# 3A, 14V Step-Up DC-DC Converter

## General Description

The RT8509 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 RT8509 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 RT8509 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 3.5A (typ.). Other features include programmable soft-start, over voltage protection, and over temperature protection.

The RT8509 is available in a WDFN-10L 3x3 package.

## Ordering Information

RT8509 □□

Package Type
QW : WDFN-10L 3x3 (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.

## Features

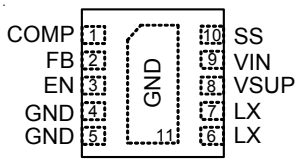
- **90% Efficiency**
- **Adjustable Output Up to 24V**
- **2.8V to 14V Input Supply Voltage**
- **Input Supply Under Voltage Lockout**
- **Fixed 1.2MHz Switching Frequency**
- **Programmable Soft-Start**
- **$V_{OUT}$ Over Voltage Protection**
- **Over Temperature Protection**
- **Thin 10-Lead WDFN Package**
- **RoHS Compliant and Halogen Free**

## Applications

- GIP TFT LCD Panels

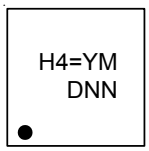
## Pin Configuration

(TOP VIEW)




WDFN-10L 3x3

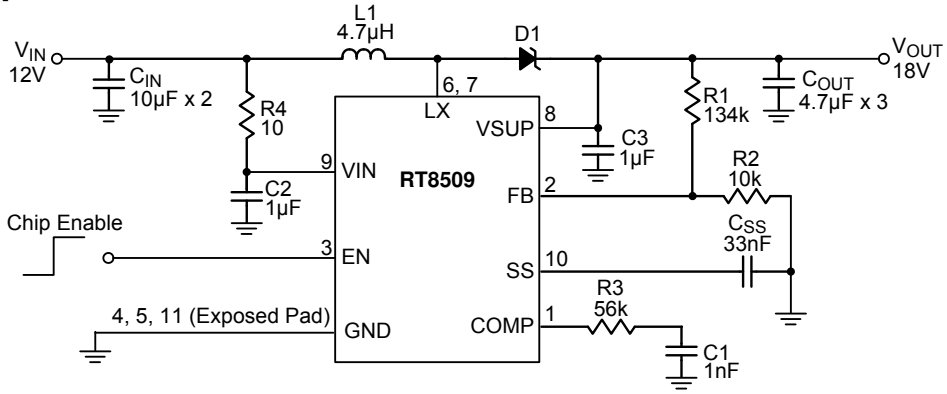
## Marking Information




H4= : Product Code

YMDNN : Date Code

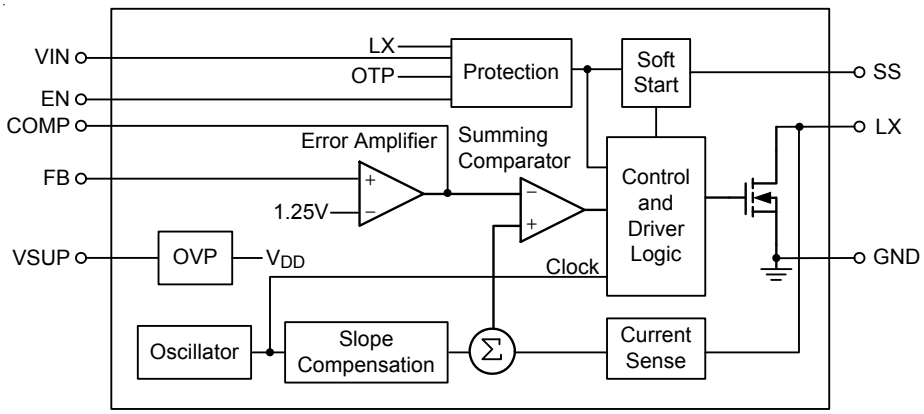
## Typical Application Circuit



## Functional Pin Description

| Pin No. | Pin Name | Pin Function |
|---|---|---|
| 1 | COMP | Compensation pin for error amplifier. Connect a series RC from COMP to ground. |
| 2 | FB | Feedback. 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 | Chip enable. Drive EN low to turn off the Boost. |
| 4, 5, 11 (Exposed Pad) | GND | Ground. The Exposed Pad must be soldered to a large PCB and connected to GND for maximum power dissipation. |
| 6, 7 | LX | Switch. LX is the drain of the internal MOSFET. Connect the inductor/rectifier diode junction to LX and minimize the trace area for lower EMI. |
| 8 | VSUP | Boost converter over voltage protection input. Bypass VSUP with a minimum 1μF ceramic capacitor directly to GND. |
| 9 | VIN | Supply input. Bypass VIN with a minimum 1μF ceramic capacitor directly to GND. |
| 10 | SS | Soft-start control. 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. |

