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

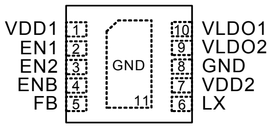
- **Boost Converter**
  - **VIN Operating Range : 2.7V to 5.5V**
  - **Maximum Output Voltage Up to 20V**
  - **Output Current up to 100mA at V_{OUT} = 12V.**
  - **Low Shutdown Supply Current**
  - **Minimize the External Component**
  - **Small LC Filter**
  - **Internal Soft Start**
- **Dual LDO**
  - **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

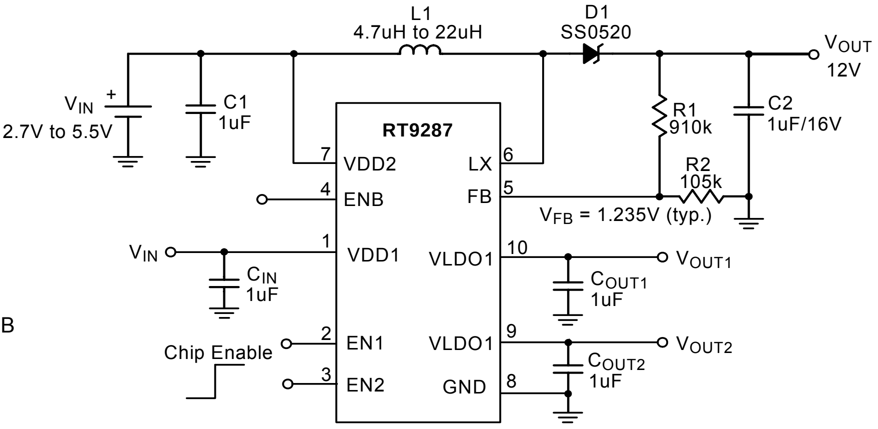
Pin Configurations

(TOP VIEW)



WDFN-10L 3x3

Typical Application Circuit



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

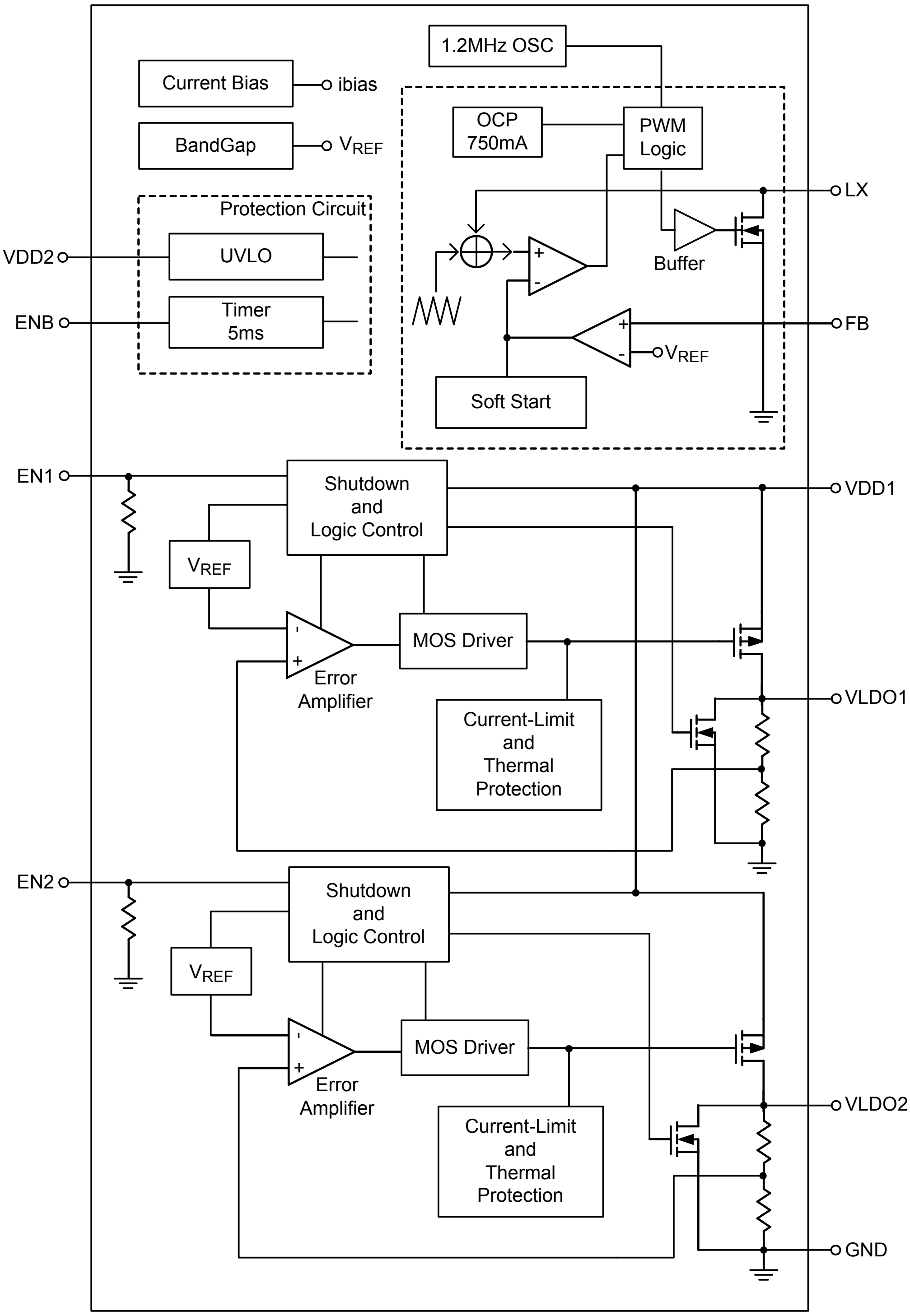
$V_{FB} = 1.235$ (typ.)

