Synchronous Boost Converter with Voltage Detector

General Description

The RT9276 is a synchronous boost converter, which is based on a fixed frequency Pulse-Width-Modulation (PWM) controller using a synchronous rectifier to obtain maximum efficiency. The converter provides a power supply solution for products powered by a variety of batteries such as single cell, dual cell alkaline, NiMH and NiCd battery. At light load currents, the converter enters power save mode to maintain a high efficiency over a wide load current range.

The output voltage can be programmed by an external resistor divider, or fixed at a certain voltage. Moreover, the converter can be disabled to minimize battery drain. During shutdown, the load is completely disconnected from the battery. The maximum peak current in the boost switch is limited to 2A for current limit.

For the RT9276, a low-EMI mode is implemented to reduce ringing of the inductor phase pin when the converter enters discontinuous conduction mode. Moreover, a voltage detector is built-in in the chip for low battery detection.

Ordering Information

RT9276(-□□)□□

Package Type
QW : WDFN-10L 3x3 (W-Type)

Lead Plating System
G : Green (Halogen Free and Pb Free)

Boost VOUT
Default : Adjustable
33 : 3.3V
50 : 5.0V

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

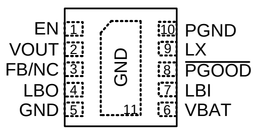
- **True Load Disconnection During Shutdown**
- **Internal Synchronous Rectifier**
- **Up to 96% Efficiency**
- **Current Mode PWM Operation with Internal Compensation**
- **Low Start-Up Voltage**
- **Low Quiescent Current**
- **Internal Soft-Start Control**
- **Low Battery Comparator**
- **Low EMI Converter (Anti-Ringing)**
- **Power Save Mode for Improved Efficiency at Light Load Current**
- **Over Current Protection**
- **Short Circuit Protection**
- **Over Temperature Protection**
- **Over Voltage Protection**
- **Small WDFN-10L 3x3 Package**
- **RoHS Compliant and Halogen Free**

Applications

- All One-Cell, Two-Cell and Three-Cell Alkaline, NiCd, NiMH and Single-Cell Li Batteries
- Hand-Held Devices
- WLED Flash Light

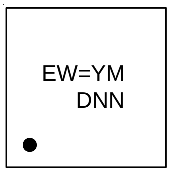
Pin Configurations

(TOP VIEW)



WDFN-10L 3x3

Marking Information



EW= : Product Code

YMDNN : Date Code

Typical Application Circuit

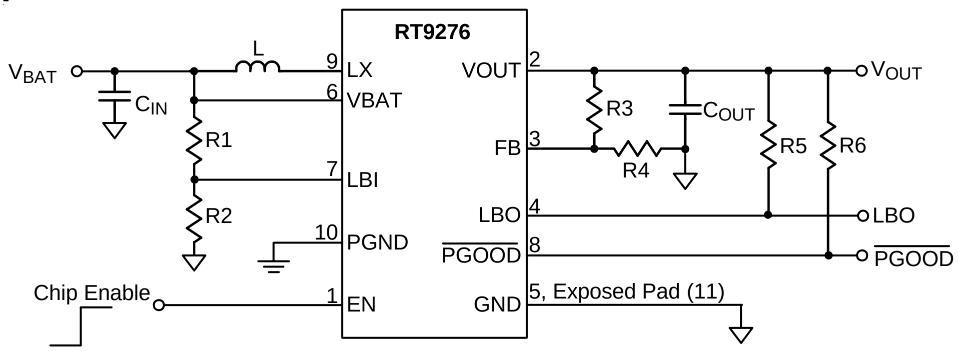


Figure 1. Adjustable Output Voltage Boost Converter with Voltage Detector

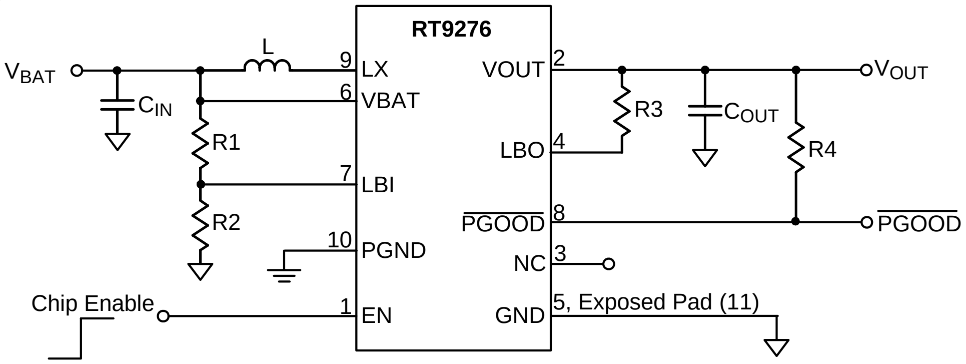


Figure 2. Fixed Output Voltage Boost Converter with Voltage Detector

Functional Pin Description

Pin No.	Pin Name	Pin Function
1	EN	Chip Enable (Active High).
2	VOUT	Boost Output.
3	FB / NC	Feedback Input for Adjustable Output Voltage Version / No Internal Connection for Fixed Output Voltage Version.
4	LBO	Voltage Detector Output.
5	GND	Ground.
6	VBAT	Battery Supply Input.
7	LBI	Voltage Detector Input.
8	$\overline{\text{PGOOD}}$	Power Good Indicator.
9	LX	Switching Node. Connect this pin to an inductor.
10	PGND	Power Ground.
11 (Exposed Pad)	GND	Ground. The exposed pad must be soldered to a large PCB and connected to GND for maximum power dissipation.

