RICHTEK® **RTQ2516**

2A, Low Input Voltage, Ultra-Low Dropout LDO Regulator with Enable

1 General Description

The RTQ2516 is a high performance positive voltage regulator designed for use in applications requiring ultra- low input voltage and ultra-low dropout voltage at up to 2 amperes. It operates with an input voltage as low as 1.4V, with output voltage programmable as low as 0.5V. The RTQ2516 features ultra low dropout, ideal for applications where output voltage is very close to input voltage. Additionally, the RTQ2516 has an enable pin to further reduce power dissipation while shutdown. The RTQ2516 provides excellent regulation over variations in line, load and temperature. The RTQ2516 is available in the SOP-8 (Exposed Pad) package. The output voltage can be set by an external divider depending on how the FB pin is configured. The recommended junction temperature range is –40°C to 125°C.

2 Ordering Information

RTQ2516□□-QT

- Grade
  QT: AEC-Q100 Qualified
- Package Type(1)
  SP: SOP-8 (Exposed Pad-Option 2)
- Lead Plating System
  G: Richtek Green Policy Compliant(2)

Note 1.

- Marked with (1) indicated: Compatible with the current requirements of IPC/JEDEC J-STD-020.
- Marked with (2) indicated: Richtek products are Richtek Green Policy compliant.

3 Features

- **AEC-Q100 Grade 2 Qualified**
- **Input Voltage as Low as 1.4V**
- **Ultra-Low Dropout Voltage 400mV at 2A**
- **Overcurrent Protection**
- **Over-Temperature Protection**
- **1μA Input Current in Shutdown Mode**
- **Enable Control**

4 Applications

- **Telecom/Networking Cards**
- **Motherboards/Peripheral Cards**
- **Industrial Applications**
- **Wireless Infrastructure**
- **Set Top Box**
- **Medical Equipment**
- **Notebook Computers**
- **Battery Powered Systems**

5 Marking Information

RTQ2516
GSPQTYMDNN
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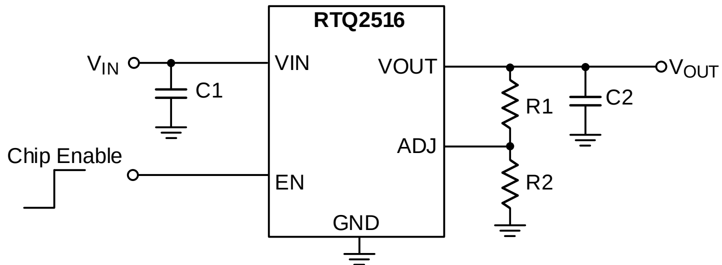
RTQ2516GSPQT: Product Code
YMDNN: Date Code

6 Simplified Application Circuit



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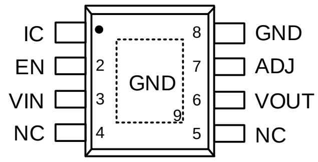
7 Pin Configuration

(TOP VIEW)

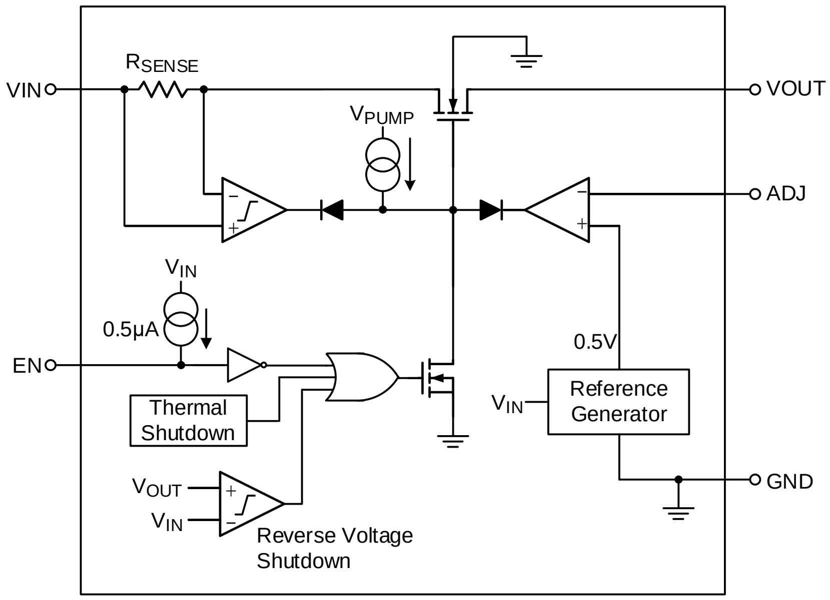


SOP-8 (Exposed Pad)