$R2 > 100k\Omega$

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, θ_{JA} ---------- 108°C/W
  WDFN−10L 3x3, θ_{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	ΔV	I_{OUT} = 1mA	–2	--	+2	%
Line Regulation	ΔV_{LINE}	V_{DD1} = ($V_{LDO1,2}$ + 0.3V) to 5.5V or V_{DD1} > 2.7V, whichever is larger	--	--	0.2	%
Load Regulation	ΔV_{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	ΔT_{SD}		--	40	--	°C
Thermal Shutdown Hysteresis	ΔT_{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.

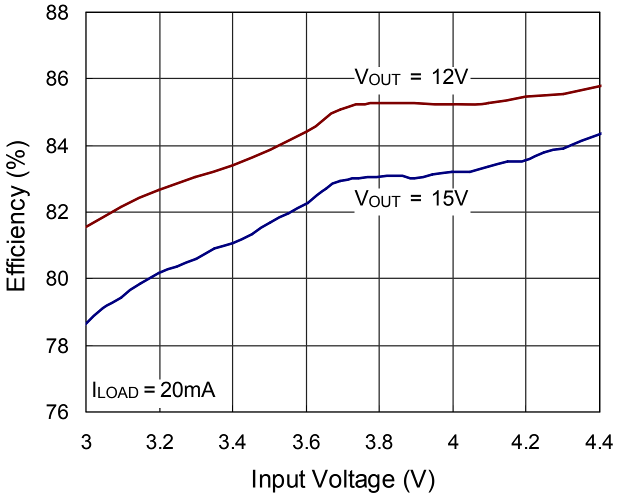
Note 3. The device is not guaranteed to function outside its operating conditions.

Note 4. θ_{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 θ_{JC} is on the expose pad for the WDFN package.

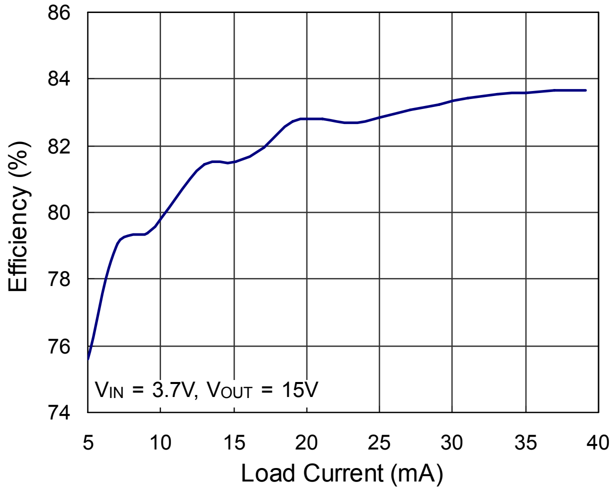
Note 5. The dropout voltage is defined as V_{IN} -V_{OUT}, which is measured when V_{OUT} is $V_{OUT(NORMAL)}$ – 100mV.

