# Boost Converter for OLED Power with Dual LDO

## General Description

The RT9287 integrates a boost converter for OLED power and a Dual LDO for camera image sensor power. To achieve high efficiency, the boost converter optimizes its operating frequency for small LC filters value and reduces the operating current. Moreover, the internal soft-start function reduces the inrush current.

For the Dual LDO part, it possesses functions of 2% accuracy, dual channel, low dropout voltage (240mV@300mA), low noise, low ground current and low dropout regulator sourcing up to 300mA at each channel. For battery-powered devices, it provides near zero shutdown current. Moreover, it also integrates functions such as current limiting, over temperature, output short circuit, 27μA low ground current per LDO and short circuit thermal folded back protection. When output short circuit occurs, the RT9287 reduces its over temperature protection trip point to provide maximum safety to users. The RT9287 is available in WDFN-10L 3x3 package.

## Ordering Information

RT9287-□□□□

- Package Type
  QW : WDFN-10L 3x3 (W-Type)
- Operating Temperature Range
  P : Pb Free with Commercial Standard
  G : Green (Halogen Free with Commercial Standard)
- LDO Output Voltage : VOUT1/VOUT2
  MG : 2.80V/1.80V

Note :

Richtek Pb-free and Green 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.
- 100% matte tin (Sn) plating.

## Marking Information

For marking information, contact our sales representative directly or through a Richtek distributor located in your area, otherwise visit our website for detail.

## Features

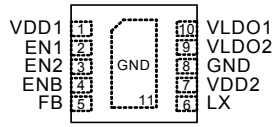
- **Boost Converter**
  - **VIN Operating Range : 2.7V to 5.5V**
  - **Maximum Output Voltage Up to 20V**
  - **Output Current up to 100mA at $V_{OUT}$ = 12V.**
  - **Low Shutdown Supply Current**
  - **Minimize the External Component**
  - **Small LC Filter**
  - **Internal Soft Start**
- **Dual LDO**
  - **Wide Operating Voltage Ranges : 2.7V to 5.5V**
  - **Low-Noise for RF Application**
  - **No Noise Bypass Capacitor Required**
  - **Fast Response in Line/Load Transient**
  - **TTL-Logic-Controlled Shutdown Input**
  - **Low Temperature Coefficient**
  - **Dual LDO Outputs (300mA/300mA)**
  - **Ultra-low Quiescent Current 27μA/LDO**
  - **High Output Accuracy 2%**
  - **Short Circuit Protection**
  - **Thermal Shutdown Protection**
  - **Current Limit Protection**
  - **Short Circuit Thermal Folded Back Protection**
- **RoHS Compliant and 100% Lead (Pb)-Free**

## Applications

- Camera Phone
- OLED Power

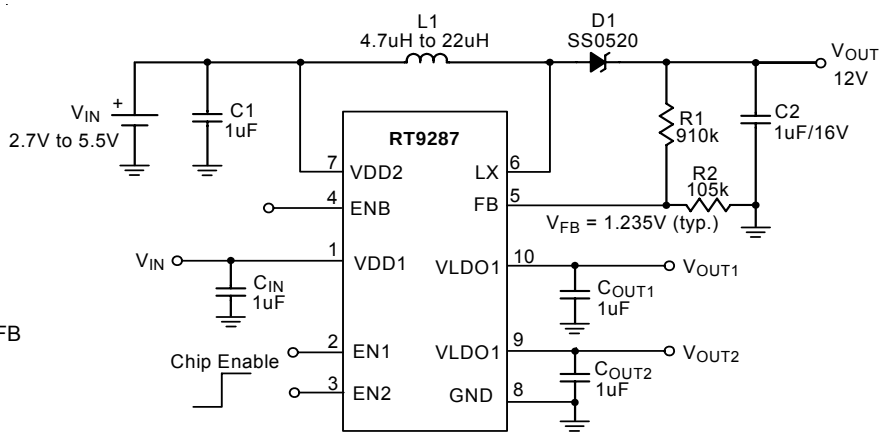
## Pin Configurations

(TOP VIEW)




WDFN-10L 3x3

## Typical Application Circuit




$$V_{OUT} = \frac{R1+R2}{R2} \times V_{FB}$$

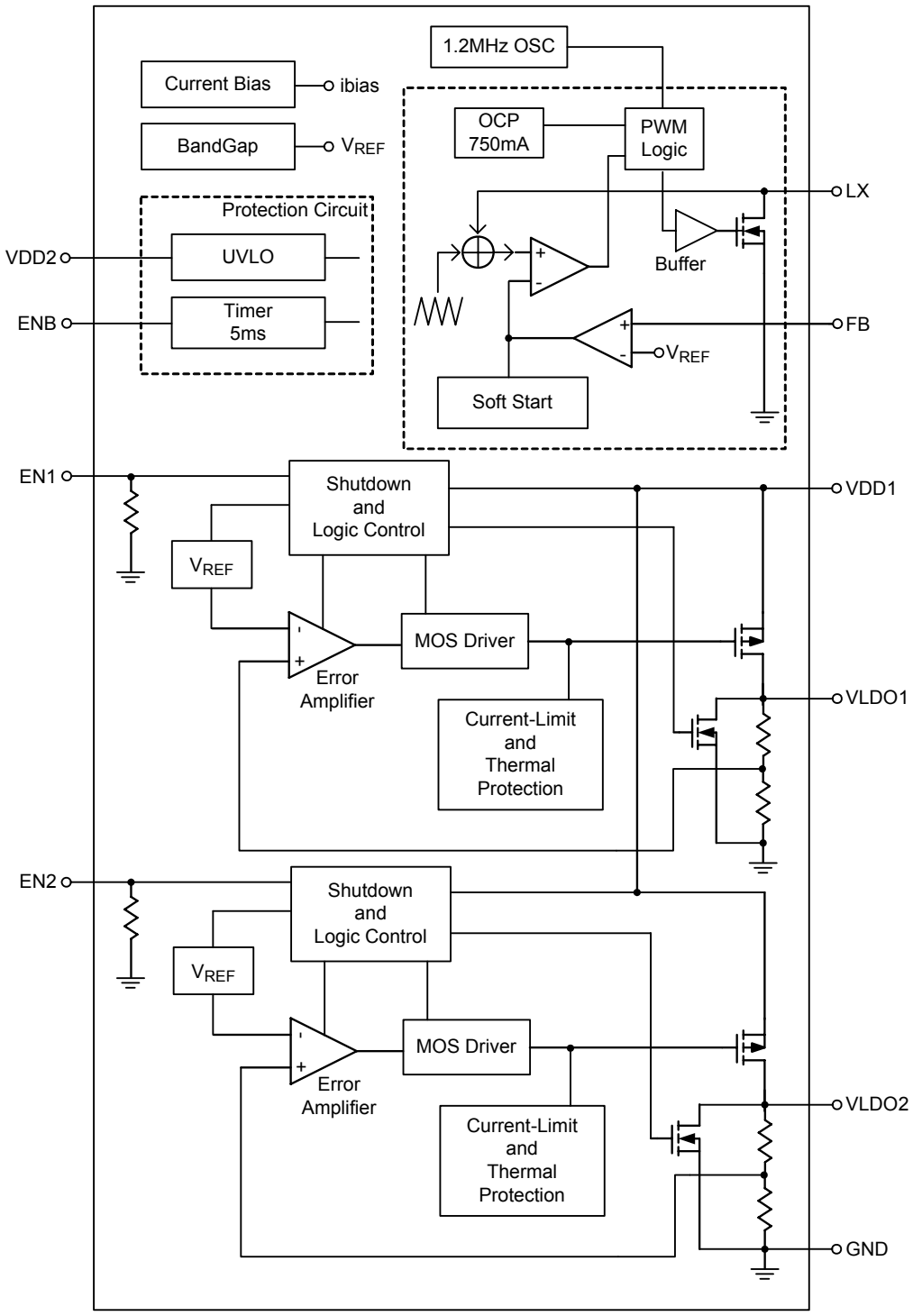
$V_{FB} = 1.235$ (typ.)