8 Functional Pin Description

Pin No.	Pin Name	Pin Function
1	IC	Internal connection. Keep this pin floating for normal operation.
4, 5	NC	No internal connection.
2	EN	Chip enable (Active-High). Pulling this pin below 0.4V to turn the regulator off. The device will be enabled if this pin is left open. Connect to VIN for controlling by VIN.
3	VIN	Power input. For regulation at full load, the input to this pin must be between (V_{OUT} + 0.5V) and 6V. Minimum input voltage is 1.4V. A large bulk capacitance should be placed closely to this pin to ensure that the input supply does not sag below 1.4V. A minimum of 10μF ceramic capacitor should be placed directly at this pin.
6	VOUT	LDO output pin. Connect a ceramic capacitor with an capacitance of at least 10μF as close as possible from this pin to GND to minimize the input impedance.
7	ADJ	Feedback voltage input. This pin is used to set the output voltage via an external resistive voltage divider. The feedback reference voltage is 0.5V (typical). Place the resistive voltage divider as close to the FB pin as possible. Do not leave this pin floating.
8, 9 (Exposed pad)	GND	Ground. This pin must be soldered to a large PCB copper area for maximum power dissipation.

9 Functional Block Diagram



10 Absolute Maximum Ratings

(Note 2)

- Supply Voltage, VIN-- –0.3V to 7V
- Other Pins --- –0.3V to 7V
- Lead Temperature (Soldering, 10 sec.) --- 260°C
- Junction Temperature -- 150°C
- Storage Temperature Range --- –65°C to 150°C

Note 2. Stresses beyond those listed under “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.

11 ESD Ratings

(Note 3)

- ESD Susceptibility
- HBM (Human Body Model)-- 2kV

Note 3. Devices are ESD sensitive. Handling precautions are recommended.

12 Recommended Operating Conditions

(Note 4)

- Supply Input Voltage, VIN --- 1.4V to 6V
- Junction Temperature Range-- –40°C to 125°C

Note 4. Recommended operating conditions indicate conditions for which the device is intended to be functional, but do not ensure specific performance limits. For ensured specifications, see the Electrical Characteristics table.

13 Thermal Information

(Note 5 and Note 6)

Thermal Parameter		SOP-8 (Exposed Pad)	Unit
θ_{JA}	Junction-to-ambient thermal resistance (JEDEC standard)	40.1	°C/W
$\theta_{JC(Top)}$	Junction-to-case (top) thermal resistance	63	°C/W
$\theta_{JC(Bottom)}$	Junction-to-case (bottom) thermal resistance	4.5	°C/W
$\theta_{JA(EVB)}$	Junction-to-ambient thermal resistance (specific EVB)	51.2	°C/W
$\Psi_{JC(Top)}$	Junction-to-top characterization parameter	10.9	°C/W
Ψ_{JB}	Junction-to-board characterization parameter	32	°C/W

Note 5. For more information about thermal parameter, see the Application and Definition of Thermal Resistances report, AN061.

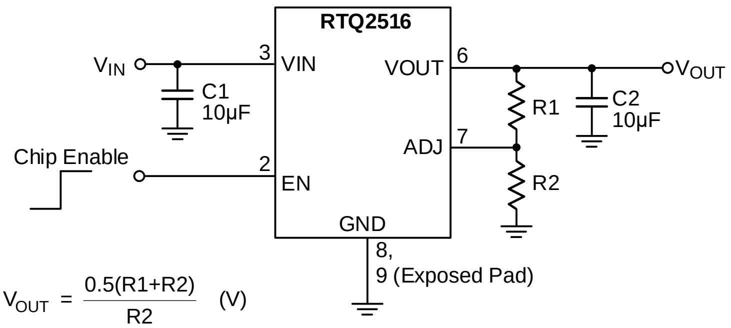
Note 6. $\theta_{JA(EVB)}$, $\Psi_{JC(TOP)}$, and Ψ_{JB} are measured on a high effective-thermal-conductivity two-layer test board which is in size of 70mm x 50mm; furthermore, all layers with 1 oz. Cu. Thermal resistance/parameter values may vary depending on the PCB material, layout, and test environmental conditions.