## Functional Block Diagram



## Absolute Maximum Ratings (Note 1)

- LX, VSUP to GND ---------- –0.3V to 28V
- VIN, EN to GND ---------- –0.3V to 16.5V
- Other Pins to GND ---------- –0.3V to 6.5V
- Power Dissipation, $P_D$ @ $T_A$ = 25°C
  WDFN-10L 3x3 ---------- 1.429W
- Package Thermal Resistance (Note 2)
  WDFN-10L 3x3, $\theta_{JA}$ ---------- 70°C/W
  WDFN-10L 3x3, $\theta_{JC}$ ---------- 8.2°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 | $\Delta V_{UVLO}$ | | -- | 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 | $\Delta T_{SD}$ | | -- | 10 | -- | °C |
| VSUP Over Voltage Threshold | | VSUP rising | -- | 26 | -- | V |
| **Oscillator** | | | | | | |
| Oscillator Frequency | $f_{OSC}$ | | 1000 | 1200 | 1500 | kHz |
| Maximum Duty Cycle | $D_{MAX}$ | | -- | 90 | -- | % |
| **Error Amplifier** | | | | | | |
| FB Regulation Voltage | $V_{REF}$ | | -- | 1.25 | -- | V |
| FB Input Bias Current | $I_{FB}$ | | -- | -- | 100 | nA |
| FB Line Regulation | | | -- | 0.05 | 0.2 | %/V |

| Parameter | | Symbol | Test Conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|---|
| Transconductance | | gm | ΔI = ±2.5μA at $V_{COMP}$ = 1V | -- | 100 | -- | μA/V |
| Voltage Gain | | $A_V$ | FB to COMP | -- | 700 | -- | V/V |
| **N-MOSFET** | | | | | | | |
| Current Limit | | $I_{LIM}$ | | 3 | 3.5 | -- | A |
| On-Resistance | | $R_{DS(ON)}$ | | -- | 100 | 250 | mΩ |
| Leakage Current | | $I_{LEAK}$ | $V_{LX}$ = 24V | -- | 30 | 45 | μA |
| Current Sense Transresistance | | $R_{CS}$ | | -- | 0.25 | -- | V/A |
| **Soft-Start** | | | | | | | |
| Charge Current | | | | -- | 5 | -- | μA |
| **Control Inputs** | | | | | | | |
| EN Input Voltage | Logic-High | $V_{IH}$ | | 1.5 | -- | -- | V |
| | Logic-Low | $V_{IL}$ | | -- | -- | 0.5 | |

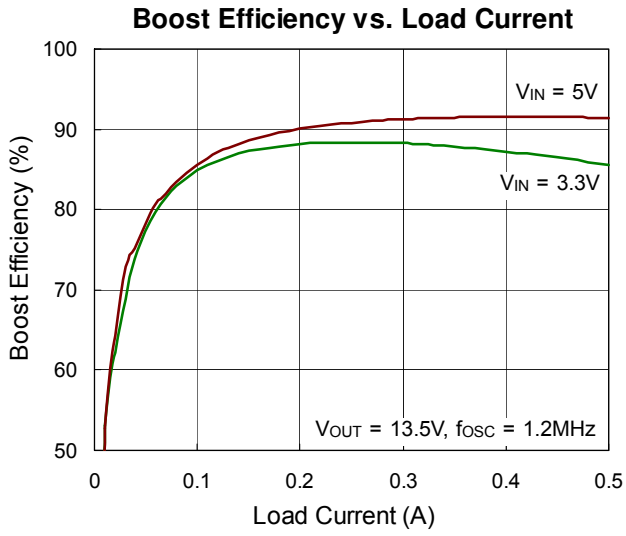
**Note 1.** Stresses beyond those listed "Absolute Maximum Ratings" may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated in the operational sections of the specifications is not implied. Exposure to absolute maximum rating conditions may affect device reliability.