$R2 > 100k\Omega$

## Functional Pin Description

| Pin No. | Pin Name | Pin Function |
|---|---|---|
| 1 | VDD1 | LDO Power Input Voltage. |
| 2 | EN1 | LDO Channel 1 Enable. (Active High). |
| 3 | EN2 | LDO Channel 2 Enable. (Active High). |
| 4 | ENB | Boost Enable (Active High). Voltage sensing input to trigger the function of over voltage protection. Note that this pin is high impedance. There should be a pull low 100kΩ resistor connected to GND when the control signal is floating. |
| 5 | FB | Boost Feedback Reference Voltage Pin. Series connect a resistor between WLED and ground as a current sense. Sense the current feedback voltage to set the current rating. |
| 6 | LX | Boost Switch Pin. Connect this Pin to inductor and catch diode. Minimize the track area to reduce EMI. |
| 7 | VDD2 | Boost Supply Input Voltage Pin. Bypass 1μF capacitor to GND to reduce the input noise. |
| 8 | GND | GND pin should be soldered to PCB board and connected to GND. |
| 9 | VLDO2 | LDO Channel 2 Output Voltage. |
| 10 | VLDO1 | LDO Channel 1 Output Voltage. |
| Exposed Pad (11) | GND | The exposed pad must be soldered to a large PCB and connected to GND for maximum power dissipation. |

## Function Block Diagram



## Absolute Maximum Ratings (Note 1)

- Supply Input Voltage, $V_{DD}$ ---------- –0.3V to 7V
- LX Input Voltage ---------- –0.3V to 22V
- The Other Pins ---------- –0.3V to 6V
- Power Dissipation, $P_D$ @ $T_A$ = 25°C
  WDFN–10L 3x3 ---------- 0.926W
- Package Thermal Resistance (Note 4)
  WDFN–10L 3x3, $\theta_{JA}$ ---------- 108°C/W
  WDFN–10L 3x3, $\theta_{JC}$ ---------- 8.2°C/W
- Junction Temperature ---------- 150°C
- Lead Temperature (Soldering, 10 sec.) ---------- 260°C
- Storage Temperature Range ---------- –65°C to 150°C
- ESD Susceptibility (Note 2)
  HBM (Human Body Mode) ---------- 2kV
  MM (Machine Mode) ---------- 200V

## Recommended Operating Conditions (Note 3)

- Supply Input Voltage Range ---------- 2.7V to 5.5V
- Junction Temperature Range ---------- –40°C to 125°C
- Ambient Temperature Range ---------- –40°C to 85°C

## Electrical Characteristics

($V_{DD2}$ = 3.7V, $V_{DD1}$ = $V_{OUT}$ + 1V, $V_{EN}$ = $V_{IN}$, $C_{IN}$ = $C_{OUT}$ = 1µA, $T_A$ = 25°C, unless otherwise specified)

| Parameter | Symbol | Test Condition | Min | Typ | Max | Units |
|---|---|---|---|---|---|---|
| **Boost** | | | | | | |
| **System Supply Input** | | | | | | |
| Operating Voltage Range | $V_{DD2}$ | | 2.7 | -- | 5.5 | V |
| Under Voltage Lockout | $V_{DD2}$ | | – | 2.2 | -- | V |
| Quiescent Current | $I_{DD2}$ | $V_{FB}$ = 1.5V, No switch | -- | 300 | -- | µA |
| Supply Current | $I_{DD2}$ | $V_{FB}$ = 0V, Switch | -- | 2 | -- | mA |
| Shut Down Current | $I_{DD2}$ | $V_{ENB}$ < 0.4V | -- | -- | 1 | µA |
| Line Regulation | | $V_{DD2}$ = 3.0V to 4.3V | -- | 3 | -- | % |
| **Oscillator** | | | | | | |
| Operating Frequency | $f_{OSC}$ | | -- | 1.2 | -- | MHz |
| Maximum Duty Cycle | | | 85 | -- | -- | % |
| **Reference Voltage** | | | | | | |
| Feedback Reference Voltage | $V_{REF}$ | | 1.173 | 1.235 | 1.296 | V |
| **MOSFET** | | | | | | |
| On Resistance of MOSFET | $R_{DS(ON)}$ | | – | 0.75 | -- | Ω |
| OCP | | | -- | 750 | -- | mA |
| Enable Voltage Low | VEN_L | | -- | -- | 0.4 | V |
| Enable Voltage High | VEN_H | | 1.5 | -- | -- | V |

