V
Oscillator						
Oscillator Frequency	f_{OSC}		1000	1200	1500	kHz
Maximum Duty Cycle	D_{MAX}		--	90	--	%
Error Amplifier						
FB Regulation Voltage	V_{REF}		1.2312	1.25	1.2688	V
FB Input Bias Current	I_{FB}		--	--	100	nA
FB Line Regulation			--	0.05	0.2	%/V

<table>
<tr><th colspan="2">Parameter</th><th>Symbol</th><th>Test Conditions</th><th>Min</th><th>Typ</th><th>Max</th><th>Unit</th></tr>
<tr><td colspan="2">Transconductance</td><td>gm</td><td>ΔI = ±2.5μA at V_{COMP} = 1V</td><td>--</td><td>100</td><td>--</td><td>μA/V</td></tr>
<tr><td colspan="2">Voltage Gain</td><td>A_V</td><td>FB to COMP</td><td>--</td><td>700</td><td>--</td><td>V/V</td></tr>
<tr><td colspan="8">N-MOSFET</td></tr>
<tr><td colspan="2">Current Limit</td><td>I_{LIM}</td><td></td><td>4.5</td><td>5</td><td>--</td><td>A</td></tr>
<tr><td colspan="2">On-Resistance</td><td>$R_{DS(ON)}$</td><td></td><td>--</td><td>100</td><td>250</td><td>mΩ</td></tr>
<tr><td colspan="2">Leakage Current</td><td>I_{LEAK}</td><td>V_{LX} = 24V</td><td>--</td><td>30</td><td>45</td><td>μA</td></tr>
<tr><td colspan="2">Current Sense Transresistance</td><td>R_{CS}</td><td></td><td>--</td><td>0.25</td><td>--</td><td>V/A</td></tr>
<tr><td colspan="8">Soft-Start</td></tr>
<tr><td colspan="2">Charge Current</td><td></td><td></td><td>--</td><td>5</td><td>--</td><td>μA</td></tr>
<tr><td colspan="8">Control Inputs</td></tr>
<tr><td rowspan="2">EN Input Voltage</td><td>Logic-High</td><td>V_{IH}</td><td></td><td>1.5</td><td>--</td><td>--</td><td rowspan="2">V</td></tr>
<tr><td>Logic-Low</td><td>V_{IL}</td><td></td><td>--</td><td>--</td><td>0.5</td></tr>
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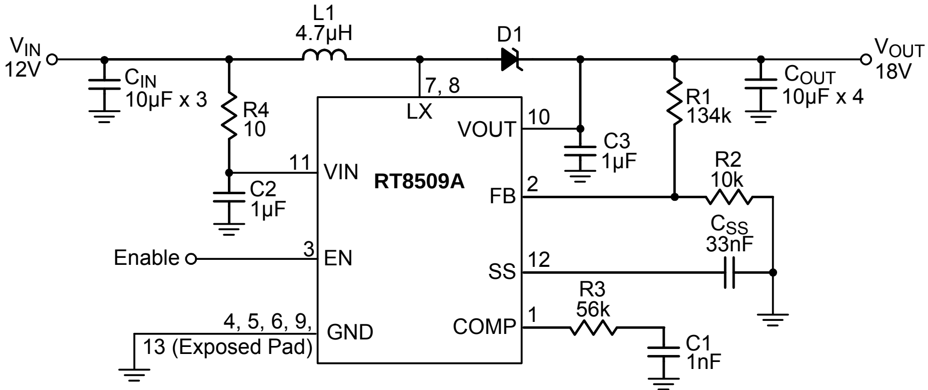
Note 1. Stresses beyond those listed "Absolute Maximum Ratings" may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated in the operational sections of the specifications is not implied. Exposure 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. θ_{JC} is measured at the exposed pad of the package.

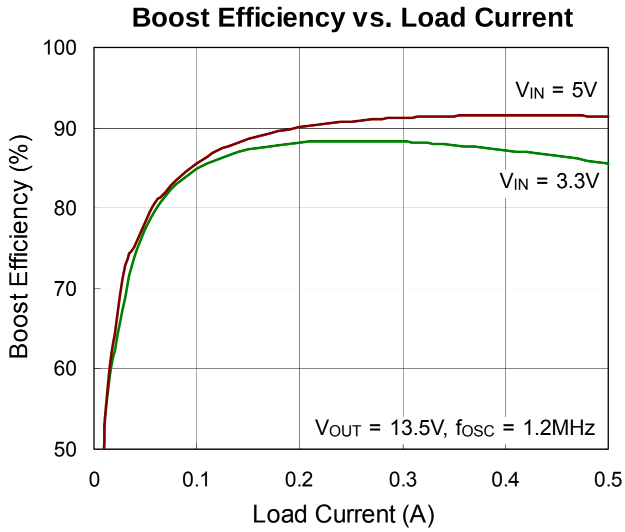
Note 3. Devices are ESD sensitive. Handling precaution is recommended.

