

## 120mΩ, 2.5A Power Switch with Adjustable Current Limit

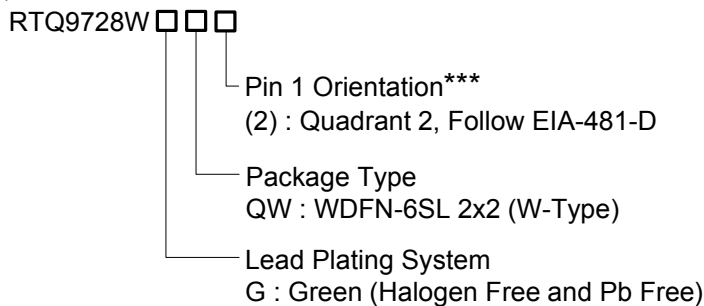
### General Description

The RTQ9728W is a cost effective, low voltage, P-MOSFET power switch IC with an adjustable current limit feature. Low on-resistance (74mΩ typ.) and low supply current (120μA typ.) are designed in this IC.

The RTQ9728W can offer an adjustable current limit threshold between 0.5A and 2.5A (typ.) via an external resistor. The ±10% current limit accuracy can be realized for all current limit settings.

The RTQ9728W is an ideal solution for power supply applications since it is functional for various current limit requirements. It is available in WDFN-6SL 2x2 package.

### Ordering Information



Note :

\*\*\*Empty means Pin1 orientation is Quadrant 1

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.

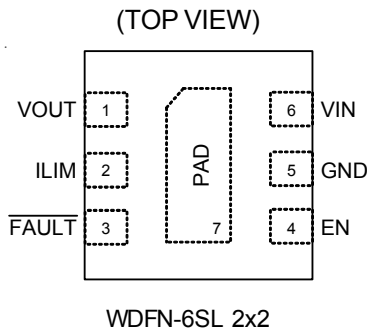
### Features

- Adjustable Current Limit : 0.5A to 2.5A (typ.)
- ±10% Current Limit Accuracy @ 2A Over Temperature
- 120mΩ P-MOSFET
- Low Supply Current : 120μA
- Input Operating Voltage Range : 2.5V to 5.5V
- Reverse Input-Output Voltage Protection
- Built-in Soft-Start
- RoHS Compliant and Halogen Free