*To be continued*

| Parameter | Symbol | Test Condition | Min | Typ | Max | Units |
|---|---|---|---|---|---|---|
| **Dual LDO** | | | | | | |
| Input Voltage | $V_{DD1}$ | $V_{DD}$ = 2.7V to 5.5V | 2.7 | -- | 5.5 | V |
| Dropout Voltage (Note 5) | $V_{DROP}$ | $I_{OUT}$ = 150mA | -- | 120 | -- | mV |
| | | $I_{OUT}$ = 300mA | -- | 240 | -- | mV |
| Output Voltage Range | $V_{LDO1}$, $V_{LDO2}$ | | 1.2 | -- | 3.6 | V |
| VLDO1,2 Accuracy | $\Delta V$ | $I_{OUT}$ = 1mA | –2 | -- | +2 | % |
| Line Regulation | $\Delta V_{LINE}$ | $V_{DD1}$ = ($V_{LDO1,2}$ + 0.3V) to 5.5V or $V_{DD1}$ > 2.7V, whichever is larger | -- | -- | 0.2 | % |
| Load Regulation | $\Delta V_{LOAD}$ | 1mA < $I_{OUT}$ < 300mA | -- | -- | 0.6 | % |
| Current Limit | | $R_{LOAD}$ = 1Ω | 330 | 450 | 700 | mA |
| Quiescent Current | $I_Q$ | $V_{EN1, 2}$ > 1.5V | -- | 58 | 80 | μA |
| Shutdown Current | $I_{SHDN}$ | $V_{EN1, 2}$ < 0.4V | -- | -- | 1 | μA |
| EN1,2 Threshold | $V_{IH}$ | $V_{DD}$ = 2.7V to 5.5V, Power On | 1.5 | -- | -- | V |
| | $V_{IL}$ | $V_{DD}$ = 2.7V to 5.5V, Shutdown | -- | -- | 0.4 | V |
| Output Voltage TC | | | -- | 100 | -- | ppm/°C |
| Thermal Shutdown | $T_{SD}$ | | -- | 165 | -- | °C |
| Thermal Shutdown Hysteresis | $\Delta T_{SD}$ | | -- | 40 | -- | °C |
| Thermal Shutdown Hysteresis | $\Delta T_{SD}$ | | -- | 40 | -- | °C |
| PSRR $I_{LOAD}$ = 10mA | PSRR | f = 100Hz | -- | 65 | -- | dB |
| | | f = 1kHz | -- | 60 | -- | dB |
| | | f = 10kHz | -- | 50 | -- | dB |
| PSRR $I_{LOAD}$ = 150mA | | f = 100Hz | -- | 65 | -- | dB |
| | | f = 1kHz | -- | 50 | -- | dB |
| | | f = 10kHz | -- | 50 | -- | dB |

**Note 1.** Stresses listed as the above "Absolute Maximum Ratings" may cause permanent damage to the device. These are for stress ratings. 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 for extended periods may remain possibility to affect device reliability.

**Note 2.** Devices are ESD sensitive. Handling precaution recommended.

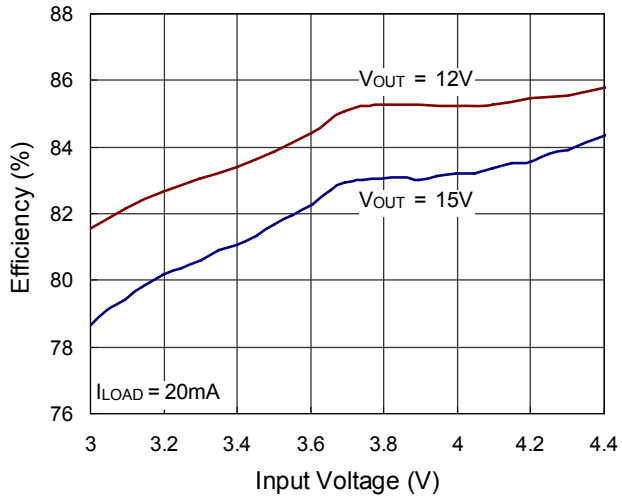
**Note 3.** The device is not guaranteed to function outside its operating conditions.

**Note 4.** $\theta_{JA}$ is measured in the natural convection at $T_A$ = 25°C on a low effective thermal conductivity test board of JEDEC 51-3 thermal measurement standard. The case point of $\theta_{JC}$ is on the expose pad for the WDFN package.

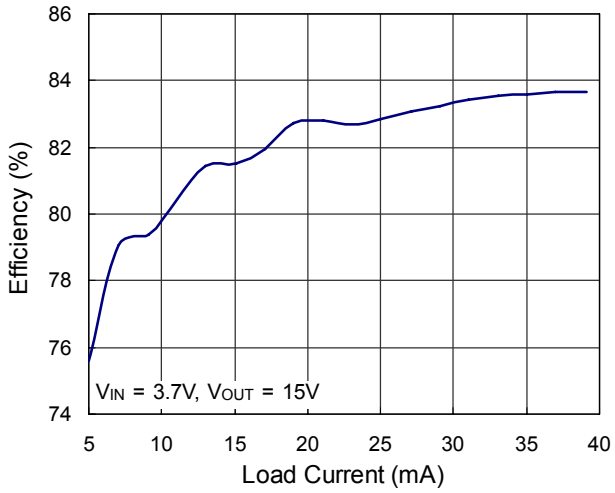
**Note 5.** The dropout voltage is defined as $V_{IN}$ -$V_{OUT}$, which is measured when $V_{OUT}$ is $V_{OUT(NORMAL)}$ – 100mV.