Function Block Diagram

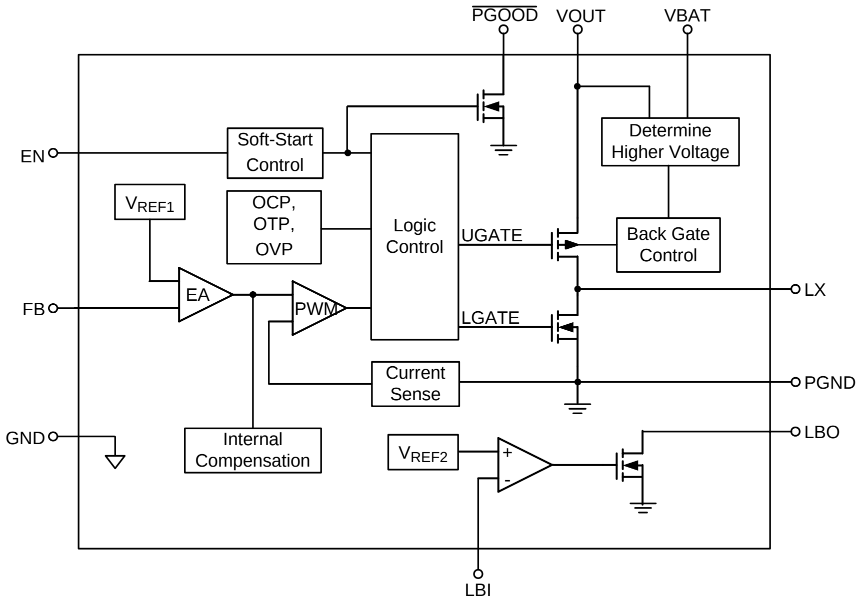


Figure 3. Adjustable Voltage Regulator

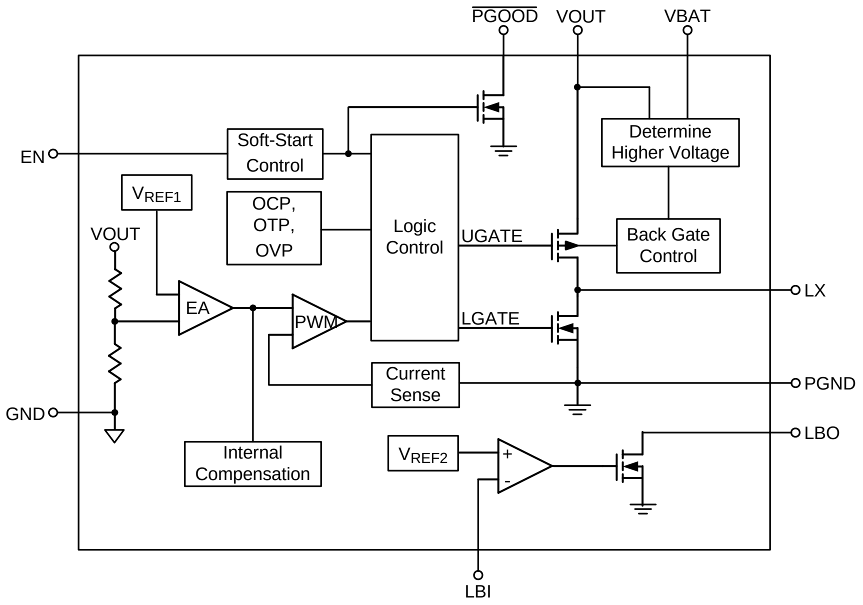


Figure 4. Fixed Voltage Regulator

Absolute Maximum Ratings (Note 1)

- Supply Input Voltage, V_{BAT} ---------- –0.3V to 6V
- Boost Output Voltage, V_{OUT} ---------- –0.3V to 6.5V
- Switch Output Voltage, LX ---------- –0.3V to 6.5V
  <10ns ---------- –2V to 7.5V
- Digital Input Voltage, EN, LBI ---------- –0.3V to 6V
- Digital Output Voltage, LBO, $\overline{PGOOD}$ ---------- –0.3V to 6V
- Others Pin ---------- –0.3V to 6V
- Power Dissipation, P_D @ T_A = 25°C
  WDFN-10L 3x3 ---------- 1.429W
- Package Thermal Resistance (Note 2)
  WDFN-10L 3x3, θ_{JA} ---------- 70°C/W
  WDFN-10L 3x3, θ_{JC} ---------- 8.2°C/W
- Junction Temperature Range ---------- 150°C
- Lead Temperature (Soldering, 10 sec.) ---------- 260°C
- Storage Temperature Range ---------- –65°C to 150°C
- ESD Susceptibility (Note 3)
  HBM (Human Body Mode) ---------- 2kV
  MM (Machine Mode) ---------- 200V