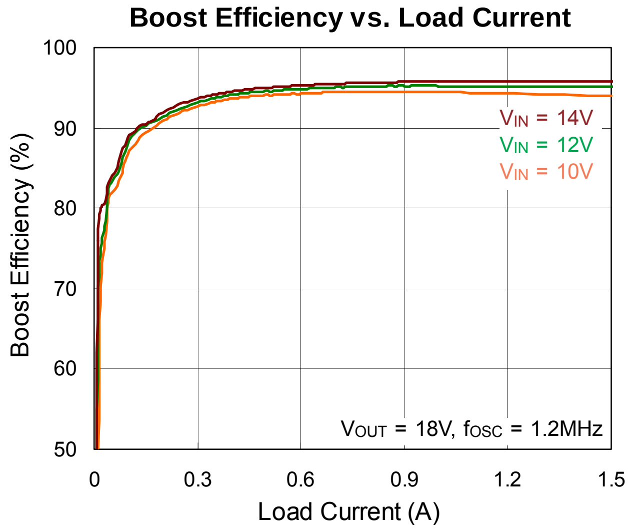
Note 4. The device is not guaranteed to function outside its operating conditions.

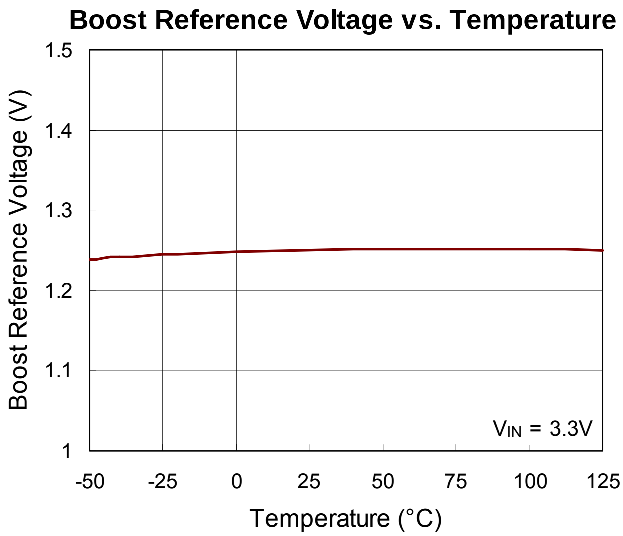
Typical Application Circuit

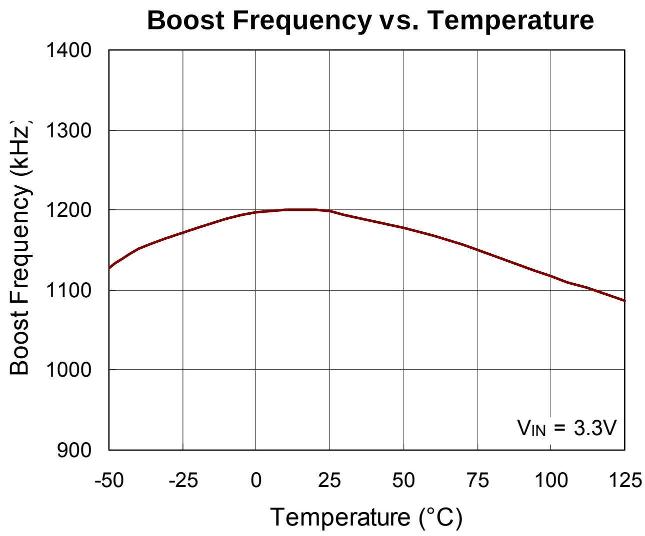


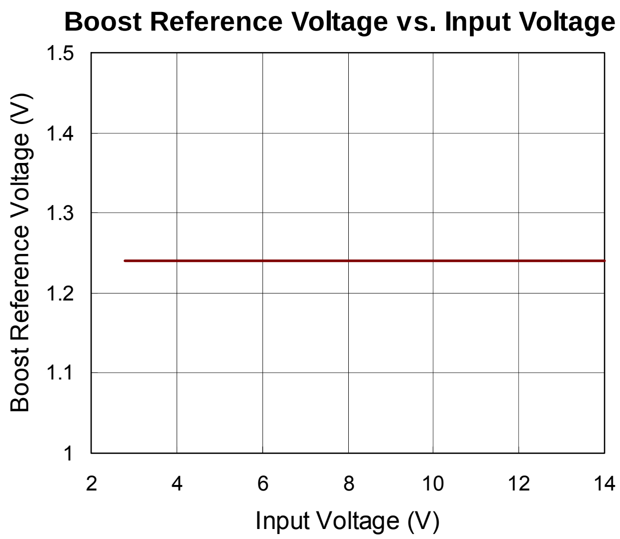
Typical Operating Characteristics

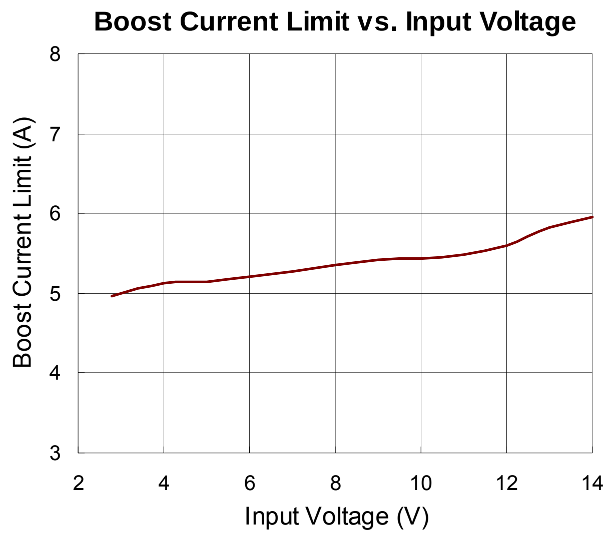












Application Information

The RT8509A is a high performance step-up DC/DC converter that provides a regulated supply voltage for panel source driver ICs. The RT8509A incorporates current mode, fixed frequency, Pulse Width Modulation (PWM) circuitry with a built-in N-MOSFET to achieve high efficiency and fast transient response. The internal driver power is supplied from the VOUT pin and that will increase efficiency when low input voltage condition. The following content contains detailed description and information for component selection.

Boost Regulator

The RT8509A is a current mode Boost converter integrated with a 24V/5A power switch, covering a wide V_{IN} range from 2.8V to 14V. It performs fast transient responses to generate source driver supplies for TFT-LCD display. The high operation frequency allows the use of smaller components to minimize the thickness of the LCD panel. The output voltage can be adjusted by setting the resistive voltage-divider sensing at the FB pin. The error amplifier varies the COMP voltage by sensing the FB pin to regulate the output voltage. For better stability, the slope compensation signal summed with the current sense signal will be compared with the COMP voltage to determine the current trip point and duty cycle. The Boost minimum gain ratio depends on minimum on-time. It's suggested that V_{OUT} higher than 1.2 x V_{IN} for better performance.