## Typical Operating Characteristics

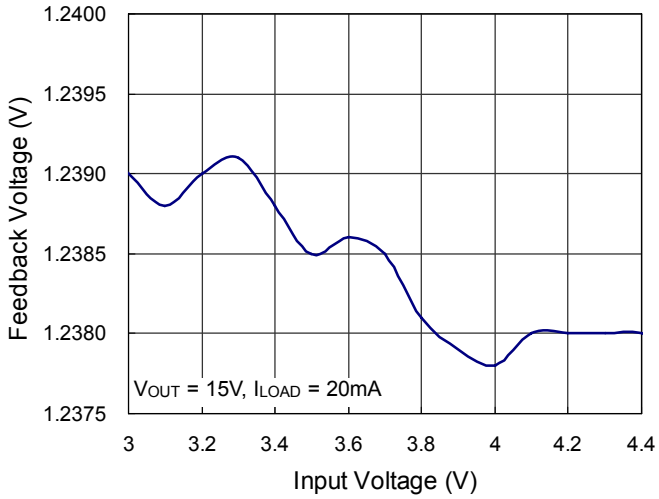
**Boost Efficiency vs. Input Voltage**



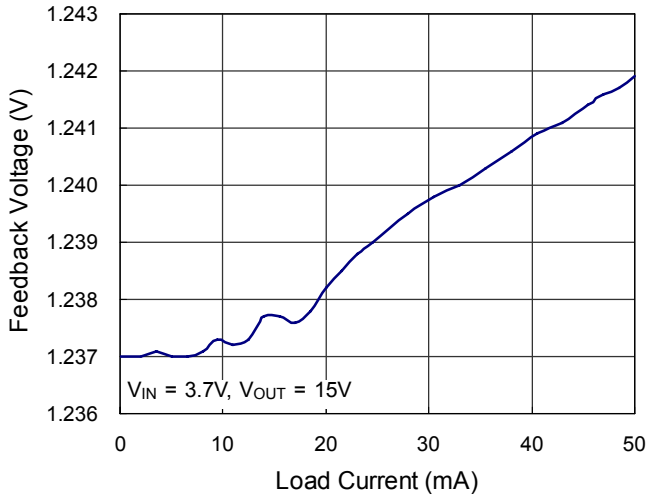

**Boost Efficiency vs. Load Current**



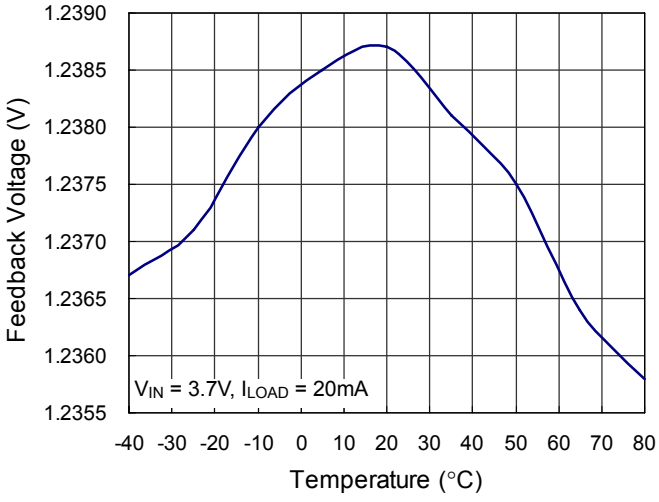

**Boost Feedback Voltage vs. Input Voltage**



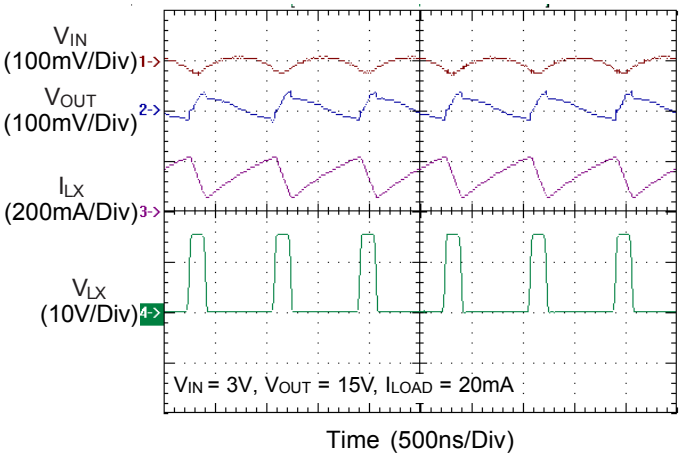

**Boost Feedback Voltage vs. Load Current**




**Boost Feedback Voltage vs.Temperature**




**Boost Normal Operation**



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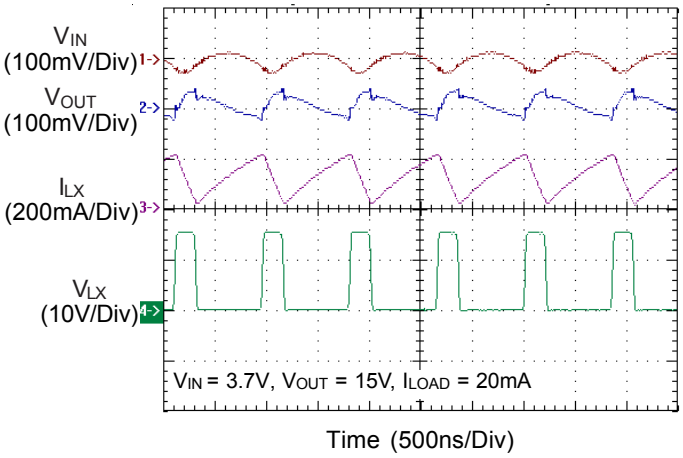


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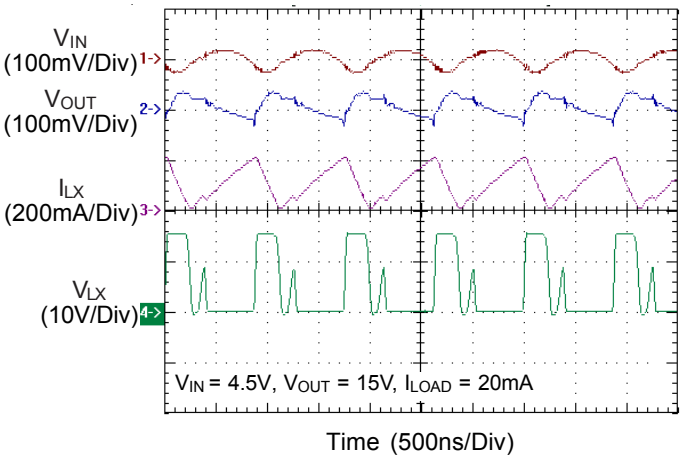
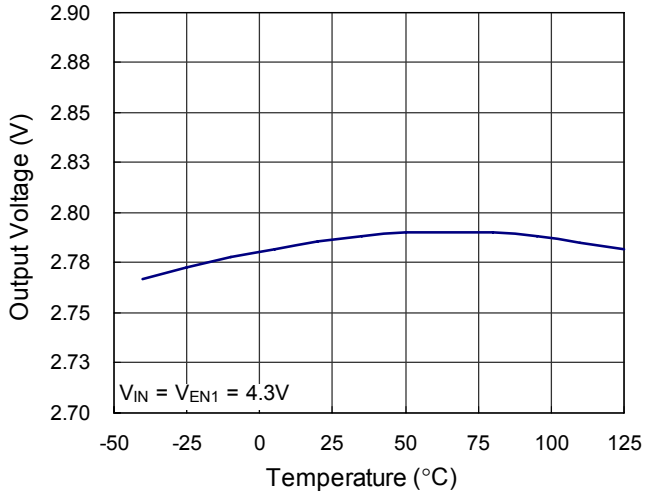
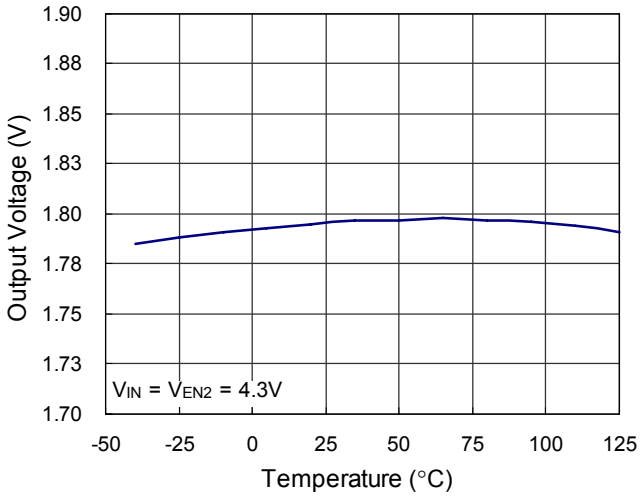