Recommended Operating Conditions (Note 4)

- Supply Input Voltage Range, V_{BAT} ---------- 1.2V to 5V
- Junction Temperature Range ---------- –40°C to 125°C
- Ambient Temperature Range ---------- –40°C to 85°C

Electrical Characteristics

($V_{BAT} \geq$ 2.5V or V_{BAT} = V_{OUT} + 0.7V, V_{EN} = V_{BAT}, C_{IN} = 10µF, C_{OUT} = 22µF, T_A = 25°C, unless otherwise specified)

Parameter	Symbol	Test Conditions	Min	Typ	Max	Unit
Pre-charge Current	$I_{Pre\text{-}chg}$	V_{IN} = 5V	--	100	--	mA
DC/DC Stage						
Minimum Start-Up Input Voltage	V_{BAT}	I_{LOAD} = 1mA	--	1.2	--	V
Input Voltage Range After Start-Up	V_{BAT}		0.8	--	5	V
Output Voltage Range	V_{OUT}		--	--	5	V
Feedback Reference Voltage	V_{FB}	For Adjustable Output Voltage	0.49	0.5	0.51	V
Output Voltage Accuracy	ΔV_{OUT}	For Fixed Output Voltage	–3	--	3	%
Switching Frequency	f_{LX}		0.96	1.2	1.44	MHz
Maximum Duty Cycle	D_{MAX}		--	90	--	%
Non-Switching Quiescent Current	$I_{Q,NS}$	No Switching	--	100	--	µA
Shutdown Current	I_{SHDN}	V_{EN} = 0, V_{BAT} = 1.2V	--	2	5	µA

Parameter		Symbol	Test Conditions	Min	Typ	Max	Unit
Protection							
Over-Temperature Protection		T_{OTP}		--	170	--	°C
Over-Temperature Hysteresis		T_{OTP_Hys}		--	40	--	°C
Over-Current Protection		I_{OCP}	V_{OUT} = 3.3V	1.6	2	2.4	A
Over-Voltage Protection		V_{OVP}		5.4	--	6	V
Power MOSFET							
N-MOSFET ON-Resistance		$R_{DS(ON)\_N}$	V_{OUT} = 3.3V	--	220	--	mΩ
			V_{OUT} = 5V	--	200	--	
P-MOSFET ON-Resistance		$R_{DS(ON)\_P}$	V_{OUT} = 3.3V	--	260	--	mΩ
			V_{OUT} = 5V	--	240	--	
Enable Control							
EN Threshold Voltage	Logic-High	V_{IH}	Rising	0.8	--	--	V
	Logic-Low	V_{IL}	Falling	--	--	0.2	
Voltage Detector							
LBI Voltage Threshold		V_{LBI_Rising}		0.49	0.5	0.51	V
LBI Voltage Hysteresis		V_{LBI_Hys}		--	10	--	mV
LBO Output Impedance		R_{ON_LBO}	V_{LBI} = 0V, V_{OUT} = 3.3V	--	15	--	Ω

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.

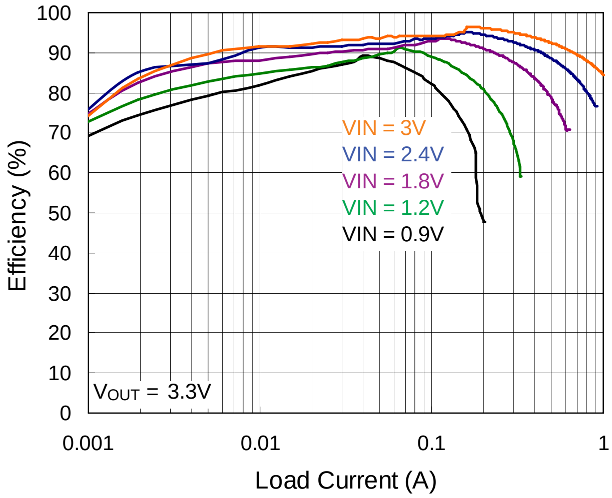
Note 3. Devices are ESD sensitive. Handling precaution is recommended.