Typical Operating Characteristics

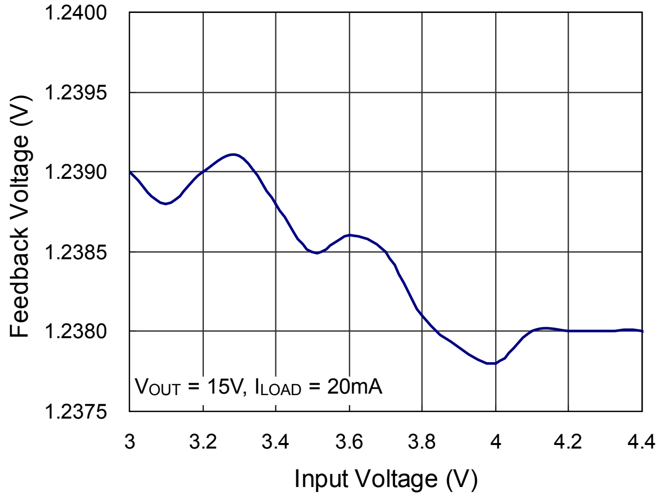
Boost Efficiency vs. Input Voltage



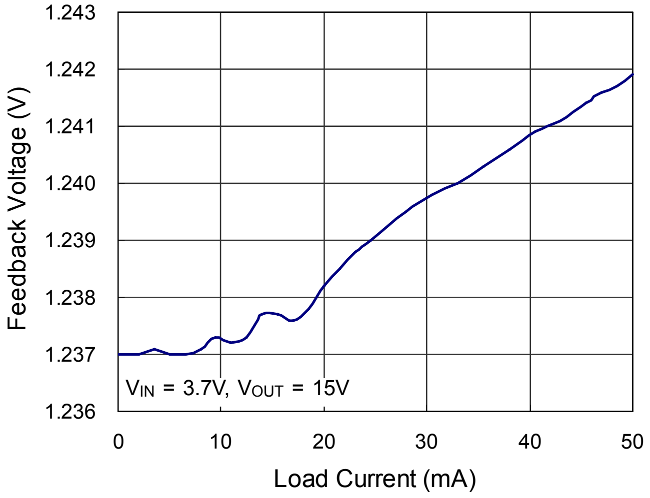
Boost Efficiency vs. Load Current



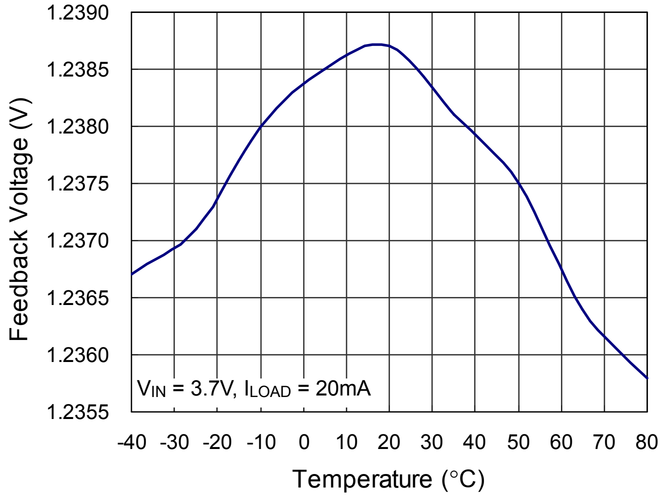
Boost Feedback Voltage vs. Input Voltage