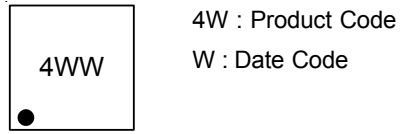
### Applications

- USB Ports and Hubs
- Digital TVs
- Set Top Boxes
- VOIP Phones

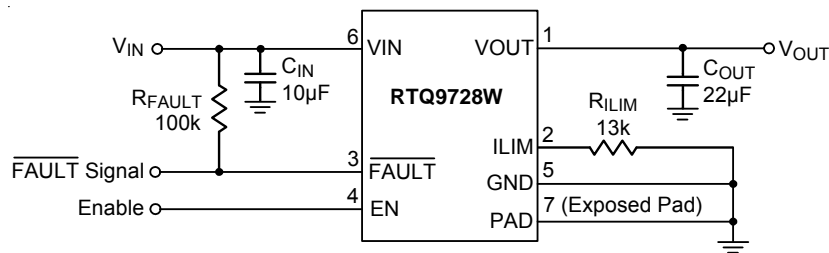
Pin Configuration



Marking Information



Typical Application Circuit

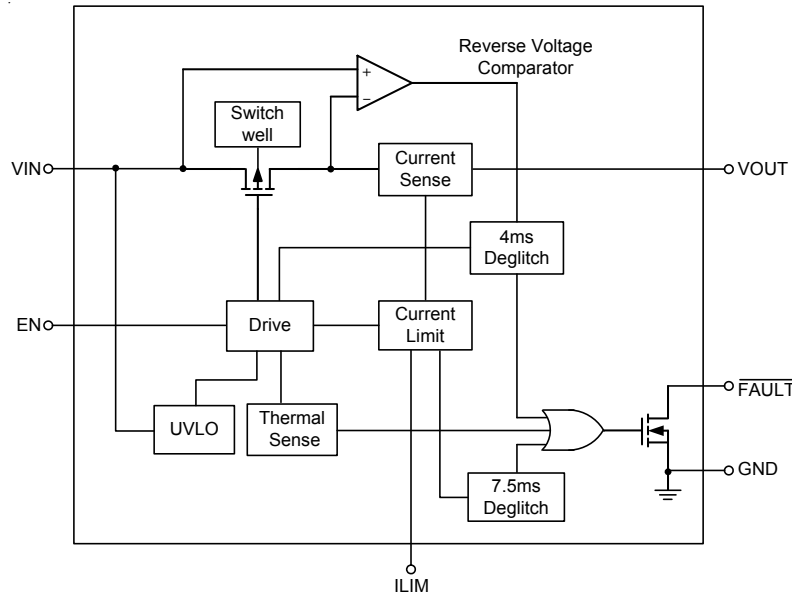


Note :  $R_{ILIM} = 13k\Omega$  for 2A Power Switch Operation

Functional Pin Description

Pin No.	Pin Name	Pin Function
1	VOUT	Output.
2	ILIM	Current limit setting. Connect an external resistor to set current limit threshold. The recommended resistance range is $10k\Omega \leq R_{ILIM} \leq 49.9k\Omega$ .
3	$\overline{FAULT}$	Active-low open-drain output. Asserted during over-current, over-temperature, or reverse-voltage conditions.
4	EN	Enable control input. Logic high turns on the power switch.
5	GND	Ground.
6	VIN	Power input. Connect a $10\mu F$ or greater ceramic capacitor from the VIN to GND as close to the IC as possible.
7 (Exposed Pad)	PAD	Exposed pad. The exposed pad is internally unconnected and must be soldered to a large GND plane. Connect this GND plane to other layers with thermal vias to help dissipate heat from the device.

**Functional Block Diagram**



**Operation**

The RTQ9728W is a current-limited power switch using P-MOSFETs for applications where short-circuit or heavy capacitive loads will be encountered. These devices allow users to adjust the current limit threshold between 500mA and 2.5A (typ.) via an external resistor. Additional device shutdown features include over-temperature protection and reverse-voltage protection.

The RTQ9728W provides built-in soft-start function. The driver controls the gate voltage of the power switch. The driver incorporates circuitry that controls the rising time and falling time of the output voltage to limit large inrush current and voltage surges. The RTQ9728W enters constant-current mode when the load exceeds the current limit threshold.

## Absolute Maximum Ratings (Note 1)

- Supply Input Voltage,  $V_{IN}$  ----- -0.3V to 6V
- Other Pins ----- -0.3V to 6V
- Power Dissipation,  $P_D @ T_A = 25^\circ\text{C}$   
 WDFN-6SL 2x2 ----- 2.98W
- Package Thermal Resistance (Note 2)  
 WDFN-6SL 2x2,  $\theta_{JA}$  ----- 33.5°C/W  
 WDFN-6SL 2x2,  $\theta_{JC}$  ----- 8.5°C/W
- Lead Temperature (Soldering, 10 sec.) ----- 260°C
- Junction Temperature ----- 150°C
- Storage Temperature Range ----- -65°C to 150°C
- ESD Susceptibility (Note 3)  
 HBM (Human Body Model) ----- 2kV

## Recommended Operating Conditions (Note 4)

- Supply Input Voltage,  $V_{IN}$  ----- 2.5V to 5.5V
- Temperature Range Junction ----- -40°C to 125°C