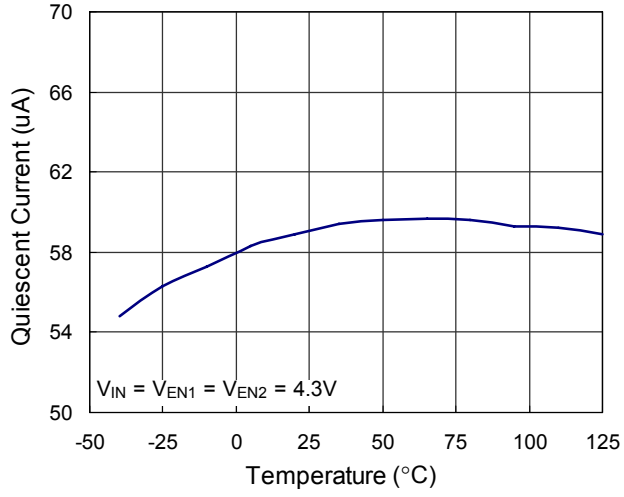

**LDO 1 Output Voltage vs. Temperature**



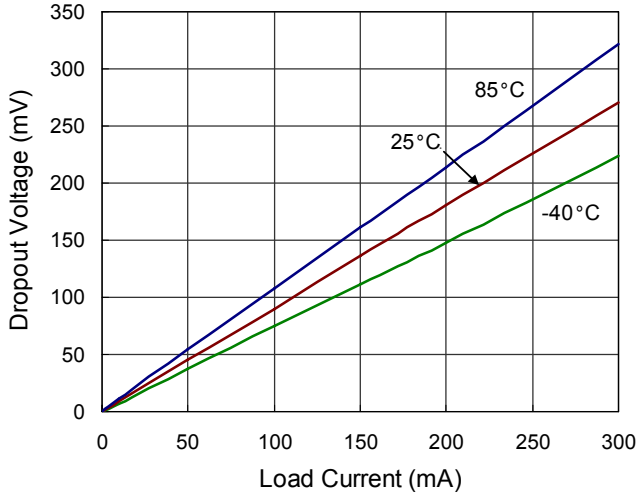

**LDO 2 Output Voltage vs. Temperature**



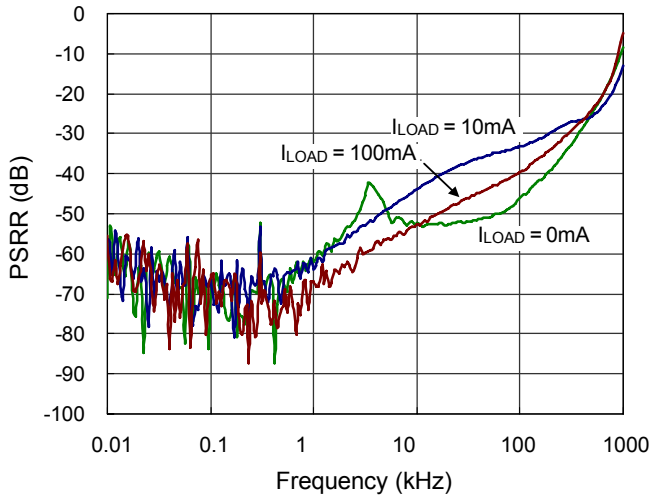

**LDO Quiescent Current vs. Temperature**



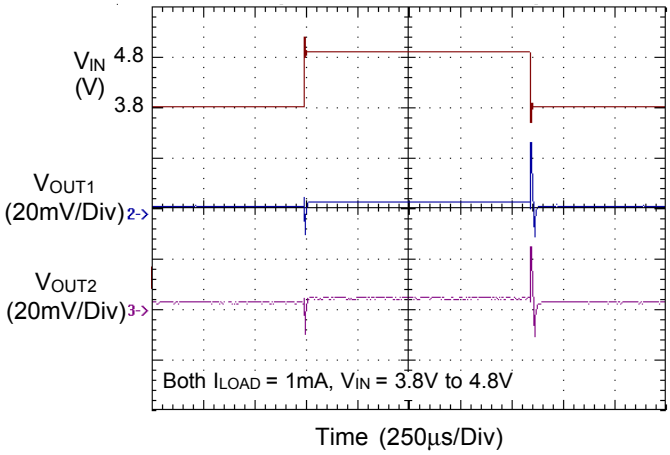

**LDO Dropout Voltage vs. Load Current**



**LDO PSRR**




**LDO Line Transient Response**

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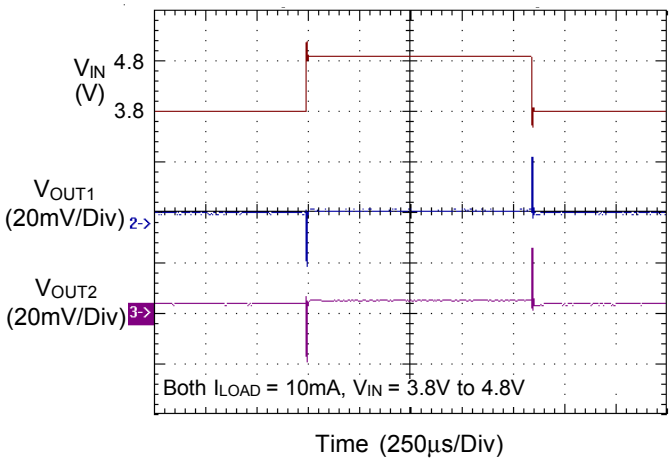
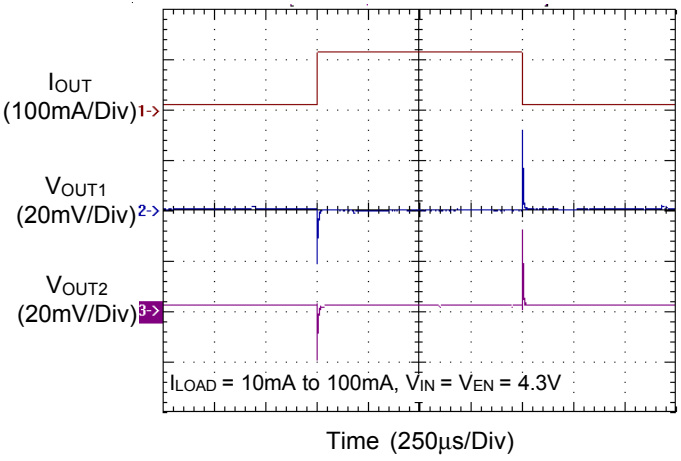
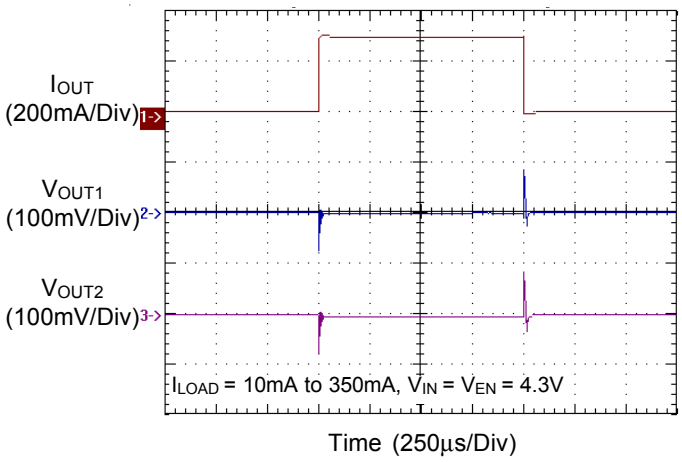