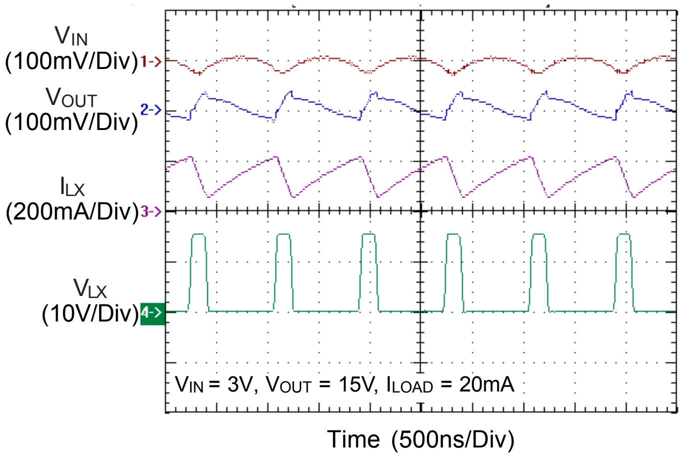
Boost Feedback Voltage vs. Load Current



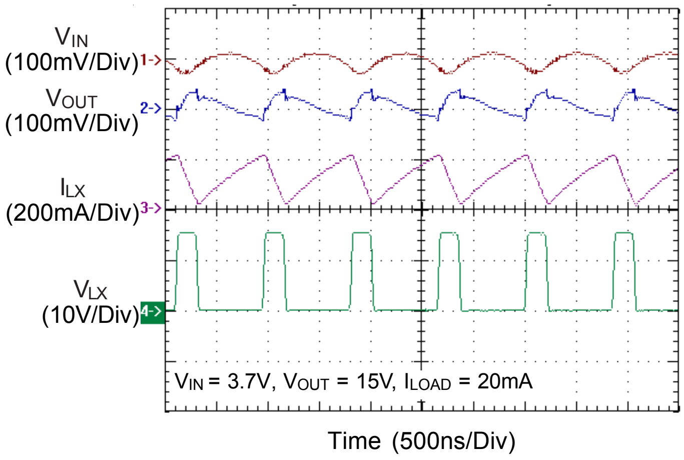
Boost Feedback Voltage vs.Temperature



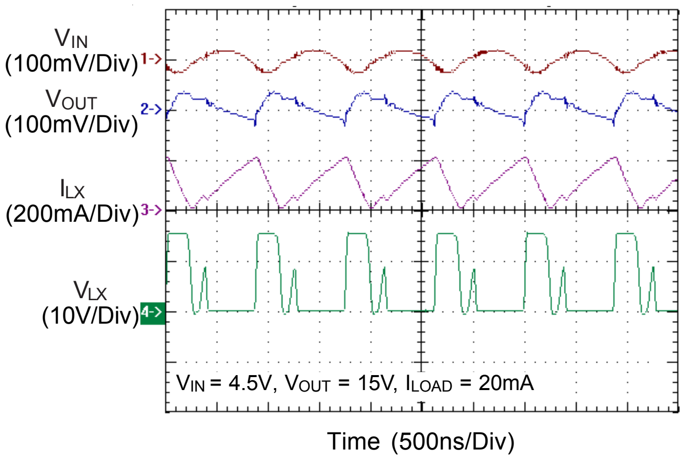
Boost Normal Operation



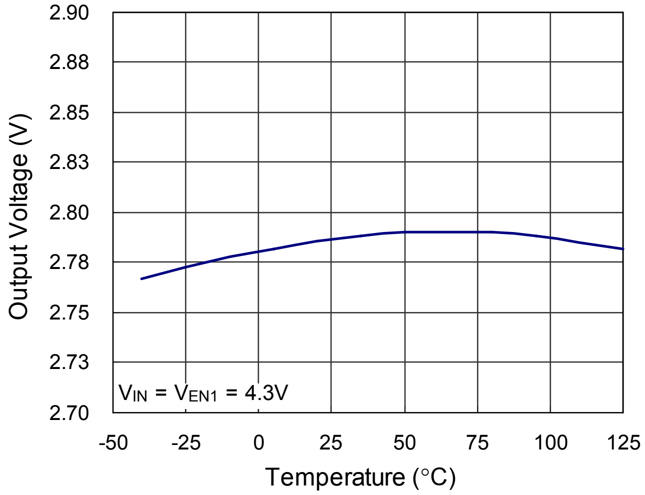
Boost Normal Operation



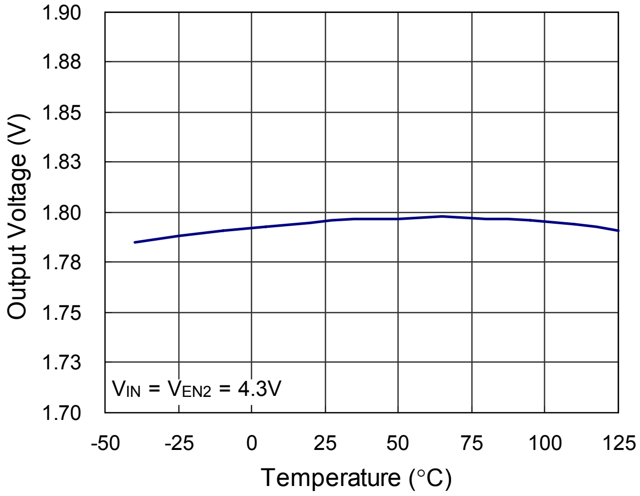
Boost Normal Operation



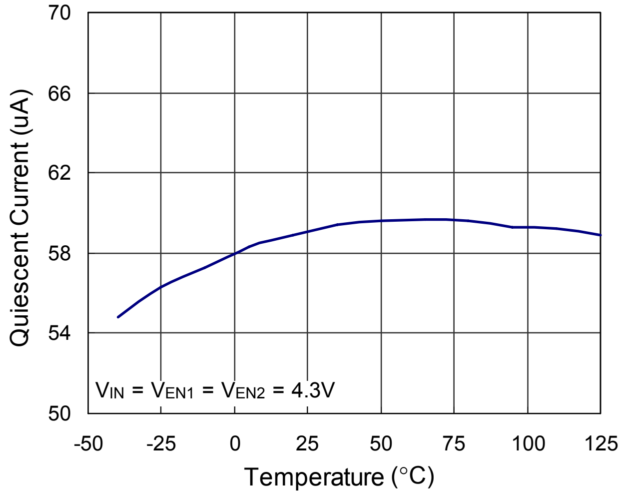
LDO 1 Output Voltage vs. Temperature



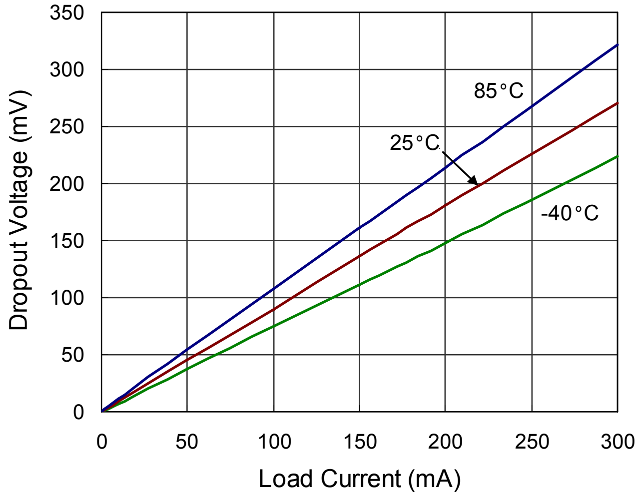