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

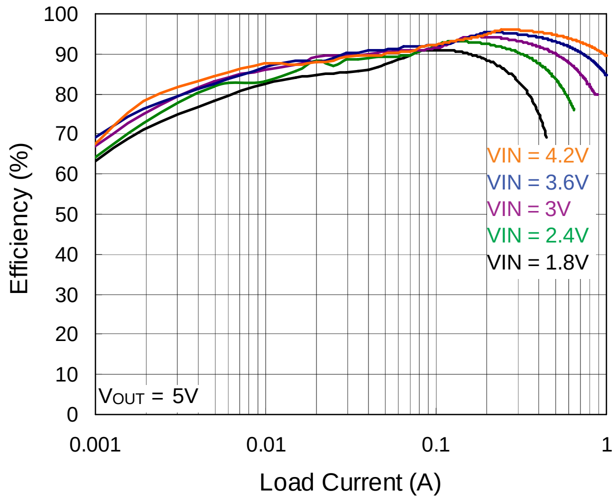
Typical Operating Characteristics

C_{IN} = 10µF, C_{OUT} = 22µF, L = 4.7µH, unless otherwise specified.

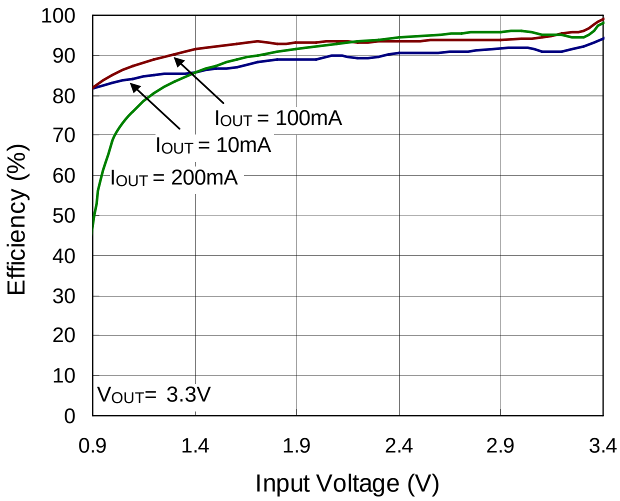
Efficiency vs. Load Current



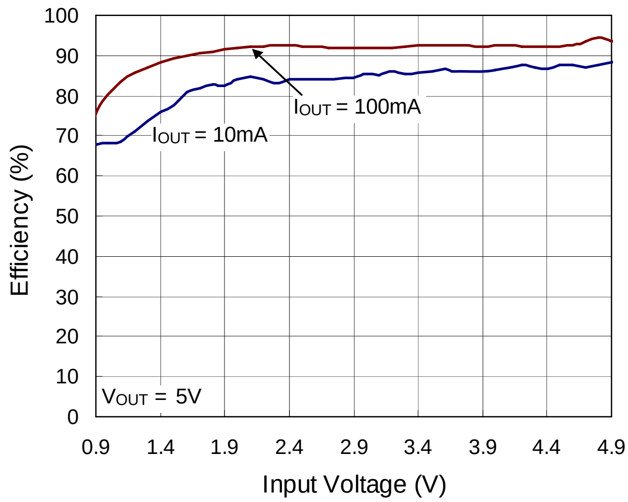
Efficiency vs. Load Current



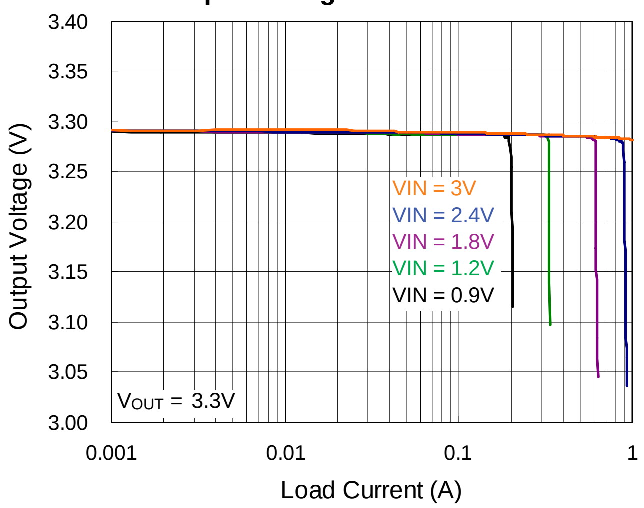
Efficiency vs. Input Voltage



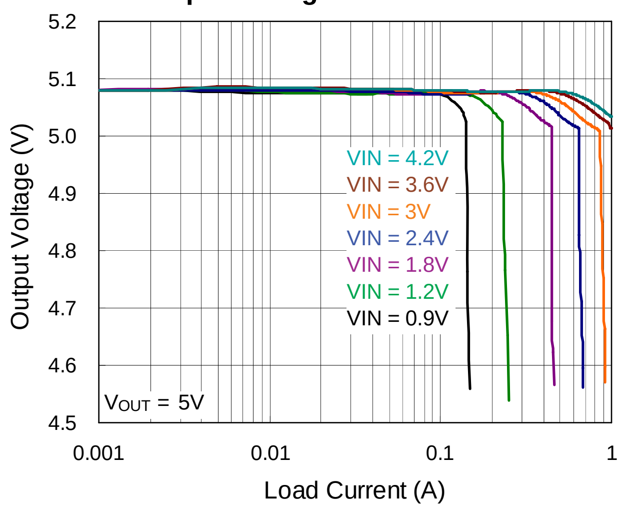