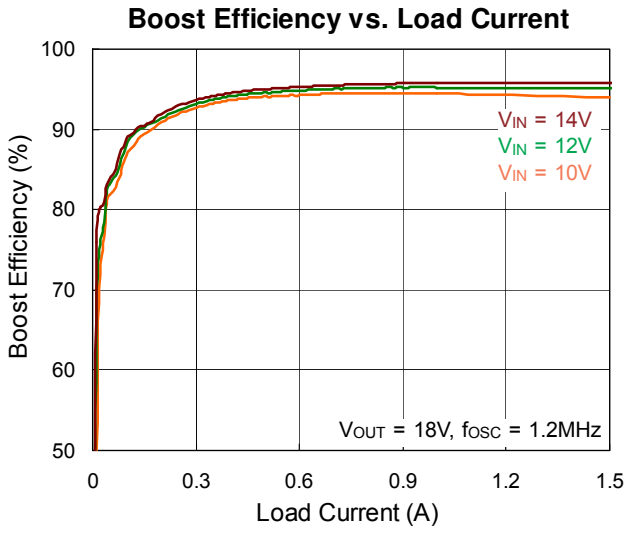
**Note 2.** $\theta_{JA}$ is measured under natural convection (still air) at $T_A$ = 25°C with the component mounted on a high effective-thermal-conductivity four-layer test board on a JEDEC 51-7 thermal measurement standard. $\theta_{JC}$ is measured at the exposed pad of the package.

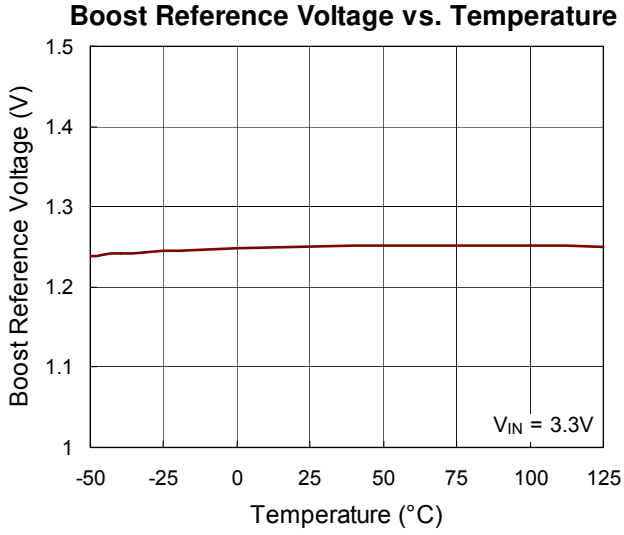
**Note 3.** Devices are ESD sensitive. Handling precaution is recommended.

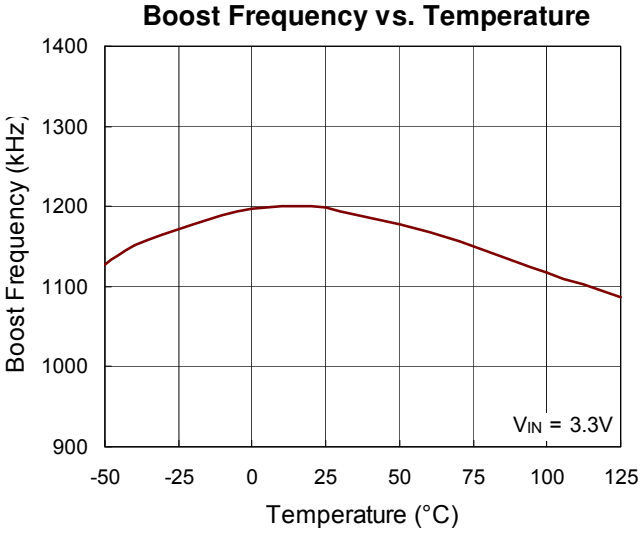
**Note 4.** The device is not guaranteed to function outside its operating conditions.