14 Electrical Characteristics

(V_{IN} = 1.4V to 6V, I_{OUT} = 10μA to 2A, V_{ADJ} = V_{OUT}, –40°C ≤ T_A ≤ 105°C, unless otherwise specified)

Parameter	Symbol	Test Conditions	Min	Typ	Max	Unit
Quiescent Current	I_Q	V_{IN} = 3.3V, I_{OUT} = 0A	--	0.7	1.5	mA
Shutdown Current	I_{SHDN}	V_{IN} = 6V, V_{EN} = 0V	--	1.5	10	μA
Line Regulation	V_{LINE_REG}	I_{OUT} = 10mA	--	0.2	0.4	%/V
Load Regulation	V_{LOAD_REG}	I_{OUT} = 10mA to 2A	--	0.5	1.5	%
Dropout Voltage	V_{DROP}	I_{OUT} = 1A, V_{IN} ≥ 1.6V	--	120	200	mV
		I_{OUT} = 1A, 1.4V < V_{IN} < 1.6V	--	--	400	
		I_{OUT} = 1.5A, V_{IN} ≥ 1.6V	--	180	300	
		I_{OUT} = 1.5A, 1.4V < V_{IN} < 1.6V	--	--	500	
		I_{OUT} = 2A, V_{IN} ≥ 1.6V	--	240	400	
		I_{OUT} = 2A, 1.4V < V_{IN} < 1.6V	--	--	600	
Current Limit	I_{LIM}	V_{IN} = 3.3V	2.3	3	4.4	A
Feedback						
ADJ Reference Voltage	V_{REF}	V_{IN} = 3.3V, V_{ADJ} = V_{OUT}, I_{OUT} = 10mA, T_A = 25°C	0.495	--	0.505	V
		V_{IN} = 3.3V, V_{ADJ} = V_{OUT}, I_{OUT} = 10mA	0.4925	--	0.5075	
ADJ Pin Current	I_{ADJ}	V_{ADJ} = 0.5V	--	20	200	nA
Enable						
EN Pin Current	I_{EN}	V_{EN} = 0V, V_{IN} = 6V	--	1	10	μA
EN Input Voltage Rising Threshold	V_{EN_R}	V_{IN} = 3.3V	1.6	--	--	V
EN Input Voltage Falling Threshold	V_{EN_F}	V_{IN} = 3.3V	--	--	0.4	
Over-Temperature Protection						
OTP Trip Level	T_{OTP}	Threshold	--	160	--	°C
Hysteresis	T_{OTP_HYS}	Hysteresis	--	30	--	°C

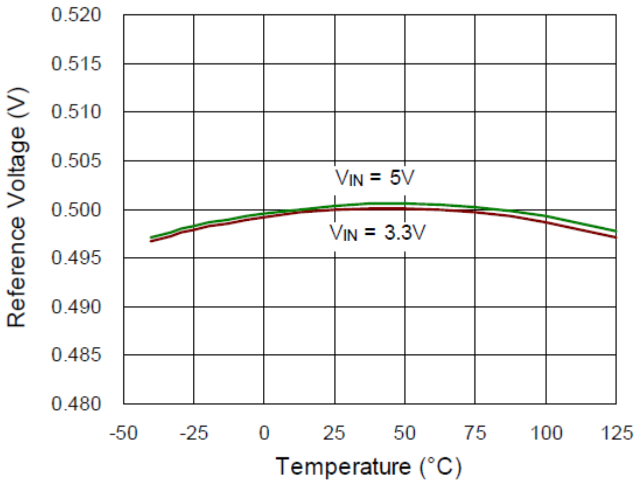
15 Typical Application Circuit



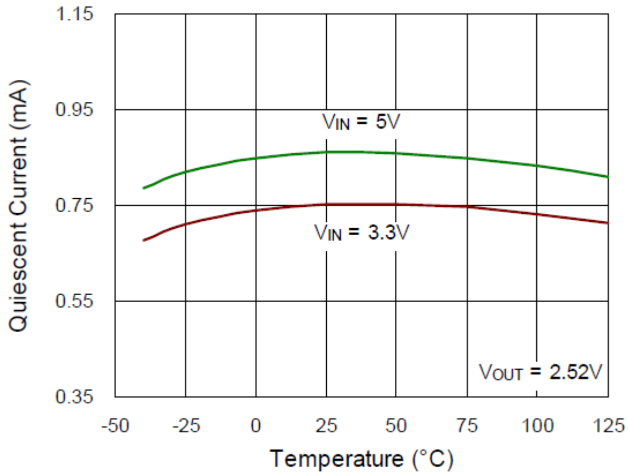
$$V_{OUT} = \frac{0.5(R1+R2)}{R2} \quad (V)$$