Soft-Start

The RT8509A provides soft-start function to minimize the inrush current. When powered on, an internal constant current charges an external capacitor. The rising voltage rate on the COMP pin is limited from V_{SS} = 0V to 1.24V and the inductor peak current will also be limited at the same time. When powered off, the external capacitor will be discharged until the next soft-start time.

The soft-start function is implemented by the external capacitor with a 5μA constant current charging to the soft-start capacitor. Therefore, the capacitor should be large enough for output voltage regulation. A typical value for soft-start capacitor is 33nF. The available soft-start capacitor range is from 10nF to 100nF.

If C_{SS} < 220pF, the internal soft-start function will be turned on and period time is approximately 1ms.

Output Voltage Setting

The regulated output voltage is shown as the following equation :

$$V_{OUT} = V_{REF} \times \left(1+\frac{R1}{R2}\right), \text{ where } V_{REF} = 1.25V \text{ (typ.)}$$

The recommended value for R2 should be at least 10kΩ without some sacrificing. Place the resistive voltage divider as close as possible to the chip to reduce noise sensitivity.

Loop Compensation

The voltage feedback loop can be compensated with an external compensation network consisting of R3. Choose R3 to set high frequency integrator gain for fast transient response and C1 to set the integrator zero to maintain loop stability. For typical application, V_{IN} = 5V, V_{OUT} = 13.6V, C_{OUT} = 4.7μF x 3, L1 = 4.7μH, while the recommended value for compensation is as follows : R3 = 56kΩ, C1 = 1nF.