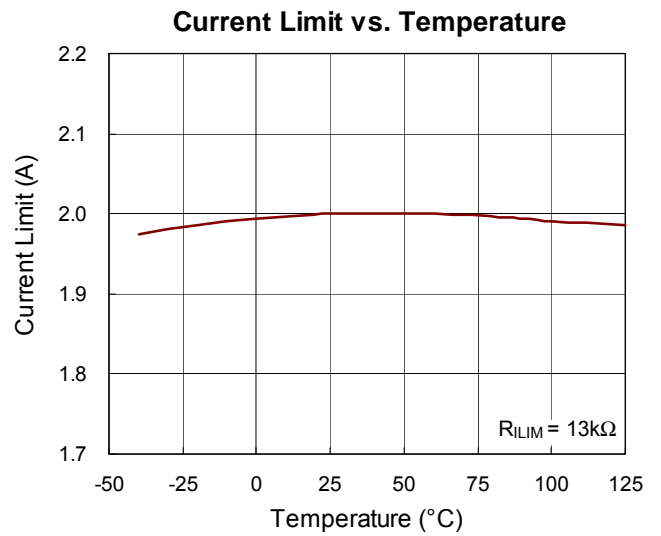
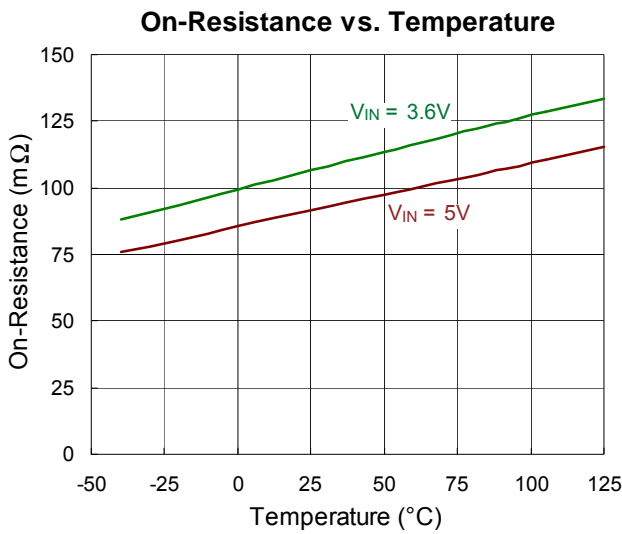
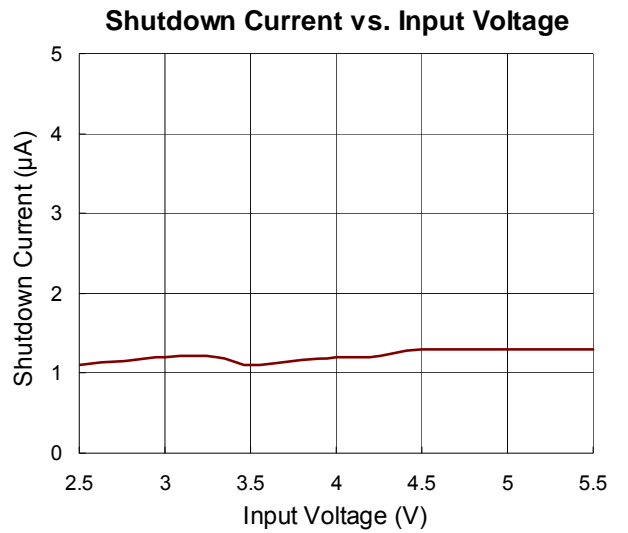
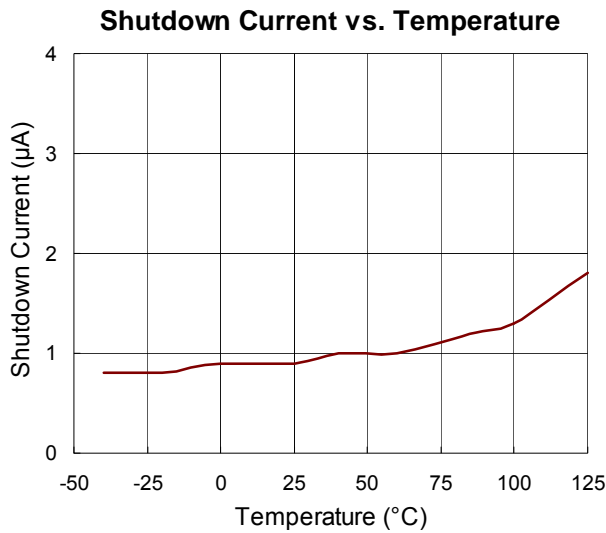
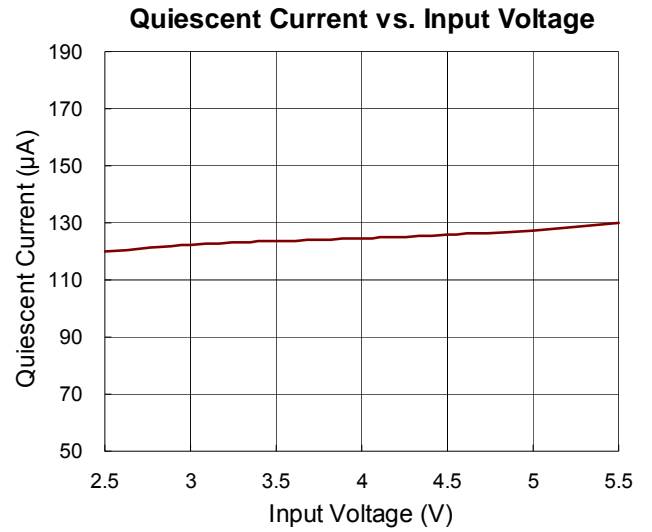
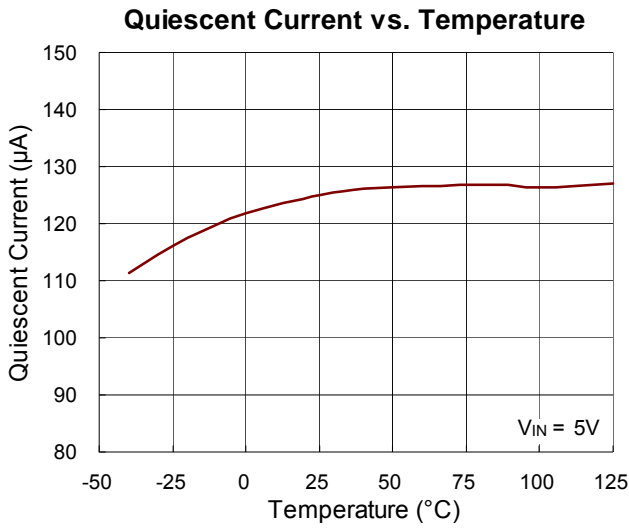
## Electrical Characteristics