Efficiency vs. Input Voltage

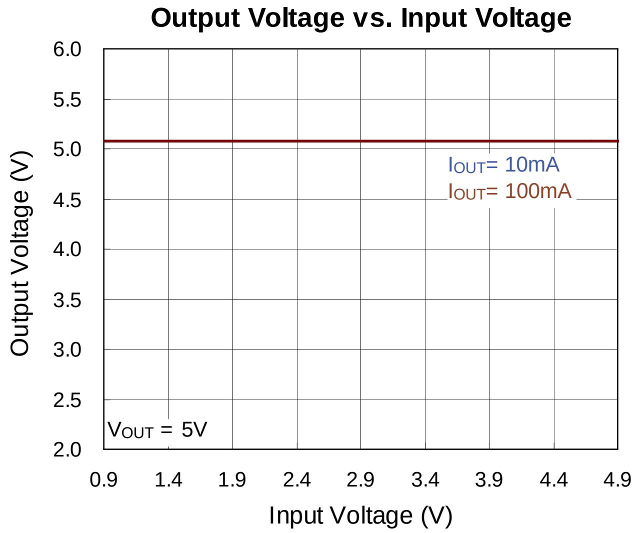


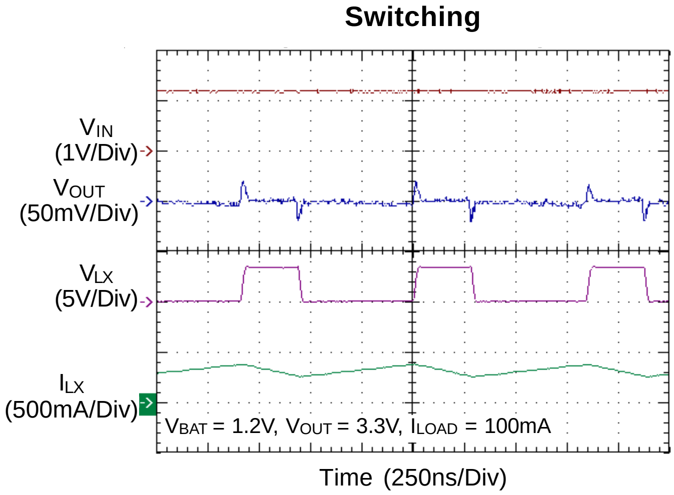
Output Voltage vs. Load Current

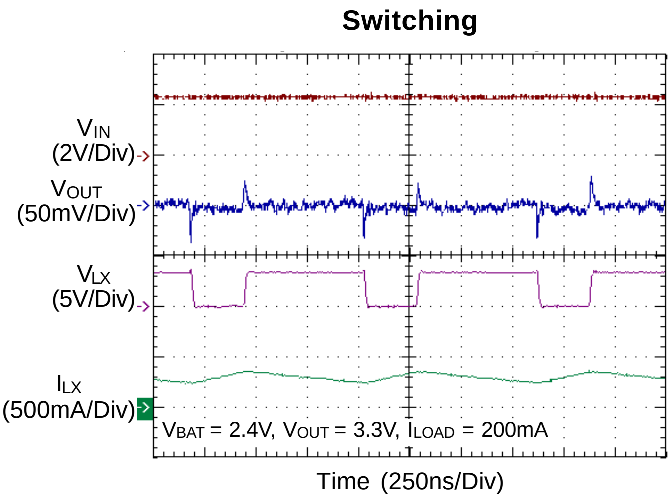


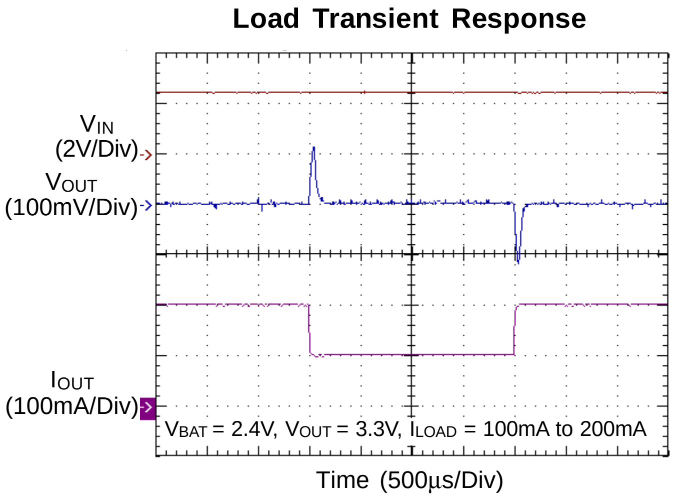
Output Voltage vs. Load Current

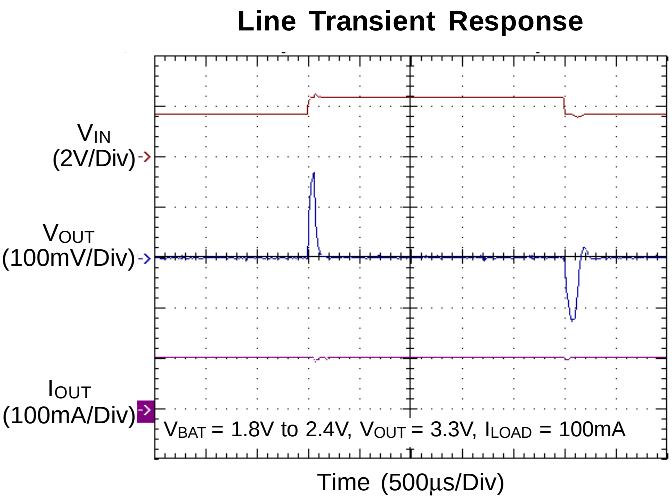


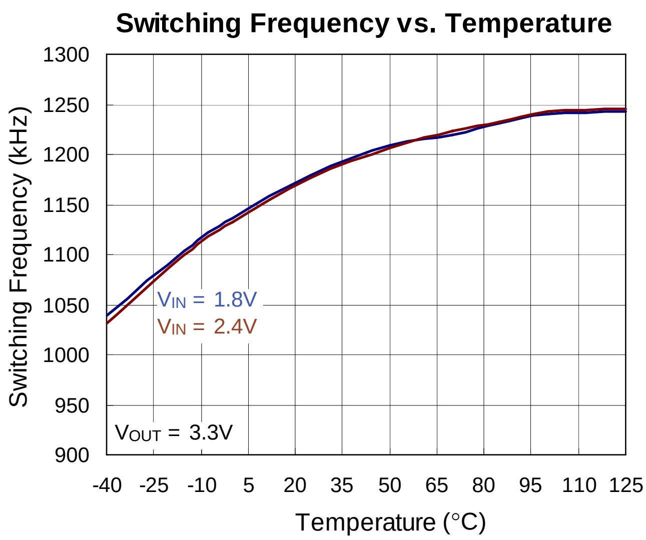

Output Voltage vs. Input Voltage
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