Over-Current Protection

The RT8509A Boost converter has over-current protection to limit the peak inductor current. It prevents the inductor and diode from damage due to large current. During the On-time, once the inductor current exceeds the current limit, the internal LX switch turns off immediately and shortens the duty cycle. Therefore, the output-voltage drops if the over current condition occurs. The current limit is also affected by the input voltage, duty cycle, and inductor value.

Over-Temperature Protection

The RT8509A Boost converter has thermal protection function to prevent the chip from overheating. When the junction temperature exceeds 155°C, the function shuts down the device. Once the device cools down by approximately 10°C, it will automatically restart to normal operation. To guarantee continuous operation, do not operate over the maximum junction temperature rating of 125°C.

Inductor Selection

The inductance depends on the maximum input current. As a general rule, the inductor ripple current range is 20% to 40% of the maximum input current. If 40% is selected as an example, the inductor ripple current can be calculated according to the following equations :

$$I_{IN(MAX)} = \frac{V_{OUT} \times I_{OUT(MAX)}}{\eta \times V_{IN}}$$

$$I_{RIPPLE} = 0.4 \times I_{IN(MAX)}$$

where η is the efficiency of the converter, $I_{IN(MAX)}$ is the maximum input current, and I_{RIPPLE} is the inductor ripple current. The input peak current can then be obtained by adding the maximum input current with half of the inductor ripple current as shown in the following equation :

$$I_{PEAK} = 1.2 \times I_{IN(MAX)}$$

Note that the saturated current of the inductor must be greater than I_{PEAK}. The inductance can eventually be determined according to the following equation :

$$L = \frac{\eta \times (V_{IN})^2 x (V_{OUT} - V_{IN})}{0.4 \times (V_{OUT})^2 x I_{OUT(MAX)} \times f_{OSC}}$$

where f_{osc} is the switching frequency. For better system performance, a shielded inductor is preferred to avoid EMI problems.

Diode Selection

Schottky diodes are chosen for their low forward voltage drop and fast switching speed. When selecting a Schottky diode, important parameters such as power dissipation, reverse voltage rating, and pulsating peak current should all be taken into consideration. A suitable Schottky diode's reverse voltage rating must be greater than the maximum output voltage and its average current rating must exceed the average output current. Last of all, the chosen diode should have a sufficiently low leakage current level, since it will increase with temperature.

Output Capacitor Selection

The output ripple voltage is an important index for estimating chip performance. This portion consists of two parts. One is the product of the inductor current with the ESR of the output capacitor, while the other part is formed by the charging and discharging process of the output capacitor. As shown in Figure 1, ΔV_{OUT1} can be evaluated based on the ideal energy equalization. According to the definition of Q, the Q value can be calculated as the following equation :

$$Q = \frac{1}{2} \times \left[\left(I_{IN} + \frac{1}{2}\Delta I_L - I_{OUT}\right) + \left(I_{IN} - \frac{1}{2}\Delta I_L - I_{OUT}\right)\right] \times \frac{V_{IN}}{V_{OUT}} \times \frac{1}{f_{OSC}} = C_{OUT} \times \Delta V_{OUT1}$$

where f_{OSC} is the switching frequency, and ΔI_L is the inductor ripple current. Bring C_{OUT} to the left side to estimate the value of ΔV_{OUT1} according to the following equation :

$$\Delta V_{OUT1} = \frac{D \times I_{OUT}}{\eta \times C_{OUT} \times f_{OSC}}$$

where D is the duty cycle and η is the Boost converter efficiency. Finally, taking ESR into account, the overall output ripple voltage can be determined by the following equation :

$$\Delta V_{OUT} = I_{IN} \times ESR + \frac{D \times I_{OUT}}{\eta \times C_{OUT} \times f_{OSC}}$$

The output capacitor, C_{OUT}, should be selected accordingly.