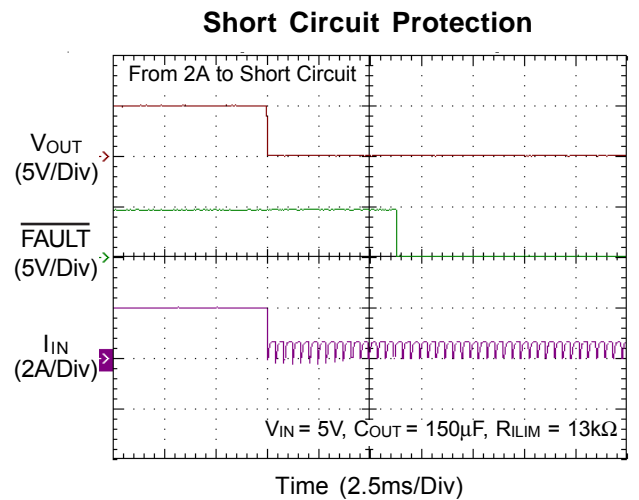
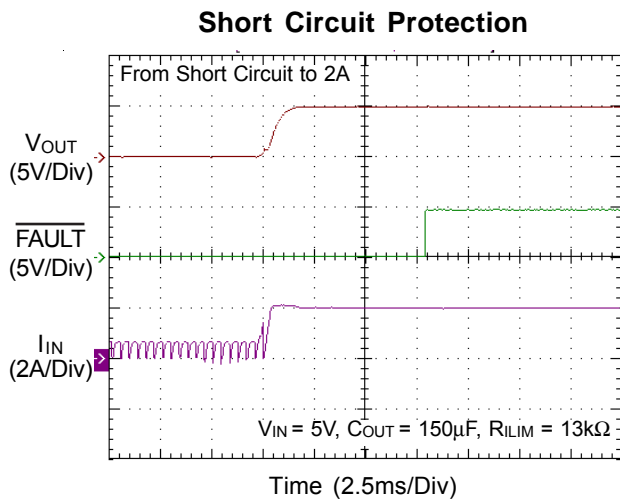
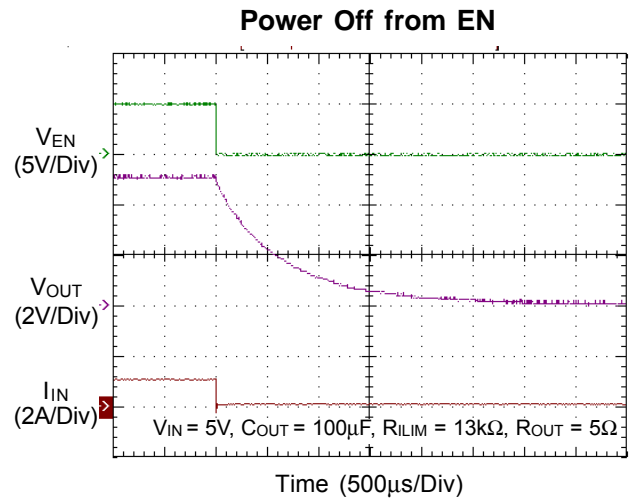
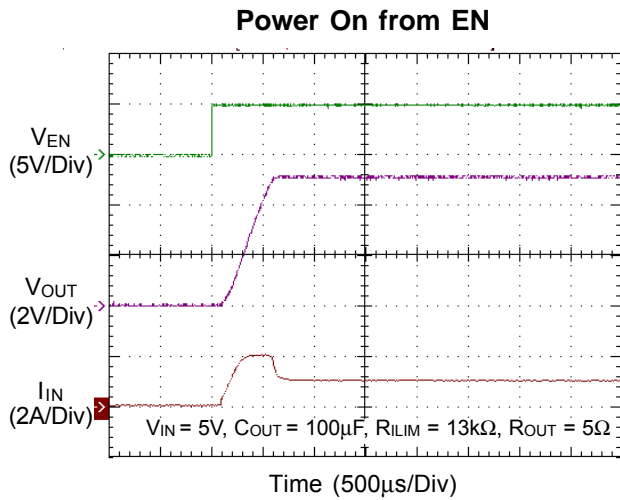
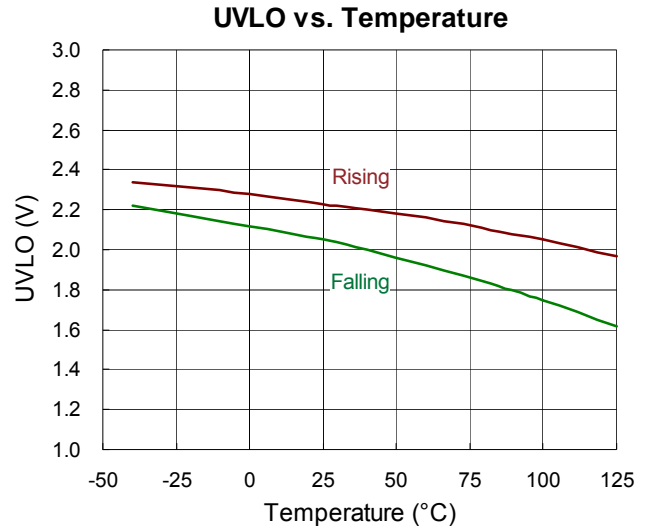
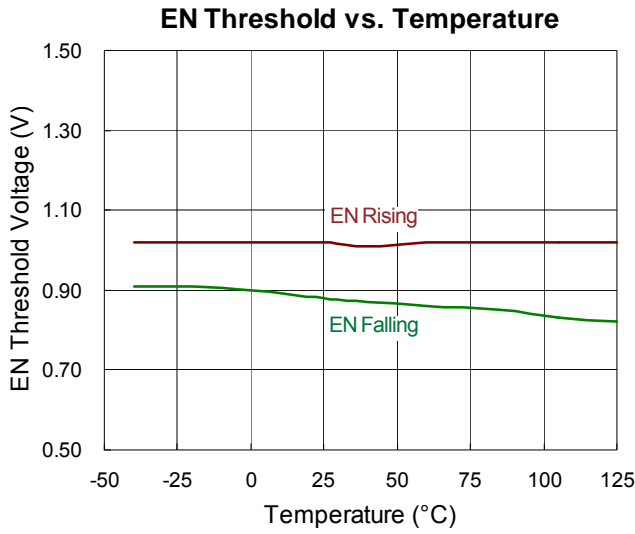
( $V_{IN} = 5V$ ,  $T_A = T_J = -40^\circ\text{C}$  to  $125^\circ\text{C}$ , unless otherwise specified)