16 Typical Operating Characteristics

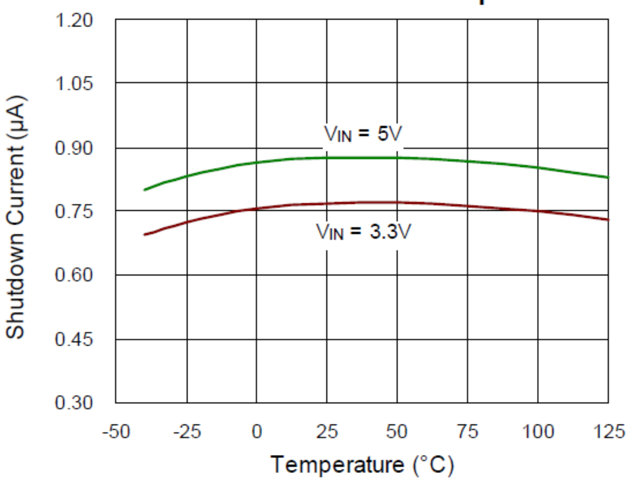
Reference Voltage vs. Temperature



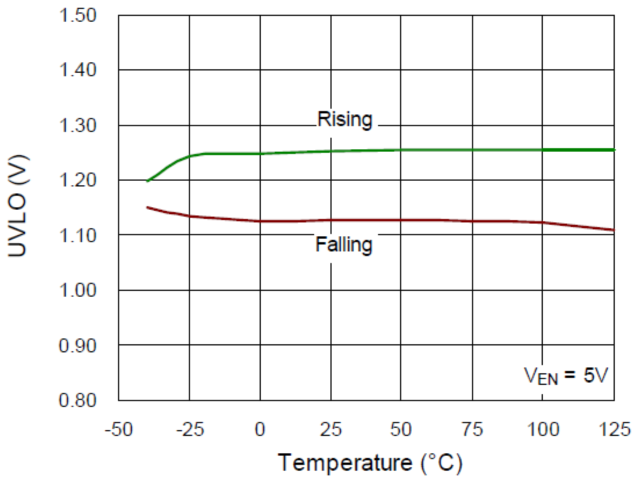
Quiescent Current vs. Temperature



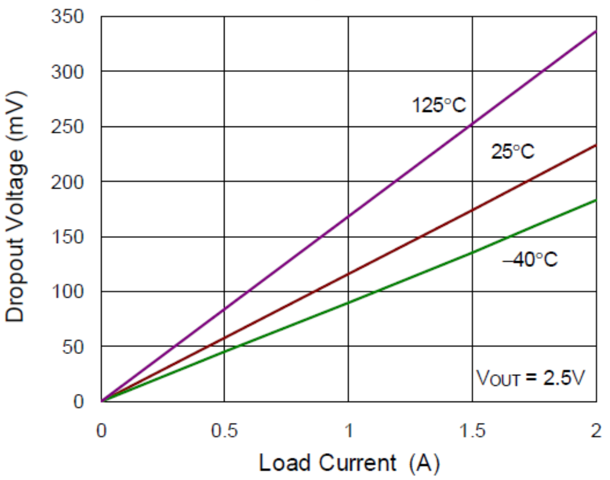
Shutdown Current vs. Temperature



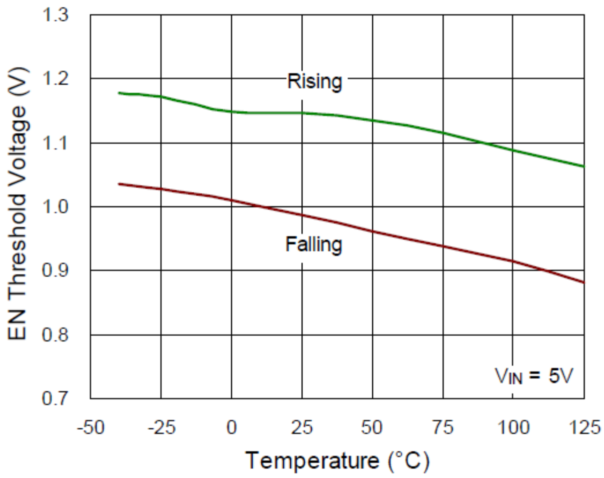
UVLO vs. Temperature



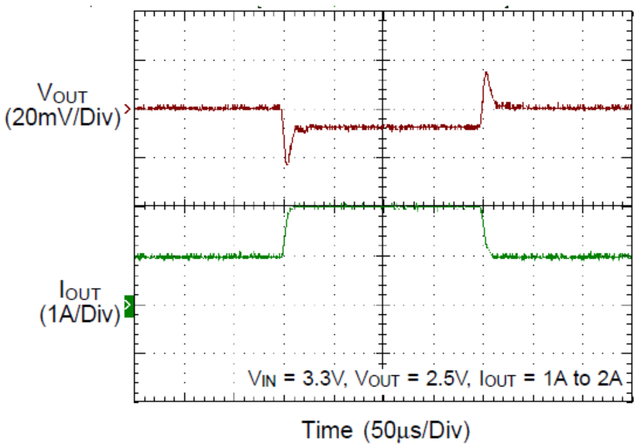
Dropout Voltage vs. Load Current



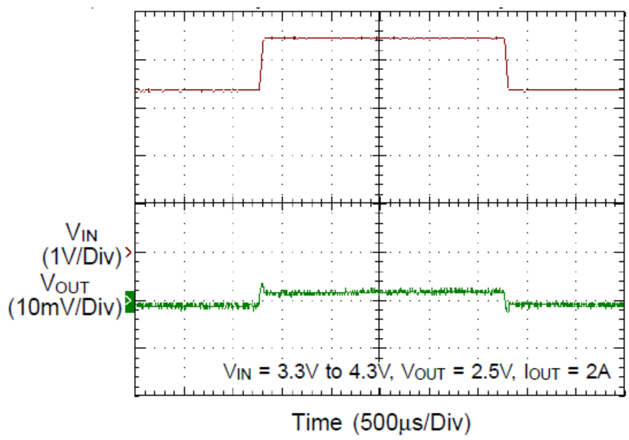
EN Threshold Voltage vs. Temperature



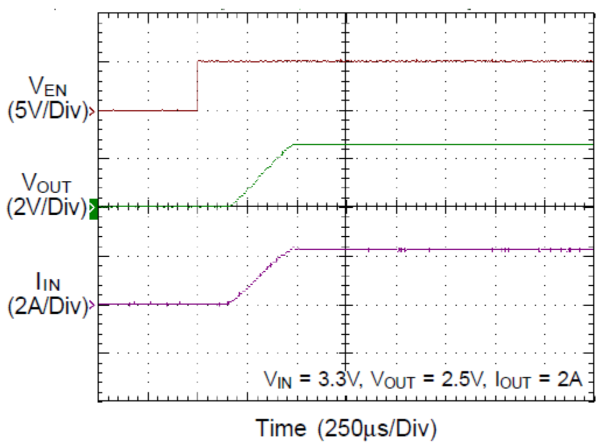
Load Transient Response



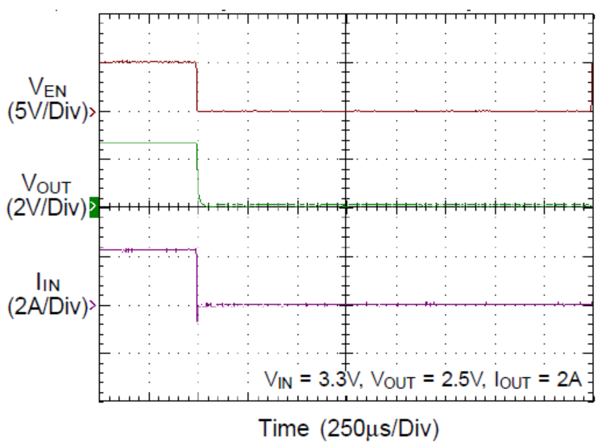
Line Transient Response



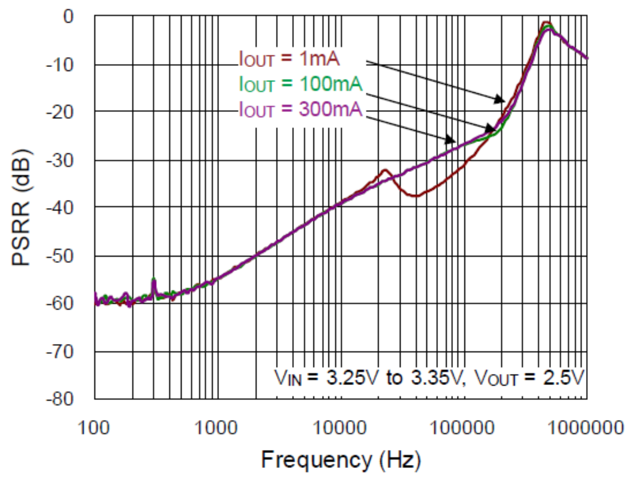
Power On from EN



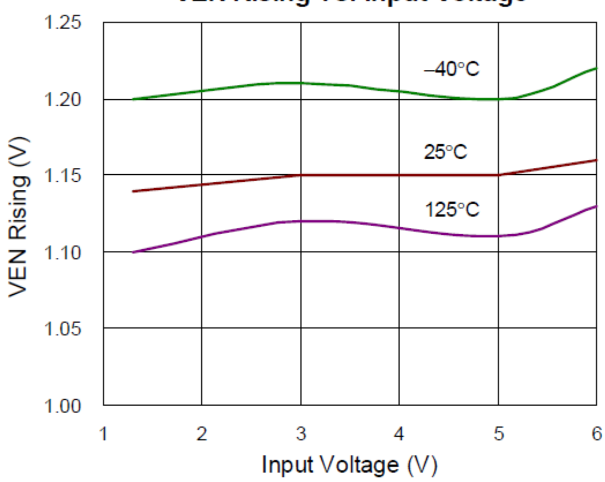
Power Off from EN



PSRR



VEN Rising vs. Input Voltage



17 Operation

The RTQ2516 is a low input voltage, low dropout LDO that can support an input voltage range from 1.4V to 6V and an output current of up to 2A. The RTQ2516 uses an internal charge pump to achieve low input voltage operation, and the internal compensation network is well designed to achieve fast transient response with good stability. In steady-state operation, the feedback voltage is regulated to the reference voltage by the internal regulator. When the feedback voltage signal is less than the reference, the on-resistance of the power MOSFET is decreased to increase the output current through the power MOSFET, and the feedback voltage will charge back to the reference. If the feedback voltage is greater than the reference, the power MOSFET current is decreased to make the output voltage discharge back to the reference by the loading current.

17.1 Reverse Current Protection

The reverse current protection is guaranteed by the N-MOSFET with bulk capacitors connected to GND and the internal circuit. The reverse voltage detection circuit shuts the entire loop down if the output voltage is higher than the input voltage.