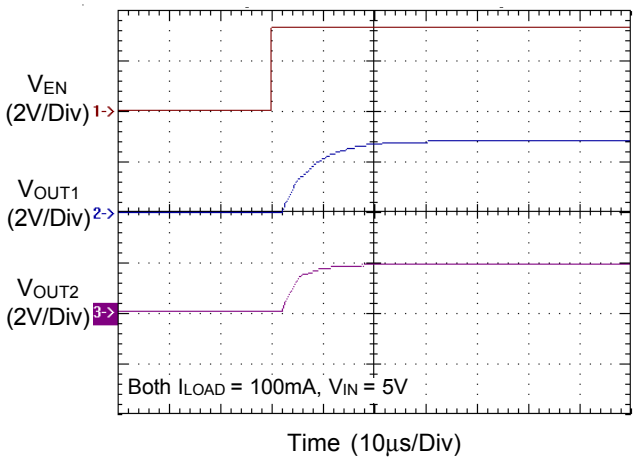

**LDO Load Transient Response**



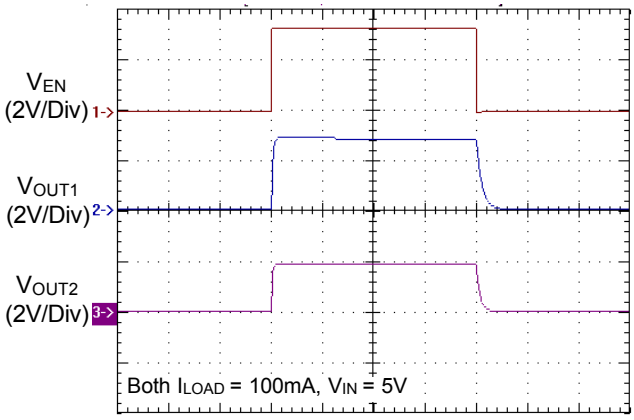

**LDO Load Transient Response**



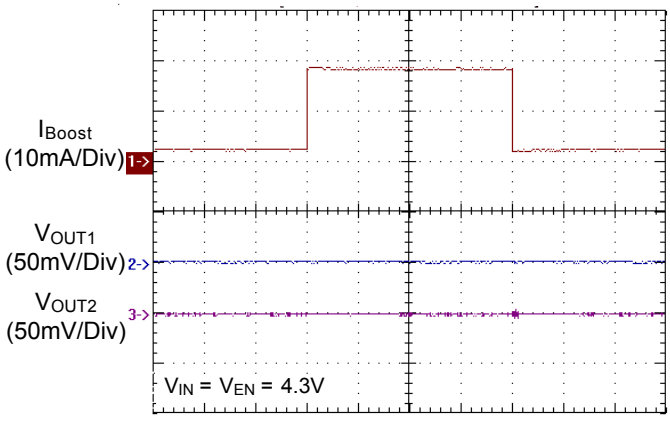

**LDO Power On from EN**



**LDO Power Off from EN**




**Cross Talk**



## Application Information

### Boost Converter

#### Power Sequence

The RT9287 must take notice of the power sequence. The power sequence of RT9287 has to VDD2 early than ENB or else the RT9287 maybe fall into the unknown state to result in RT9287 turn off.

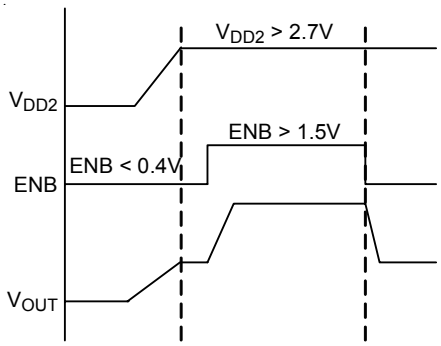



Figure 1

#### LED Current Control

As shown in Figure 2, the RT9287 regulates the LED current by setting the current sense resistor ($R_{SET}$) connected between FB pin and ground. The reference voltage of FB pin is 1.235V in typical. The LED current ($I_{LED}$) can be calculated by the following Equation.

$$I_{LED} = V_{REF} / R_{SET} \quad (1)$$

In order to have an accurate LED current, a precision resistor is preferred (1% is recommended).

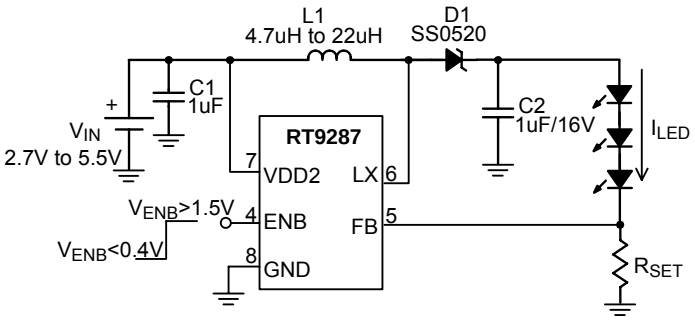



Figure 2. Application for Driving 3 Series WLEDs

#### Inductor Selection

The recommended value of the inductor is from 10μH to 22μH for 4 to 5 WLEDs applications. For 3WLEDs, the recommended value of the inductor is from 4.7μH to 22μH. Small size and better efficiency are the major concerns for portable devices, just as RT9287's application for mobile phone. The inductor should have low core loss at 1MHz and low DCR for better efficiency.