Parameter	Symbol	Test Conditions	Min	Typ	Max	Unit
Shutdown Current	$I_{SHDN}$	$V_{EN} = 0V$ , $I_{OUT} = 0A$	--	1	10	$\mu\text{A}$
Quiescent Current	$I_Q$	$I_{OUT} = 0A$	--	120	300	$\mu\text{A}$
EN Input Voltage	Logic-High	$V_{IH}$	1.2	--	--	V
	Logic-Low	$V_{IL}$	--	--	0.4	
EN Input Current	$I_{EN}$	$V_{IN} = 5.5V$ $V_{EN} = 0V$ or $5.5V$	--	0.02	0.5	$\mu\text{A}$
Reverse Leakage Current	$I_{REV}$	$V_{OUT} = 5V$ , $V_{IN} = 0V$	--	1	10	$\mu\text{A}$
Thermal Shutdown Threshold	$T_{SD}$		--	160	--	$^\circ\text{C}$
Static Drain-Source On-State Resistance	$R_{DS(ON)}$	$I_{OUT} = 0.2A$	--	74	150	$\text{m}\Omega$
Reverse Voltage Comparator Trip Point	$I_{REV\_HYS}$	$V_{OUT} - V_{IN}$	100	135	300	mV
Current Limit	$I_{LIM}$	$R_{LIM} = 13\text{k}\Omega$	1800	2000	2200	mA
		$R_{LIM} = 13\text{k}\Omega$ , $T_A = 25^\circ\text{C}$	1840	2000	2160	
		$R_{LIM} = 49.9\text{k}\Omega$	460	520	572	
$\overline{\text{FAULT}}$ Deglitch		$\overline{\text{FAULT}}$ assertion or de-assertion due to over-current condition	2	7.5	20	ms
Response Time to Short Circuit	$t_{IOS}$	$V_{IN} = 5V$ (Note 5)	--	2	--	$\mu\text{s}$