17.2 Output Undervoltage Protection (UVP) and Over- Current Fold-Back

When the feedback voltage is lower than 0.15V after the internal soft-start ends, the UVP is triggered. If the overcurrent condition is triggered during the UVP state, the OC limit current will be decreased to limit the output power and change into the re-soft-start state at the same time.

17.3 Soft-Start

An internal current source charges an internal capacitor to build the soft-start ramp voltage. During the soft-start state, the output current will be limited to prevent inrush current.

17.4 Over-Temperature Protection (OTP)

The RTQ2516 includes over-temperature protection (OTP) circuitry to prevent overheating. When the junction temperature exceeds the OTP threshold (T_{OTP}), the device is disabled. It will automatically resume normal operation once the junction temperature decreases by the amount of OTP hysteresis (T_{OTP_HYS}). Additionally, continuous operation at or into thermal shutdown, or maintaining a junction temperature above 125°C may diminish the reliability of the RTQ2516.

Note that the over-temperature protection is designed to protect the device during temporary overload conditions. It serves as a secondary fail-safe mechanism and is activated when operating conditions exceed the absolute maximum range. It should not be used as a substitute for proper thermal design in normal operation. Continuously operating the device above the specified absolute maximum junction temperature compromise device reliability or result in permanent damage.

18 Application Information

(Note 7)

The RTQ2516 is a low voltage, low dropout linear regulator. It supports an input voltage range from 1.4V to 6V and an adjustable output voltage from 0.5V to (V_{IN} – V_{DROP}).

18.1 Output Voltage Setting