LDO 2 Output Voltage vs. Temperature

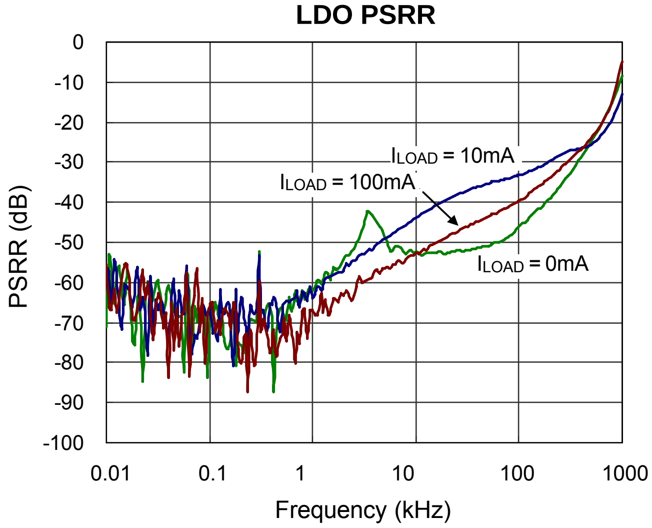


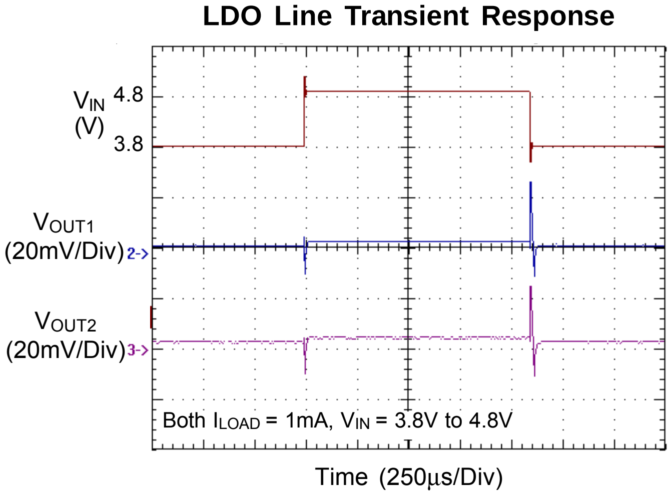
LDO Quiescent Current vs. Temperature



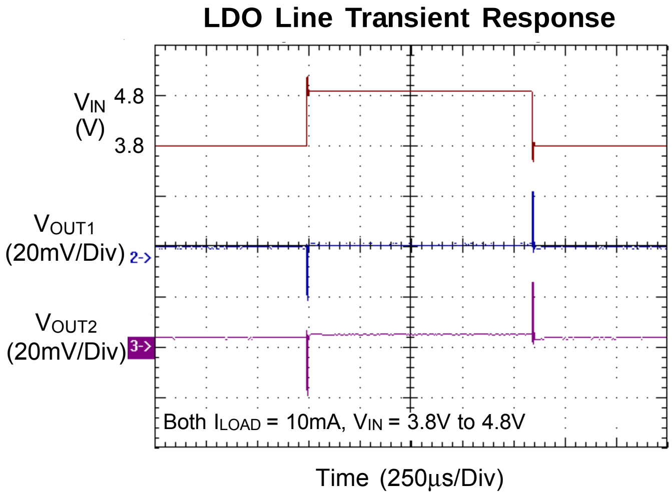
LDO Dropout Voltage vs. Load Current



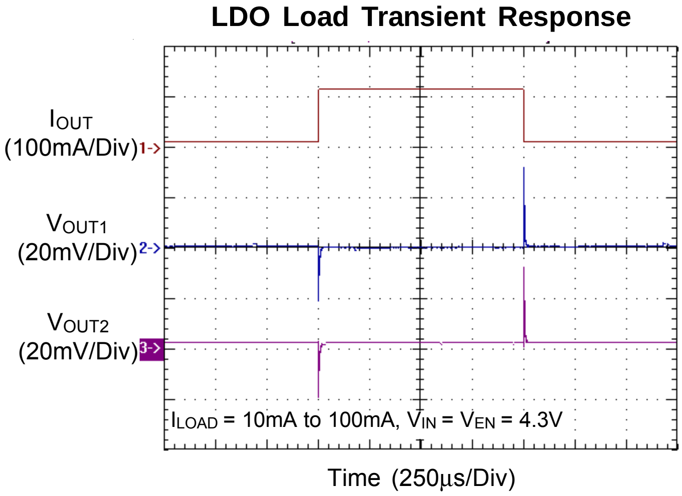

LDO PSRR


LDO Line Transient Response

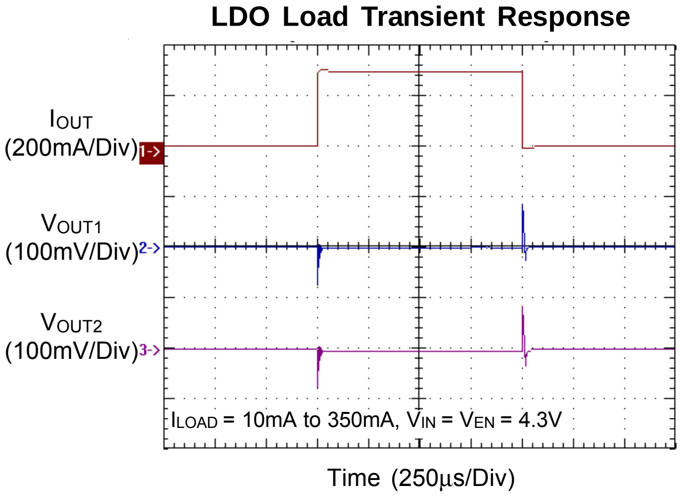
Both I_{LOAD} = 1mA, V_{IN} = 3.8V to 4.8V


LDO Line Transient Response

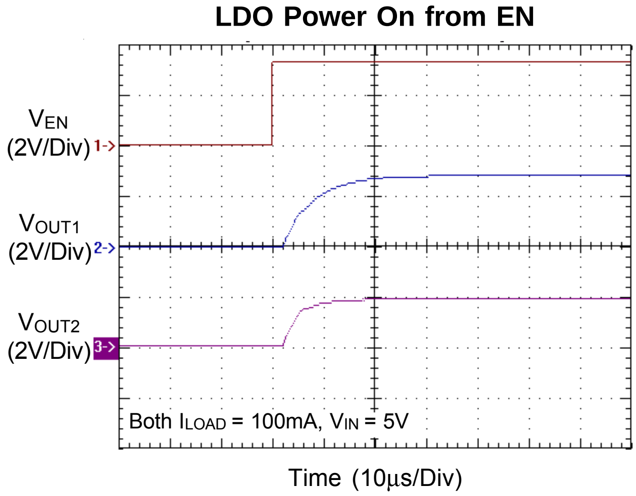