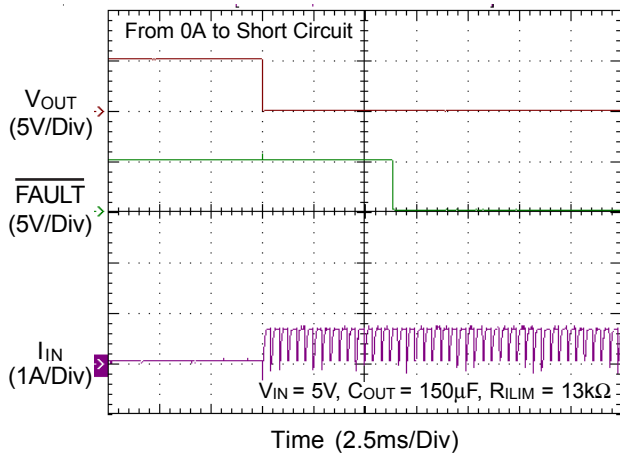
- Note 1.** Stresses beyond those listed under “Absolute Maximum Ratings” may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated in the operational sections of the specifications is not implied. Exposure to absolute maximum rating conditions may affect device reliability.
- Note 2.**  $\theta_{JA}$  is measured under natural convection (still air) at  $T_A = 25^\circ\text{C}$  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. The PCB copper area with exposed pad is  $70\text{mm}^2$ .
- Note 3.** Devices are ESD sensitive. Handling precaution is recommended.
- Note 4.** The device is not guaranteed to function outside its operating conditions.
- Note 5.** Guarantee by design.