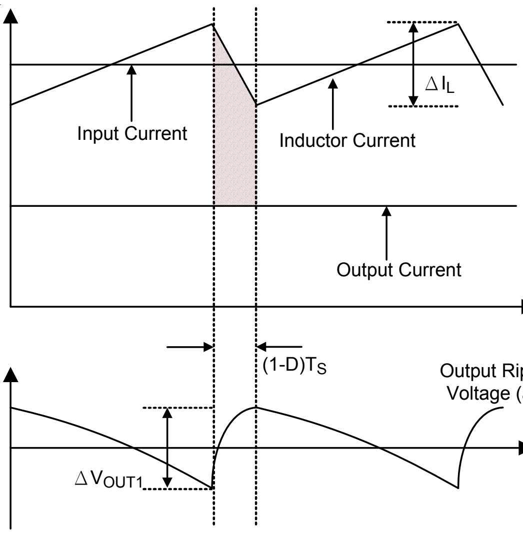


Figure 1. The Output Ripple Voltage without the Contribution of ESR

Input Capacitor Selection

Low ESR ceramic capacitors are recommended for input capacitor applications. Low ESR will effectively reduce the input voltage ripple caused by switching operation. A 10μF capacitor is sufficient for most applications.

Nevertheless, this value can be decreased for lower output current requirement. Another consideration is the voltage rating of the input capacitor which must be greater than the maximum input voltage.

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 WDFN-12L 5x5 packages, the thermal resistance, θ_{JA}, is 29.5°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) / (29.5°C/W) = 3.38W for WDFN-12L 5x5 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 2 allows the designer to see the effect of rising ambient temperature on the maximum power dissipation.

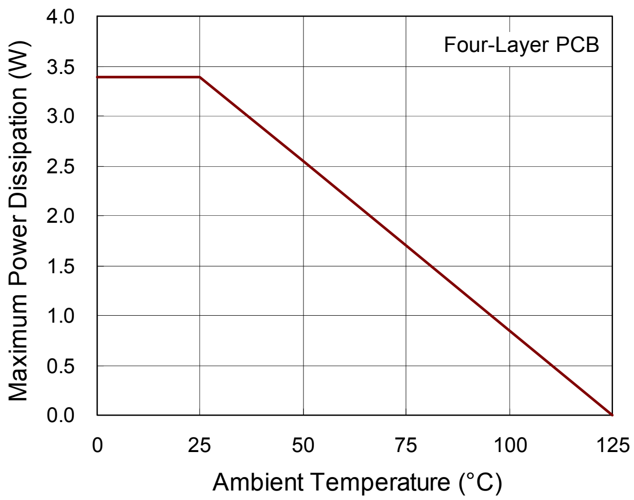


Figure 2. Derating Curve of Maximum Power Dissipation

Layout Considerations

For high frequency switching power supplies, the PCB layout is important to get good regulation, high efficiency and stability. The following descriptions are the guidelines for better PCB layout.

- For good regulation, place the power components as close as possible. The traces should be wide and short enough especially for the high current output loop.
- The feedback voltage divider resistors must be near the feedback pin. The divider center trace must be shorter and the trace must be kept away from any switching nodes.
- The compensation circuit should be kept away from the power loops and be shielded with a ground trace to prevent any noise coupling.
- Minimize the size of the LX node and keep it wide and shorter. Keep the LX node away from the FB.
- The exposed pad of the chip should be connected to a strong ground plane for maximum thermal consideration.