The RTQ2516 output voltage is adjustable from 0.5V to (VIN - VDROP) via the external resistive voltage divider. The voltage divider resistors can have values of up to 800kΩ because of the very high impedance and low bias current of the sense comparator. The output voltage is set according to the following equation:

$$V_{OUT} = V_{REF} \times \left(1 + \frac{R1}{R2}\right)$$

where V_{REF} is the reference voltage with a typical value of 0.5V.

18.2 Chip Enable Operation

The RTQ2516 goes into sleep mode when the EN pin is in a logic low condition. In this condition, the pass transistor, error amplifier, and bandgap are all turned off, reducing the supply current to only 10μA (max.). The EN pin can be directly tied to VIN to keep the part on.

18.3 Current Limit

The RTQ2516 contains an independent current limit circuitry, which monitors and controls the pass transistor's gate voltage, limiting the output current to 3A (typ.).

18.4 C_{IN} and C_{OUT} Selection

The RTQ2516 is designed specifically to work with low ESR ceramic output capacitors for space saving and performance considerations. Using a ceramic capacitor with a capacitance range from 10μF to 47μF on the output ensures stability. Input capacitance is selected to minimize transient input droop during load current steps. For general applications, an input capacitor with a value of 10μF is recommended to minimize input impedance and provide the desired effect without affecting stability.

18.5 Thermal Considerations

Thermal protection limits power dissipation in the RTQ2516. When the operating junction temperature exceeds 160°C, the OTP circuit starts the thermal shutdown function and turns the pass element off. The pass element turns on again after the junction temperature cools by 30°C. The RTQ2516 output voltage will be close to zero when an output short circuit occurs, as shown in Figure 1. This can reduce the IC temperature and provide maximum safety to end users when an output short circuit occurs.