The inductor saturation current rating should be considered to cover the inductor peak current.

#### Capacitor Selection

Input and output ceramic capacitors of 1μF are recommended for boost regulator. For better voltage filtering, ceramic capacitors with low ESR are recommended. X5R and X7R types are suitable because they have better temperature characteristics.

#### Diode Selection

Schottky diode is suitable for RT9287 because of its low forward voltage and fast reverse recovery. Using Schottky diode can get better efficiency. The high speed rectification is also a good characteristic of Schottky diode for high switching frequency. Current rating of the diode must meet the root mean square of the peak current and output average current multiplication as following :

$$I_D(RMS) \approx \sqrt{I_{OUT} \times I_{PEAK}}$$

The reverse breakdown voltage of the diode should be higher than the output voltage.

#### Output Voltage Control

For fixed output voltage application, the output voltage can be adjusted by the divider circuit on FB pin. Figure 3 shows a 2-level voltage control circuit for OLED application. The output voltage can be calculated by the following equations. Table 1 is the recommended resistance for different conditions.

$$V_{OUT} = R_A \times \{(F_B/R_B) + (F_B\text{-GPIO})/R_{GPIO}\} + F_B \quad (3)$$

As GPIO = 0V,

$$V_{OUT} = R_A \times \{(1.235/R_B) + (1.235/R_{GPIO})\} + 1.235 \quad (4)$$

As GPIO = 2.8V,

$$V_{OUT} = R_A \times \{(1.235/R_B) + (1.235\text{-}2.8)/R_{GPIO}\} + 1.235 \quad (5)$$

As GPIO = 1.8V,

$$V_{OUT} = R_A \times \{(1.235/R_B) + (1.235\text{-}1.8)/R_{GPIO}\} + 1.235 \quad (6)$$

For Efficiency Consideration set $R_A$ = 990kΩ.

**Table 1. Suggested Resistance for Output Voltage Control**

| Conditions | $R_A$ (kΩ) | $R_B$ (kΩ) | $R_{GPIO}$ (kΩ) |
|---|---|---|---|
| Case A :<br>Normal Voltage = 16V<br>(GPIO = 0V)<br>Dimming Voltage = 12V<br>(GPIO = 1.8V) | 990 | 102 | 445 |
| Case B :<br>Normal Voltage = 16V<br>(GPIO = 0V)<br>Dimming Voltage = 12V<br>(GPIO = 2.8V) | 990 | 94 | 690 |

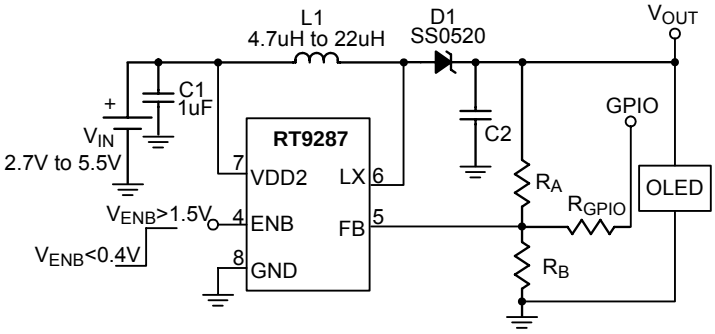



Figure 3. Application Circuit for 2-level Output Voltage Control

**Dual LDO**

Like any low-dropout regulator, the external capacitors used with the RT9287 must be carefully selected for regulator stability and performance. Using a capacitor whose value is > 1μF on the LDO input and the amount of capacitance can be increased without limit. The input capacitor must be located a distance of not more than 0.5 inch from the input pin of the IC and returned to a clean analog ground. Any high quality ceramic or tantalum capacitor can be used for this part. The capacitor with larger value and lower ESR (equivalent series resistance) provides better PSRR and line-transient response.

The output capacitor must meet both requirements for minimum amount of capacitance and ESR in all applications. The LDO is designed specifically to work with low ESR ceramic output capacitor in space-saving and performance consideration. Using a ceramic capacitor whose value is at least 1μF with ESR is > 20mΩ on the LDO output ensures stability. The LDO still works well with other kinds of output capacitor due to the wide stable ESR range. Figure 4 shows the curves of allowable ESR range as a function of load current for various output capacitor values. Output capacitor of larger capacitance can reduce noise and improve load transient response, stability, and PSRR. The output capacitor should be located not more than 0.5 inch from the VOUT pin of the LDO and returned to a clean analog ground.

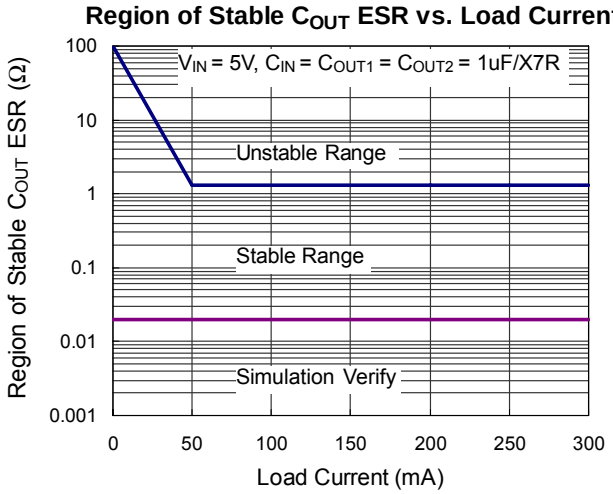



Figure 4. Stable Cout ESR Range

Thermal protection limits power dissipation in LDO. When the operating junction temperature exceeds a certain temperature, the OTP circuit starts the thermal shutdown function and turns the pass element off. The pass element turns on again after the junction temperature is cooled down. The RT9287 lowers its OTP trip level from 170°C to 110°C when output short circuit occurs ($V_{OUT}$ < 0.4V) as shown in Figure 5. It reduces operating junction temperature and provides maximum safety to customer while output short circuit occurring.