Both I_{LOAD} = 10mA, V_{IN} = 3.8V to 4.8V


LDO Load Transient Response

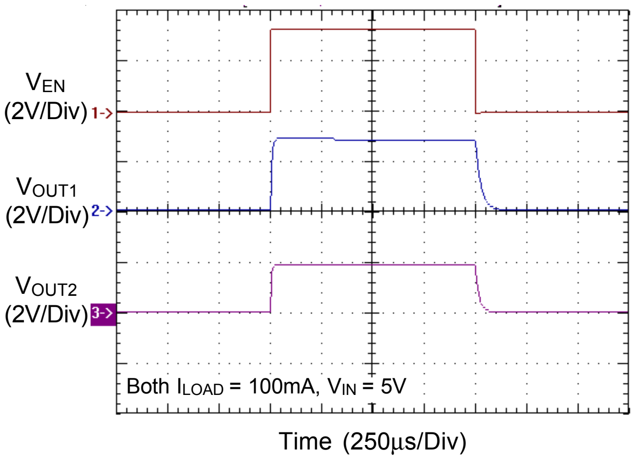
I_{LOAD} = 10mA to 100mA, V_{IN} = V_{EN} = 4.3V


LDO Load Transient Response

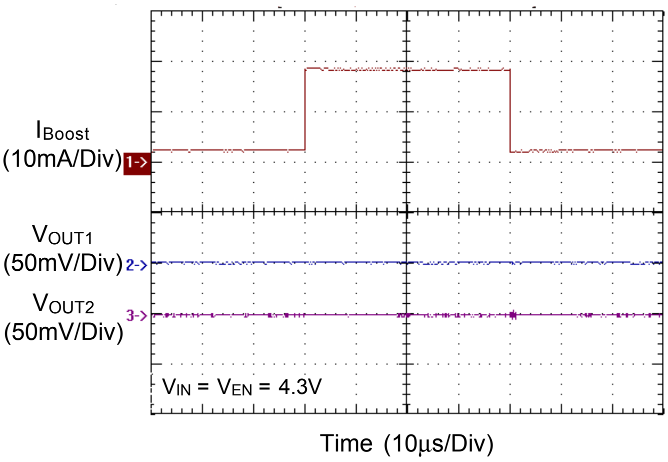
I_{LOAD} = 10mA to 350mA, V_{IN} = V_{EN} = 4.3V


LDO Power On from EN

Both I_{LOAD} = 100mA, V_{IN} = 5V


LDO Power Off from EN

Both I_{LOAD} = 100mA, V_{IN} = 5V


Cross Talk

V_{IN} = V_{EN} = 4.3V

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.