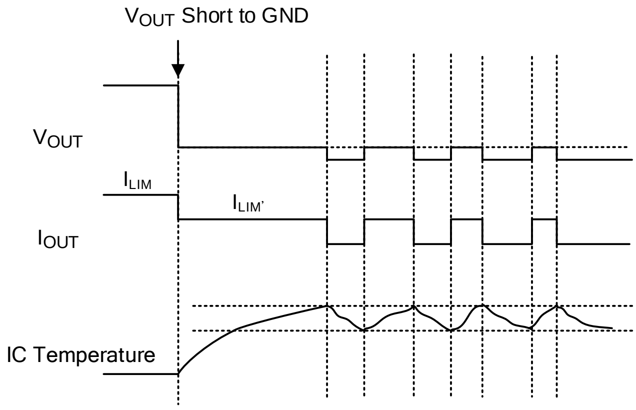


Figure 1. Short Circuit Protection when Output Short Circuit Occurs

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 θ_{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, $\theta_{JA(EVB)}$, is highly package dependent. For a SOP-8 package, the thermal resistance, $\theta_{JA(EVB)}$, is 51.2°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) / (51.2°C/W) = 1.95W for a SOP-8 package.

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

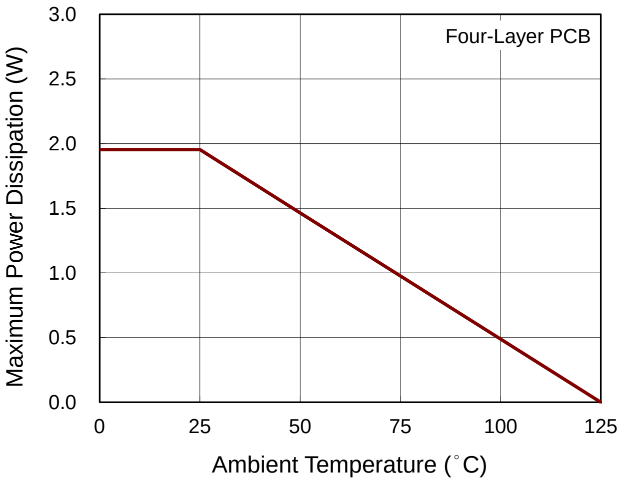
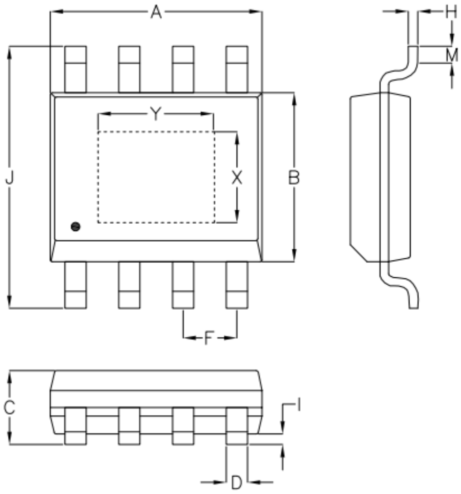


Figure 2. Derating Curve of Maximum

Note 7. The information provided in this section is for reference only. The customer is solely responsible for the designing, validating, and testing your product incorporating Richtek's product and ensure such product meets applicable standards and any safety, security, or other requirements.

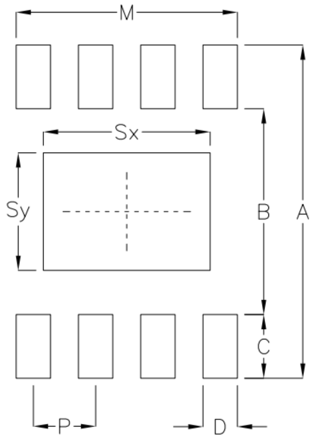
19 Outline Dimension



Symbol		Dimensions In Millimeters		Dimensions In Inches	
		Min	Max	Min	Max
A		4.801	5.004	0.189	0.197
B		3.810	4.000	0.150	0.157
C		1.346	1.753	0.053	0.069
D		0.330	0.510	0.013	0.020
F		1.194	1.346	0.047	0.053
H		0.170	0.254	0.007	0.010
I		0.000	0.152	0.000	0.006
J		5.791	6.200	0.228	0.244
M		0.406	1.270	0.016	0.050
Option 2	X	2.100	2.500	0.083	0.098
	Y	3.000	3.500	0.118	0.138