Output Voltage (V)
IOUT= 10mA
IOUT= 100mA
VOUT = 5V
0.9
1.4
1.9
2.4
2.9
3.4
3.9
4.4
4.9
Input Voltage (V)

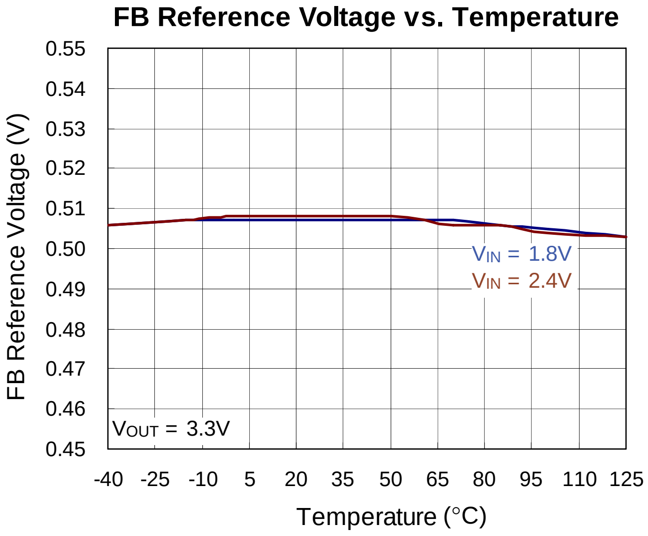

Switching
VIN (1V/Div)
VOUT (50mV/Div)
VLX (5V/Div)
ILX (500mA/Div)
VBAT = 1.2V, VOUT = 3.3V, ILOAD = 100mA
Time (250ns/Div)

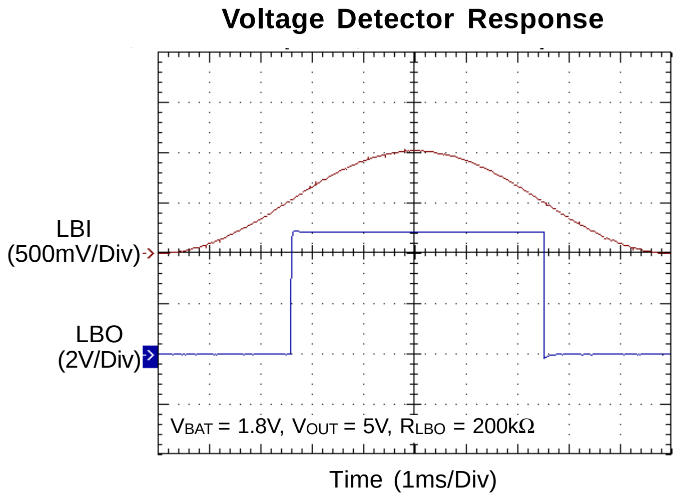

Switching
VIN (2V/Div)
VOUT (50mV/Div)
VLX (5V/Div)
ILX (500mA/Div)
VBAT = 2.4V, VOUT = 3.3V, ILOAD = 200mA
Time (250ns/Div)