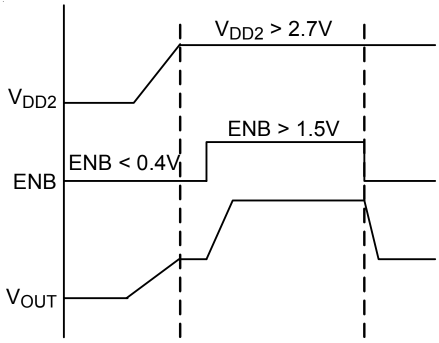


Figure 1

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.

$$I_{LED} = V_{REF} / R_{SET} \tag{1}$$

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

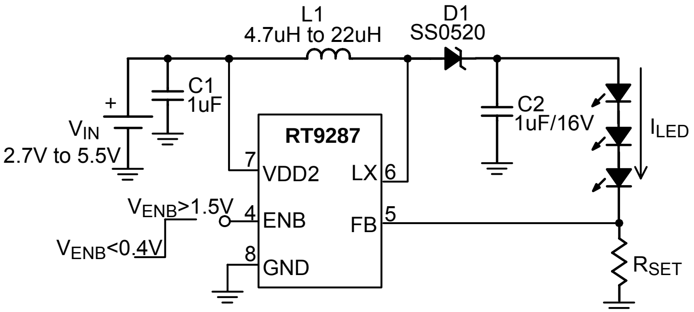


Figure 2. Application for Driving 3 Series WLEDs

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.

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

As GPIO = 0V,

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

As GPIO = 2.8V,

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

As GPIO = 1.8V,

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

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 : Normal Voltage = 16V (GPIO = 0V) Dimming Voltage = 12V (GPIO = 1.8V)	990	102	445
Case B : Normal Voltage = 16V (GPIO = 0V) Dimming Voltage = 12V (GPIO = 2.8V)	990	94	690

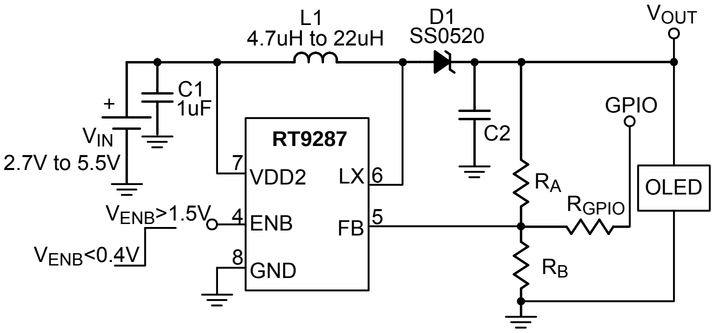


Figure 3. Application Circuit for 2-level Output Voltage Control

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.

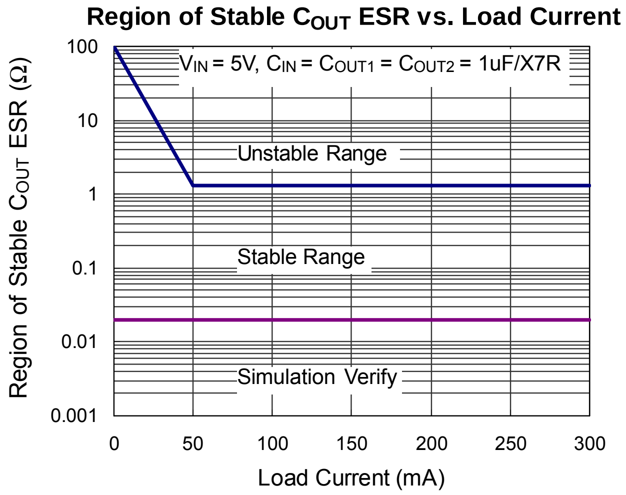


Figure 4. Stable Cout ESR Range

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.