8-Lead SOP (Exposed Pad) Plastic Package

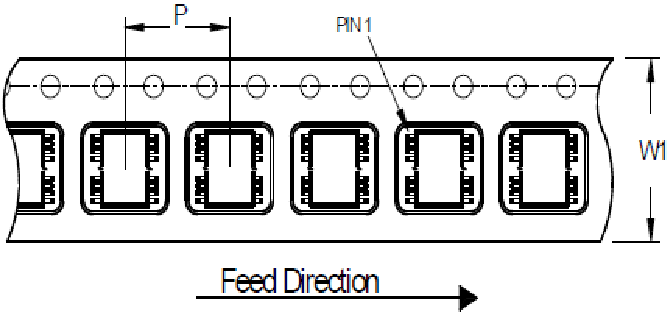
20 Footprint Information

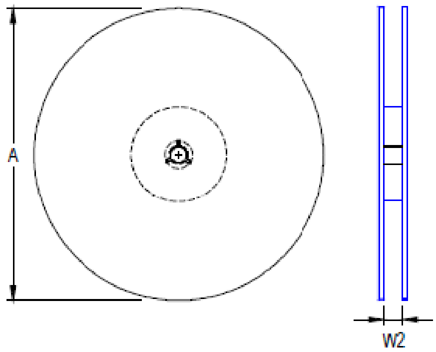


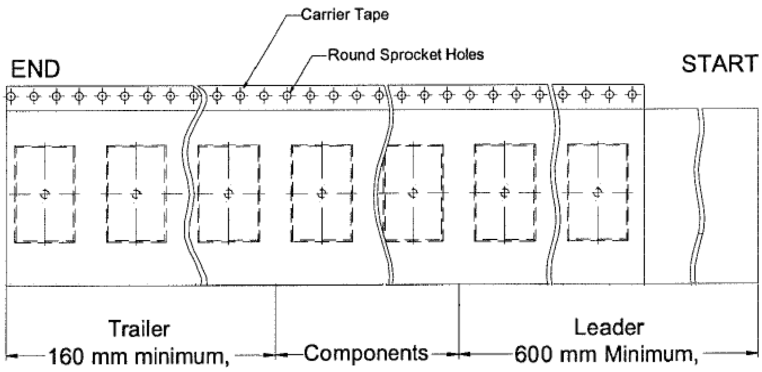
Package		Number of Pin	Footprint Dimension (mm)								Tolerance
			P	A	B	C	D	Sx	Sy	M	
PSOP-8	Option1	8	1.27	6.80	4.20	1.30	0.70	2.30	2.30	4.51	±0.10
	Option2							3.40	2.40		

21 Packing Information

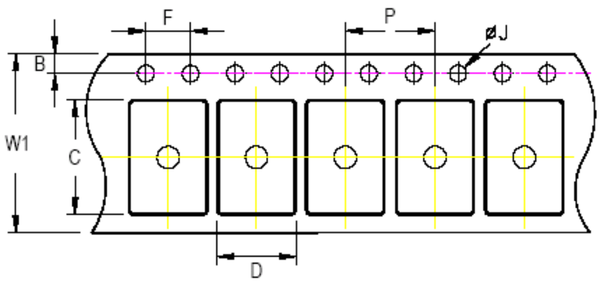
21.1 Tape and Reel Data

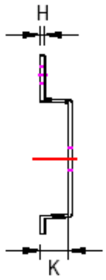






Package Type	Tape Size (W1) (mm)	Pocket Pitch (P) (mm)	Reel Size (A)		Units per Reel	Trailer (mm)	Leader (mm)	Reel Width (W2) Min./Max. (mm)
			(mm)	(in)				
PSOP-8	12	8	330	13	2,500	160	600	12.4/14.4





C, D, and K are determined by component size. The clearance between the components and the cavity is as follows:
- For 12mm carrier tape: 0.5mm max.

Tape Size	W1	P		B		F		ØJ		H
	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Max.
12mm	12.3mm	7.9mm	8.1mm	1.65mm	1.85mm	3.9mm	4.1mm	1.5mm	1.6mm	0.6mm

21.2 Tape and Reel Packing

Step	Photo/Description	Step	Photo/Description
1	 Reel 13”	**4**	 1 reel per inner box **Box G**
2	 HIC & Desiccant (2 Unit) inside	**5**	 6 inner boxes per outer box
3	 Caution label is on backside of Al bag	**6**	 Outer box **Carton A**

Container / Package	Reel		Box			Carton		
	Size	Units	Item	Reels	Units	Item	Boxes	Units
PSOP-8	13”	2,500	Box G	1	2,500	Carton A	6	15,000

21.3 Packing Material Anti-ESD Property

Surface Resistance	Aluminum Bag	Reel	Cover tape	Carrier tape	Tube	Protection Band
Ω/cm^2	**10^4 to 10^{11}**	**10^4 to 10^{11}**	**10^4 to 10^{11}**	**10^4 to 10^{11}**	**10^4 to 10^{11}**	**10^4 to 10^{11}**

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22 Datasheet Revision History

Version	Date	Description	Item
00	2024/6/17	Modify	General Description on P1 Ordering Information on P1 Functional Pin Description on P4 Absolute Maximum Ratings on P5 Thermal Information on P5 Operation on P10 Packing Information on P15, P16, P17