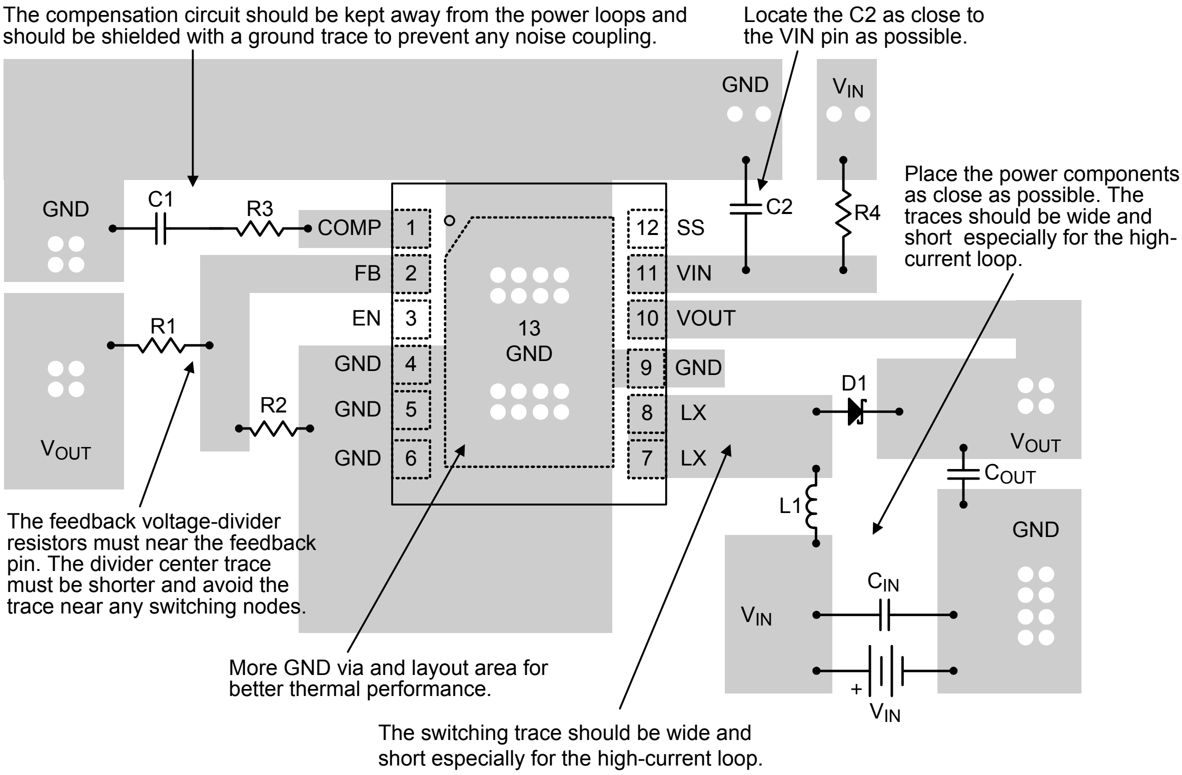
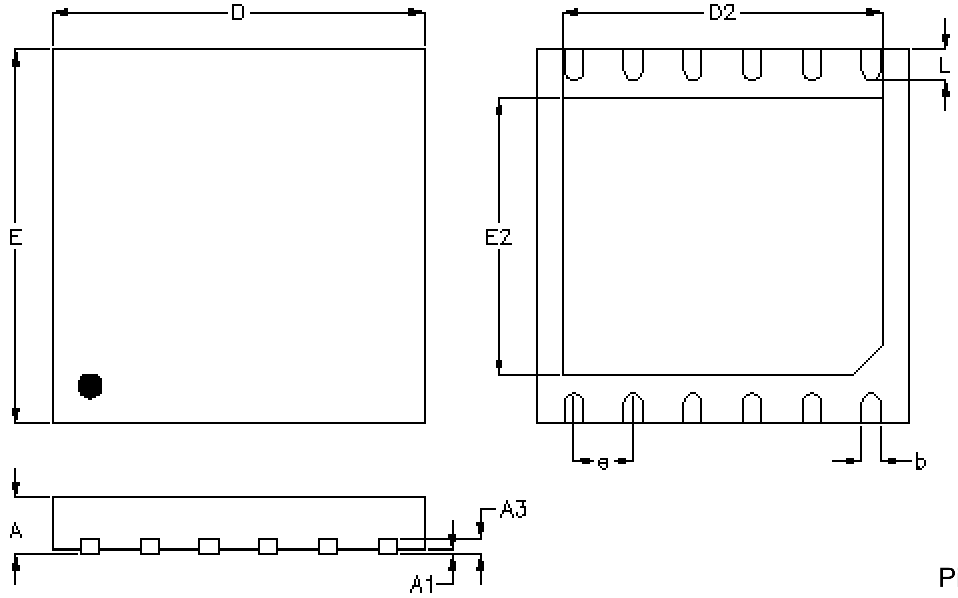
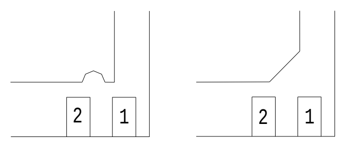


Figure 3. PCB Layout Guide

Outline Dimension





DETAIL A

Pin #1 ID and Tie Bar Mark Options

Note : The configuration of the Pin #1 identifier is optional, but must be located within the zone indicated.

Symbol	Dimensions In Millimeters		Dimensions In Inches	
	Min.	Max.	Min.	Max.
A	0.700	0.800	0.028	0.031
A1	0.000	0.050	0.000	0.002
A3	0.175	0.250	0.007	0.010
b	0.200	0.300	0.008	0.012
D	4.900	5.100	0.193	0.201
D2	4.250	4.350	0.167	0.171
E	4.900	5.100	0.193	0.201
E2	3.650	3.750	0.144	0.148
e	0.800		0.031	
L	0.350	0.450	0.014	0.018

W-Type 12L DFN 5x5 Package

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