Typical Operating Characteristics

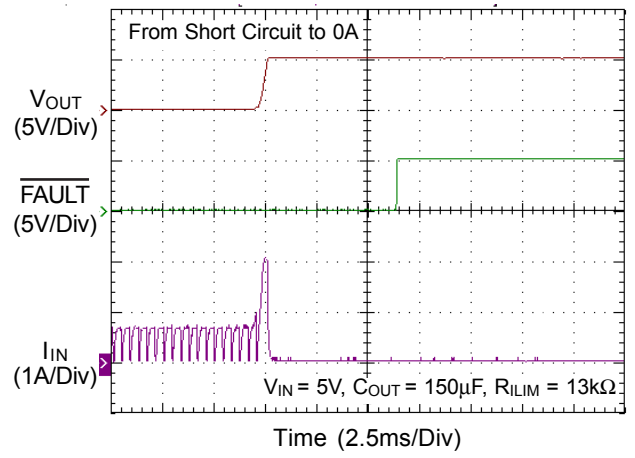




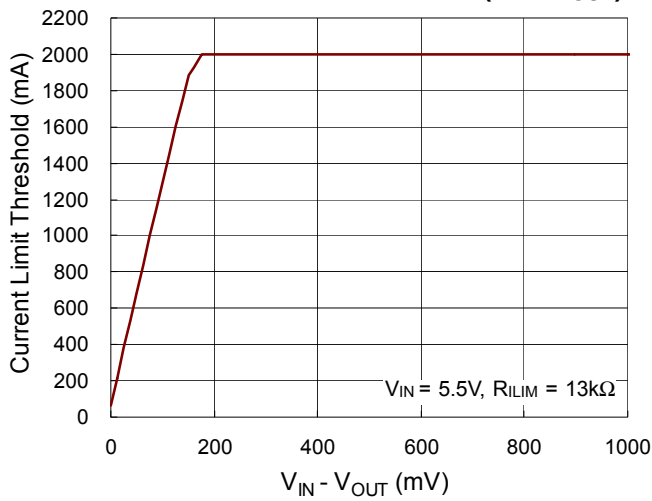
Short Circuit Protection



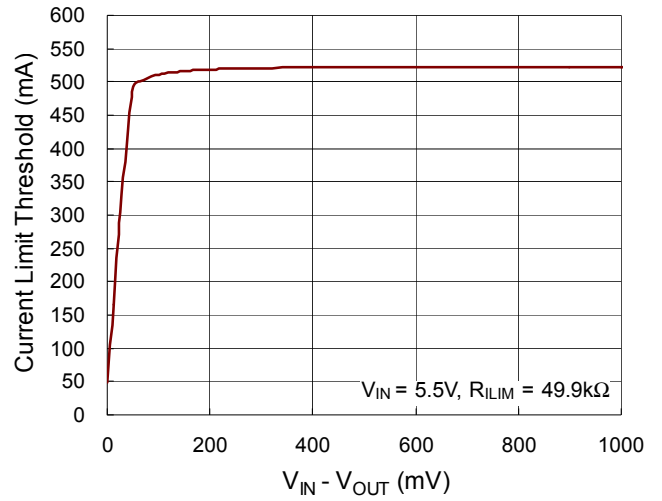
Short Circuit Protection



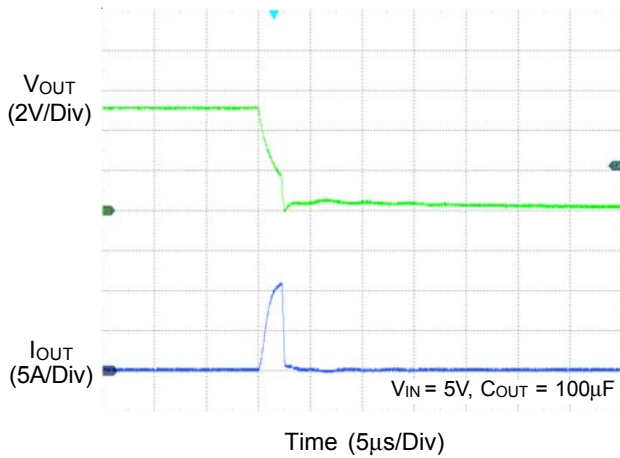
Current Limit Threshold vs. (VIN - VOUT)



Current Limit Threshold vs. (VIN - VOUT)



Response Time to Short-Circuit





**Application Information**

The RTQ9728W is a single P-MOSFET high side power switch with active high enable input, optimized for self powered and bus powered Universal Serial Bus (USB) applications. The switch's low  $R_{DS(ON)}$  meets USB voltage drop requirements and a flag output is available to indicate fault conditions to the local USB controller.

**Current Limiting and Short Circuit Protection**

When a heavy load or short circuit situation occurs while the switch is enabled, large transient current may flow through the device. The RTQ9728W includes a current limit circuitry to prevent these large currents from damaging the MOSFET switch and the hub downstream ports. The RTQ9728W provides an adjustable current limit threshold between 0.5A and 2.5A (typ.) via an external resistor,  $R_{ILIM}$ , between 10k $\Omega$  and 65k $\Omega$ . Once the current limit threshold is exceeded, and output voltage doesn't drop over 1/2 input voltage, the device enters constant current mode.

If output voltage drops under around 1/2 input voltage, the device enters re-soft start current fold-back mode until either thermal shutdown occurs or the fault is removed. The Table1 shows a recommended current limit value vs.  $R_{ILIM}$  resistor.