Load Transient Response
VIN (2V/Div)
VOUT (100mV/Div)
IOUT (100mA/Div)
VBAT = 2.4V, VOUT = 3.3V, ILOAD = 100mA to 200mA
Time (500µs/Div)


Line Transient Response
VIN (2V/Div)
VOUT (100mV/Div)
IOUT (100mA/Div)
VBAT = 1.8V to 2.4V, VOUT = 3.3V, ILOAD = 100mA
Time (500µs/Div)


Switching Frequency vs. Temperature
1300
1250
1200
1150
1100
1050
1000
950
900
Switching Frequency (kHz)
VIN = 1.8V
VIN = 2.4V
VOUT = 3.3V
-40
-25
-10
5
20
35
50
65
80
95
110
125
Temperature (°C)


FB Reference Voltage vs. Temperature
0.55
0.54
0.53
0.52
0.51
0.50
0.49
0.48
0.47
0.46
0.45
FB Reference Voltage (V)
VIN = 1.8V
VIN = 2.4V
VOUT = 3.3V
-40 -25 -10 5 20 35 50 65 80 95 110 125
Temperature (°C)


Voltage Detector Response
LBI
(500mV/Div)
LBO
(2V/Div)
VBAT = 1.8V, VOUT = 5V, RLBO = 200kΩ
Time (1ms/Div)

Application Information

The RT9276 integrates a high efficiency synchronous step-up DC-DC converter and a low battery detector. To fully utilize its advantages, peripheral components should be appropriately selected. The following information provides detailed description of application.

Inductor Selection

For a better efficiency in high switching frequency converter, the inductor selection has to use a proper core material such as ferrite core to reduce the core loss and choose low ESR wire to reduce copper loss. The most important point is to prevent core saturation when handling the maximum peak current. Using a shielded inductor can minimize radiated noise in sensitive applications. The maximum peak inductor current is the maximum input current plus half of the inductor ripple current. The calculated peak current has to be smaller than the current limitation in the electrical characteristics. A typical setting of the inductor ripple current is 20% to 40% of the maximum input current. If the selection is 40%

$$I_{PK} = I_{IN(MAX)} + \frac{1}{2} I_{RIPPLE} = 1.2 \times I_{IN(MAX)}$$

$$= 1.2 \times \left[\frac{I_{OUT(MAX)} \times V_{OUT}}{\eta \times V_{BAT(MIN)}} \right]$$

The minimum inductance value is derived from the following equation :

$$L = \frac{\eta \times I_{IN(MIN)}^2 \times \left[V_{OUT} - V_{BAT(MIN)} \right]}{0.4 \times I_{OUT(MAX)} \times V_{OUT}^2 \times f_{LX}}$$

Depending on the application, the recommended inductor value is between 2.2μH and 10μH.

Input Capacitor Selection

For better input bypassing, low-ESR ceramic capacitors are recommended for performance. A 10μF input capacitor is sufficient for most applications. For a lower output power requirement application, this value can be decreased

Output Capacitor Selection

For lower output voltage ripple, low ESR ceramic capacitors are recommended. The tantalum capacitors can be used as well, but their ESR is bigger than ceramic capacitors. The output voltage ripple consists of two components: one is the pulsating output ripple current which flows through the ESR, and the other is the capacitive ripple caused by charging and discharging.

$$V_{RIPPLE} = V_{RIPPLE(ESR)} + V_{RIPPLE(C)}$$

$$\cong I_{PEAK} \times R_{ESR} + \frac{I_{PEAK}}{C_{OUT}} \left[\frac{V_{OUT} - V_{BAT}}{V_{OUT} \times f_{LX}} \right]$$

Output Voltage Setting

Referring to application circuit (Figure 1), the output voltage of the switching regulator (V_{OUT}) can be set with below equation :

$$V_{OUT} = \left(1 + \frac{R3}{R4} \right) \times V_{FB}$$

where V_{FB} = 0.5V (typ.)

When the input voltage is larger than output setting voltage 370mV (typ.) the RT9276 will be in pre-charge mode. During pre-charge phase, the synchronous P-MOSFET is turned on until the output capacitor is charged to a value close to the input voltage minus 0.2V. Then the converter is followed by PWM operation. The adaptive pre-charge current increases linearly to overcome the loading current in the pre-charge phase. If the loading current is larger than pre-charge current, the RT9276 will be in pre-charge mode until loading current is removed or reduced.