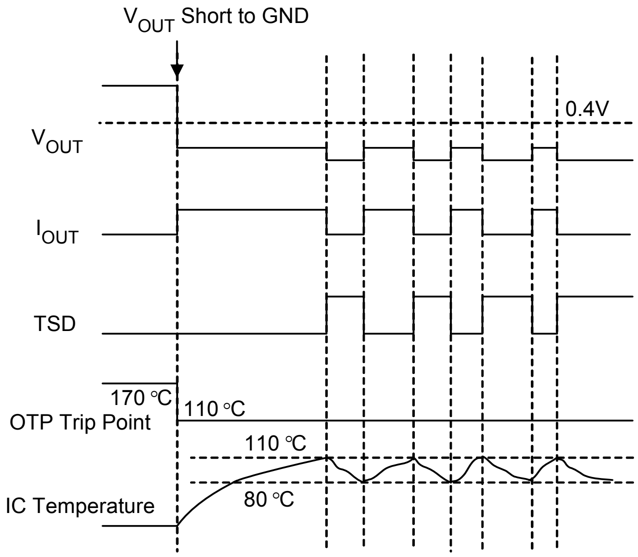


Figure 5. Short Circuit Thermal Folded Back Protection when Output Short Circuit Occurs (Patent)

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 θ_{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.

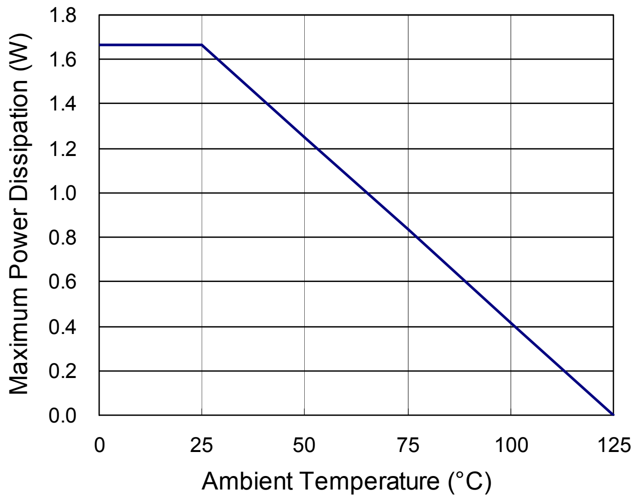


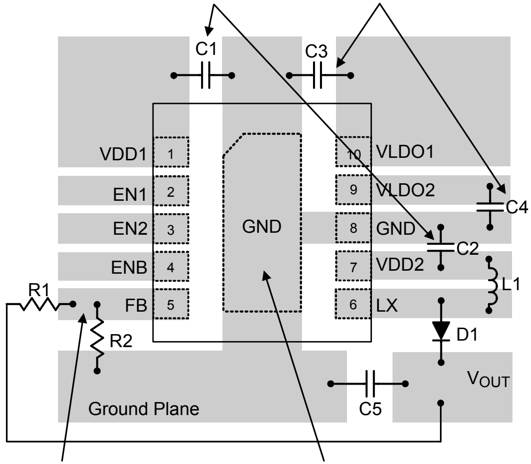
Figure 6. Derating Curves for RT9287 Packages

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.



The input capacitors C1 and C2 must be located a distance of not more than 0.5 inch from the VDD1 and VDD2 Pin.

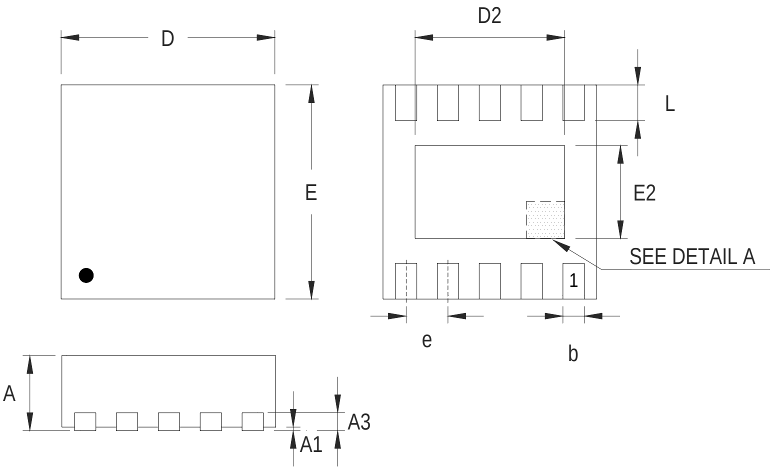
The output capacitors C3 and C4 should be located not more than 0.5 inch from the VOUT pin of the LDO .

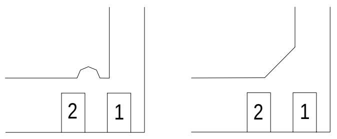
FB node copper area should be minimized and keep far away from noise sources (L_X). R1 and R2 should be placed as close as RT9287.

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

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

Richtek Technology Corporation
Headquarter
5F, No. 20, Taiyuen Street, Chupei City
Hsinchu, Taiwan, R.O.C.
Tel: (8863)5526789 Fax: (8863)5526611

Richtek Technology Corporation
Taipei Office (Marketing)
8F, No. 137, Lane 235, Paochiao Road, Hsintien City
Taipei County, Taiwan, R.O.C.
Tel: (8862)89191466 Fax: (8862)89191465
Email: marketing@richtek.com