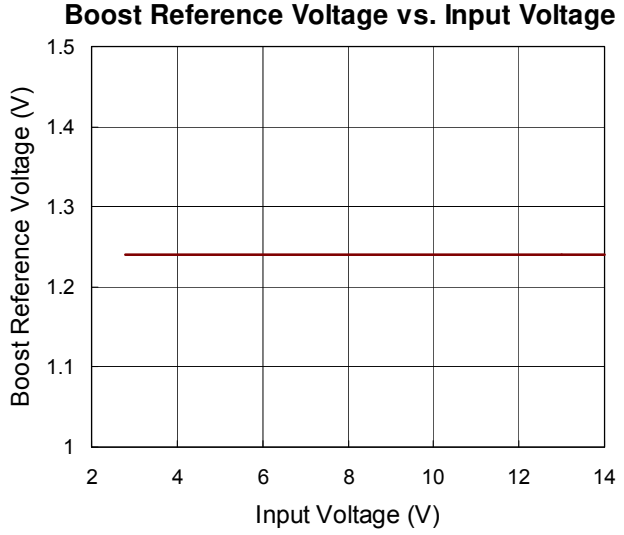
## Typical Operating Characteristics

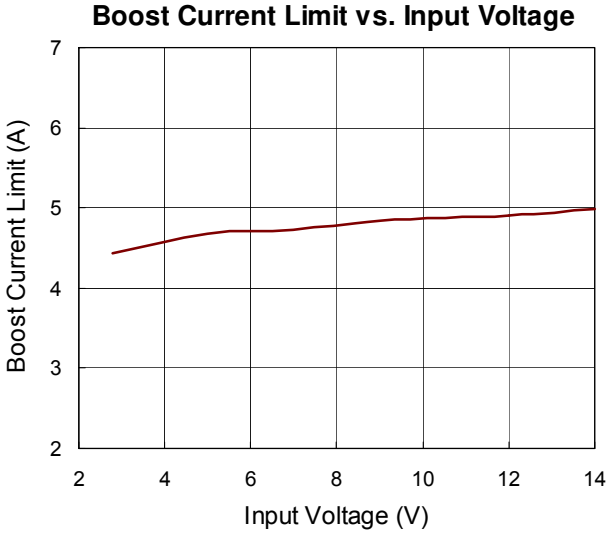


## Application Information

The RT8509 is a high performance step-up DC-DC converter that provides a regulated supply voltage for panel source driver ICs. The RT8509 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 following content contains detailed description and information for component selection.

### Boost Regulator

The RT8509 is a current mode boost converter integrated with a 24V/3.5A 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 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.

### Soft-Start

The RT8509 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 RT8509 boost converter has over current protection to limit the peak inductor current. It prevents large current from damaging the inductor and diode. 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 RT8509 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 $\eta$ 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 :

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

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, $\Delta V_{OUT1}$ 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 $\Delta I_L$ is the inductor ripple current. Bring $C_{OUT}$ to the left side to estimate the value of $\Delta V_{OUT1}$ 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 $\eta$ 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.

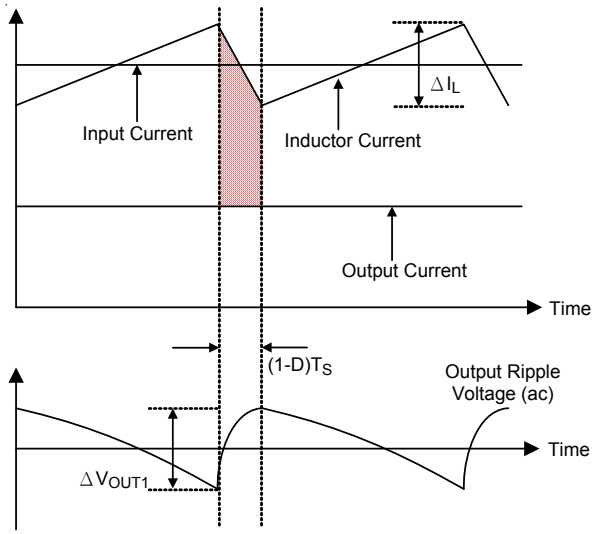



Figure 1. The Output Ripple Voltage without the Contribution of ESR

### 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

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 $\theta_{JA}$ 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, $\theta_{JA}$, is highly package dependent. For a WDFN-10L 3x3, the thermal resistance, $\theta_{JA}$, is 70°C/W on a standard JEDEC 51-7 high effective-thermal-conductivity four-layer test board. The maximum power dissipation at $T_A$ = 25°C can be calculated as below :

$P_{D(MAX)}$ = (125°C – 25°C) / (70°C/W) = 1.429Wfor a WDFN-10L 3x3 package.

The maximum power dissipation depends on the operating ambient temperature for the fixed $T_{J(MAX)}$ and the thermal resistance, $\theta_{JA}$. The derating curves in Figure 2 allows the designer to see the effect of rising ambient temperature on the maximum power dissipation.