Low Battery Voltage Detector

The low battery voltage detector is designed to monitor the battery voltage and to generate an error flag when the battery voltage drops below a user-set threshold voltage. The function is active only when the device is enabled. When the device is disabled, the LBO pin is in high impedance. The LBI threshold voltage is 0.5V typically, with 10mV hysteresis voltage. If the low-battery detection circuit is not used, the LBI pin should be connected to GND (or to V_{BAT}) and the LBO pin can be left unconnected. Do not let the LBI pin floating.

Thermal Considerations

For continuous operation, do not exceed absolute maximum operation junction temperature. The maximum power dissipation depends on the thermal resistance of IC package, PCB layout, the rate of surroundings airflow and temperature difference between junction 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, the maximum junction temperature is 125°C. The junction to ambient thermal resistance θ_{JA} is layout dependent. For WDFN-10L 3x3 package, the thermal resistance θ_{JA} is 70°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) / (70°C/W) = 1.429W for WDFN-10L 3x3 packages

The maximum power dissipation depends on operating ambient temperature for fixed $T_{J(MAX)}$ and thermal resistance θ_{JA}. The Figure 5 of derating curves allows the designer to see the effect of rising ambient temperature on the maximum power dissipation.

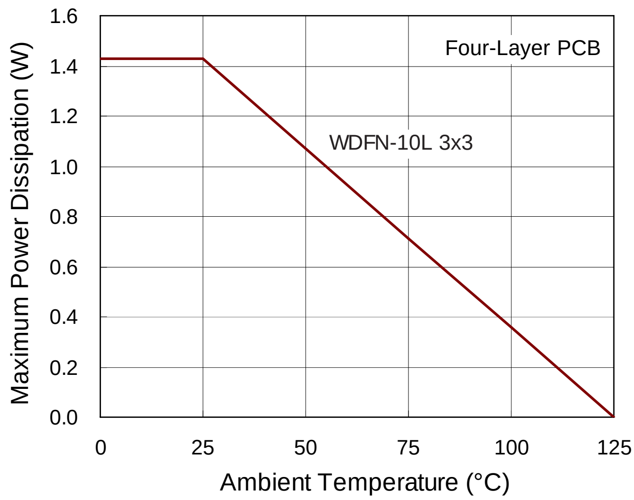


Figure 5. Derating Curve of Maximum Power Dissipation

Layout Consideration

For best performance of the RT9276, the following layout guidelines must be strictly followed :

- Input and Output capacitors should be placed close to the IC and connected to ground plane to reduce noise coupling.
- The GND and Exposed Pad should be connected to a strong ground plane for heat sinking and noise protection.
- Keep the main current traces as short and wide as possible.
- Place the feedback components as close as possible to the IC and keep away from the noisy devices.

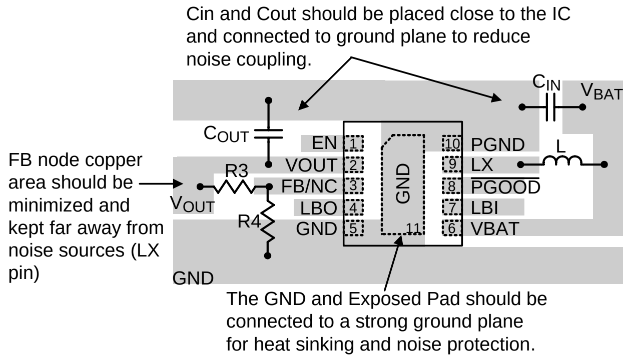
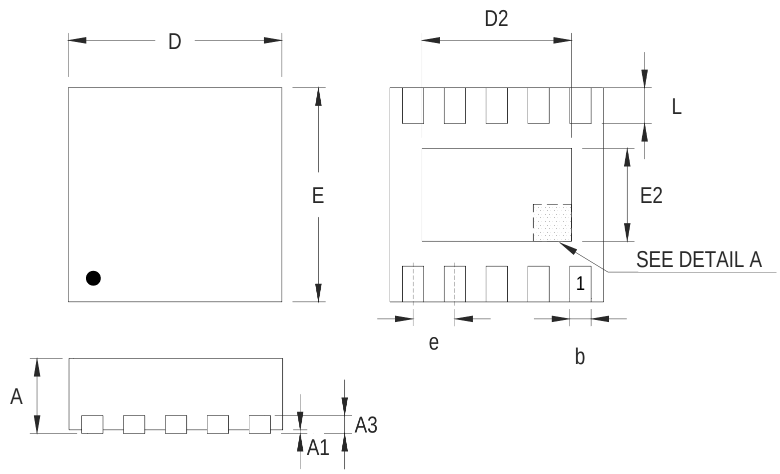
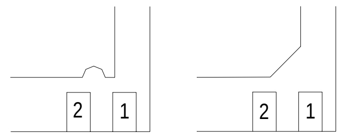


Figure 6. PCB Layout Guide

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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