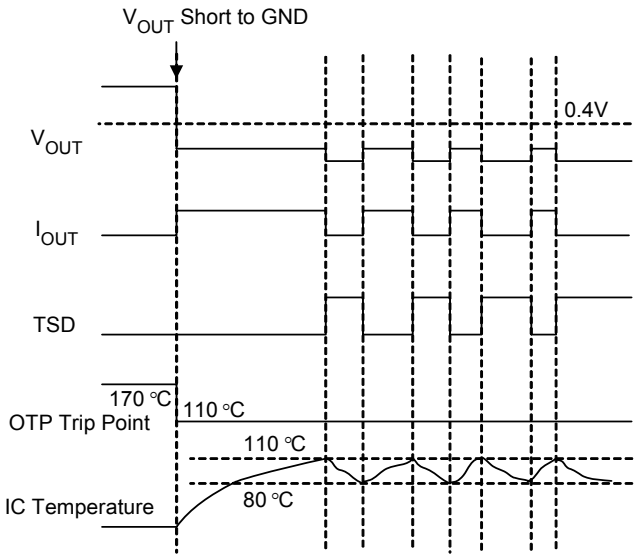



Figure 5. Short Circuit Thermal Folded Back Protection when Output Short Circuit Occurs (Patent)

### Thermal Considerations

The maximum power dissipation depends on the thermal resistance of IC package, PCB layout, the rate of surroundings airflow and temperature difference between junctions to ambient. The maximum power dissipation can be calculated by following formula :

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

Where $T_{J(MAX)}$ is the maximum operation junction temperature, $T_A$ is the ambient temperature and the $\theta_{JA}$ is the junction to ambient thermal resistance.

For recommended operating conditions specification of the RT9287, where $T_{J(MAX)}$ is the maximum junction temperature of the die and $T_A$ is the maximum ambient temperature. The junction to ambient thermal resistance $J_A$ is layout dependent. For WDFN-10L 3x3 packages, the thermal resistance $J_A$ is 60°C/W on the standard JEDEC 51-7 four-layers thermal test board. The maximum power dissipation at $T_A$ = 25°C can be calculated by following formula :

$P_{D(MAX)}$ = ( 125°C – 25°C) / (60°C/W) = 1.667W for WDFN-10L 3x3 packages

The maximum power dissipation depends on operating ambient temperature for fixed $T_{J(MAX)}$ and thermal resistance $J_{J(MAX)}$. For RT9287 packages, the Figure 6 of derating curves allows the designer to see the effect of rising ambient temperature on the maximum power allowed.

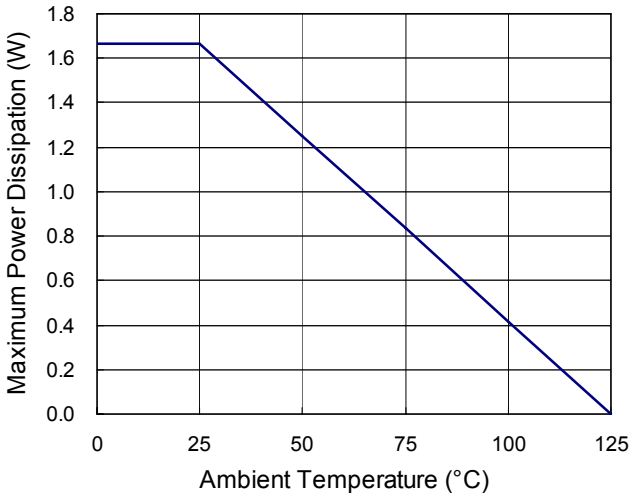



Figure 6. Derating Curves for RT9287 Packages

### Layout Guide

The exposed pad and GND should be connected to a strong ground plane for heat sinking and noise prevention.

Traces should be kept as short as possible.

- LX node copper area should be minimized for reducing EMI.
- The Dual LDO input capacitor C1 must be located a distance of not more than 0.5 inch from the VDD1 pin and returned to ground plane.
- The Boost input capacitor C2 should be placed as closed as possible to Pin 7.
- The Dual LDO output capacitor C3 and C4 must be located a distance of not more than 0.5 inch from the VLDO1 and VLDO2 pin and returned to ground plane.
- FB node copper area should be minimized and kept far away from noise sources ($L_X$).
- Feedback resistance R2 should be placed as closed as possible to Pin 5.

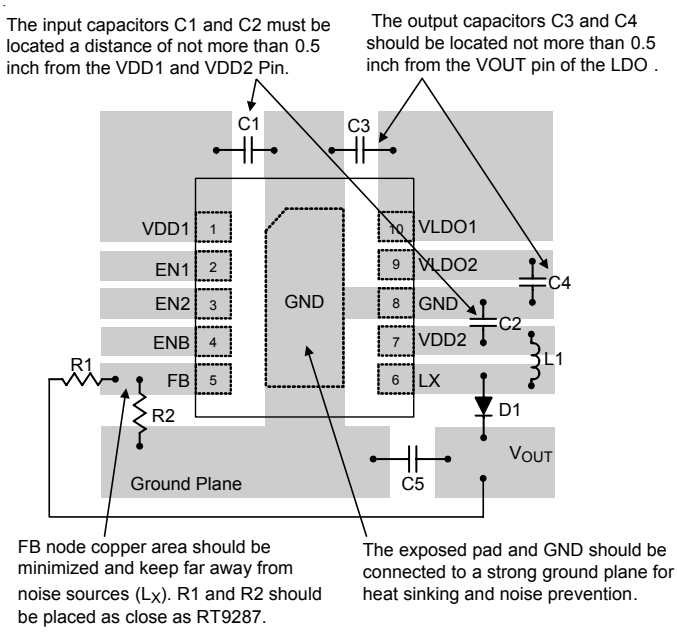
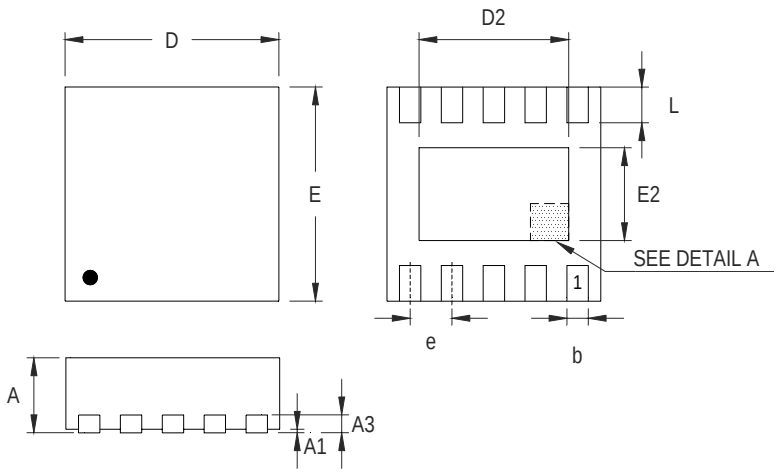
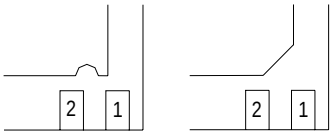



Figure 7

## 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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