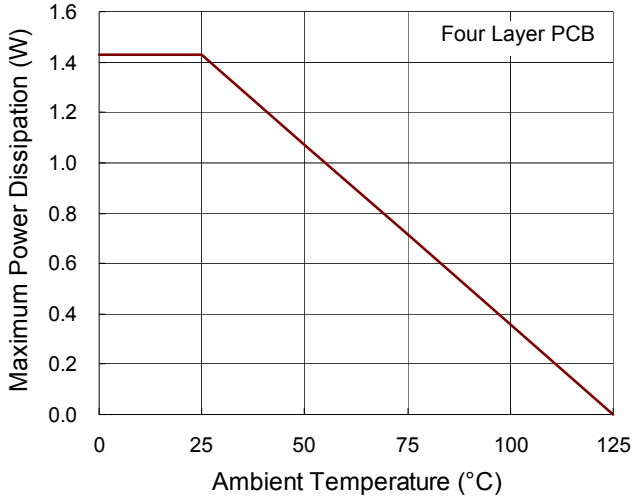



Figure 2. Derating Curve of Maximum Power Dissipation

## 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.

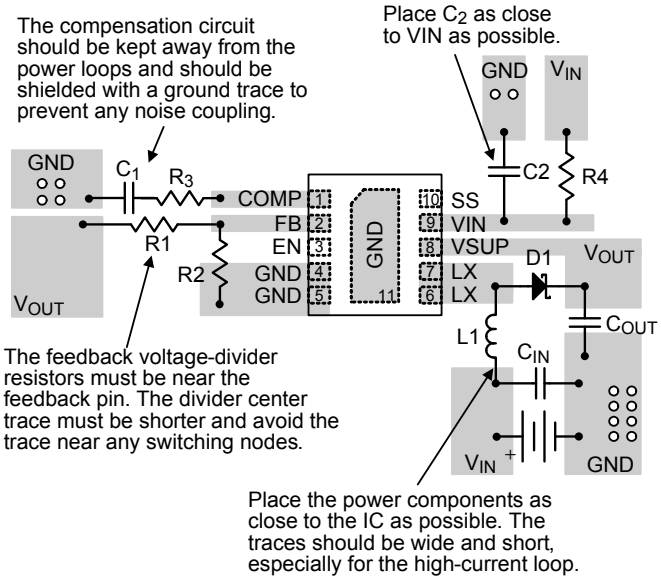
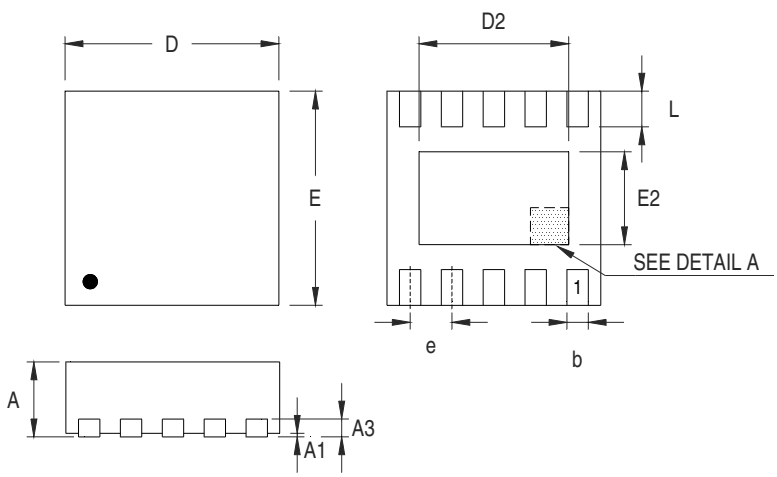
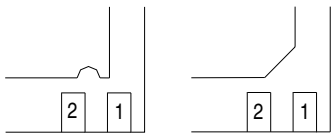



Figure 3. PCB Layout Guide

## 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 | 0.180 | 0.300 | 0.007 | 0.012 |
| D | 2.950 | 3.050 | 0.116 | 0.120 |
| D2 | 2.300 | 2.650 | 0.091 | 0.104 |
| E | 2.950 | 3.050 | 0.116 | 0.120 |
| E2 | 1.500 | 1.750 | 0.059 | 0.069 |
| e | 0.500 | | 0.020 | |
| L | 0.350 | 0.450 | 0.014 | 0.018 |

**W-Type 10L DFN 3x3 Package**

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