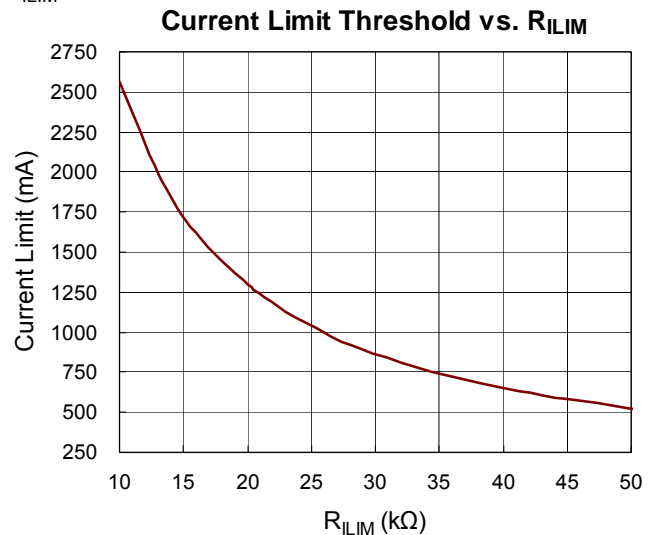


Figure 1. Current Limit Threshold vs.  $R_{ILIM}$

**Table 1. Recommended  $R_{ILIM}$  Resistor Selections**

Desired Nominal Current Limit (mA)	Ideal Resistor (k $\Omega$ )	Closest 1% Resistor (k $\Omega$ )	Actual Limits (Include R Tolerance)		
			IOS min (mA)	IOS nom (mA)	IOS max (mA)
500	52.5	52.3	443.9	501.6	562.4
600	43.5	43.2	535.1	604.6	674.1
700	37.2	37.4	616.0	696.0	776.0
800	32.4	32.4	708.7	800.8	892.9
900	28.7	28.7	797.8	901.5	1005.2
1000	25.8	26.1	875.4	989.1	1102.8
1100	23.4	23.2	982.1	1109.7	1237.3
1200	21.4	21.5	1057.9	1195.4	1332.9
1300	19.7	19.6	1158.0	1308.5	1459.0
1400	18.5	18.7	1225.7	1385.0	1544.3
1500	17.3	17.4	1317.3	1488.5	1659.7
1600	16.2	16.2	1414.8	1598.7	1782.6
1700	15.2	15.0	1528.1	1726.7	1925.3
1800	14.4	14.3	1602.9	1811.2	2019.5
1900	13.6	13.7	1673.1	1890.5	2107.9
2000	12.9	13.0	1763.2	1992.3	2221.4
2100	12.3	12.4	1848.5	2088.7	2328.9
2200	11.8	11.8	1942.6	2195.0	2447.4
2300	11.3	11.3	2028.4	2292.0	2555.6
2400	10.8	10.7	2141.7	2420.0	2698.3
2500	10.3	10.0	2292.2	2590.0	2887.9

### Fault Flag

The RTQ9728W provides a  $\overline{\text{FAULT}}$  signal pin which is an N-Channel open drain MOSFET output. This open drain output goes low when current exceeds current limit threshold. The  $\overline{\text{FAULT}}$  output is capable of sinking a 1mA load to typically 180mV above ground. The  $\overline{\text{FAULT}}$  pin requires a pull-up resistor ; this resistor should be large in value to reduce energy drain. A 100k $\Omega$  pull-up resistor works well for most applications. In case of an over current condition,  $\overline{\text{FAULT}}$  will be asserted only after the flag response delay time,  $t_D$ , has elapsed. This ensures that  $\overline{\text{FAULT}}$  is asserted upon valid over current conditions and that erroneous error reporting is eliminated. For example, false over current conditions may occur during hot-plug events when extremely large capacitive loads are connected, which induces a high transient inrush current that exceeds the current limit threshold. The  $\overline{\text{FAULT}}$  response delay time,  $t_D$ , is typically 7.5ms.

### Supply Filter/Bypass Capacitor

A 10 $\mu\text{F}$  low-ESR ceramic capacitor connected from VIN to GND and located close to the device is strongly recommended to prevent input voltage drooping during hotplug events. However, higher capacitor values may be used to further reduce the voltage droop on the input. Without this bypass capacitor, an output short may cause sufficient ringing on the input (from source lead inductance) to destroy the internal control circuitry. Note that the input transient voltage must never exceed 6V as stated in the Absolute Maximum Ratings.

### Output Filter Capacitor

A low-ESR 22 $\mu\text{F}$  ceramic capacitor connected between VOUT and GND is strongly recommended to meet the USB standard maximum droop requirement for the hub, VBUS. Standard bypass methods should be used to minimize inductance and resistance between the bypass capacitor and the downstream connector to reduce EMI and decouple voltage droop caused by hot-insertion transients in downstream cables. Ferrite beads in series with VBUS, the ground line and the 0.1 $\mu\text{F}$  bypass capacitors at the power connector pins are recommended for EMI and ESD protection. The bypass capacitor itself

should have a low dissipation factor to allow decoupling at higher frequencies.

### Chip Enable Input

The RTQ9728W don't have auto discharge function. During shutdown condition, the supply current is 1 $\mu\text{A}$  typical. The maximum guaranteed voltage for a logic-low at the EN pin is 0.4V. A minimum guaranteed voltage of 1.2V at the EN pin will turn on the RTQ9728W. Floating the input may cause unpredictable operation.

### Under-Voltage Lockout

Under-Voltage Lockout (UVLO) prevents the MOSFET switch from turning on until input voltage exceeds approximately 2.2V. If input voltage drops below approximately 2V, UVLO turns off the MOSFET switch.

### Thermal Considerations

The junction temperature should never exceed the absolute maximum junction temperature  $T_{J(\text{MAX})}$ , 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 :

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

where  $T_{J(\text{MAX})}$  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 $^{\circ}\text{C}$ . The junction-to-ambient thermal resistance,  $\theta_{JA}$ , is highly package dependent. For a WDFN-6SL 2x2 package, the thermal resistance,  $\theta_{JA}$ , is 33.5 $^{\circ}\text{C}/\text{W}$  on a standard JEDEC 51-7 high effective-thermal-conductivity four-layer test board. The maximum power dissipation at  $T_A = 25^{\circ}\text{C}$  can be calculated as below :

$$P_{D(\text{MAX})} = (125^{\circ}\text{C} - 25^{\circ}\text{C}) / (33.5^{\circ}\text{C}/\text{W}) = 2.98\text{W for a WDFN-6SL 2x2 package.}$$

The maximum power dissipation depends on the operating ambient temperature for the fixed  $T_{J(\text{MAX})}$  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.

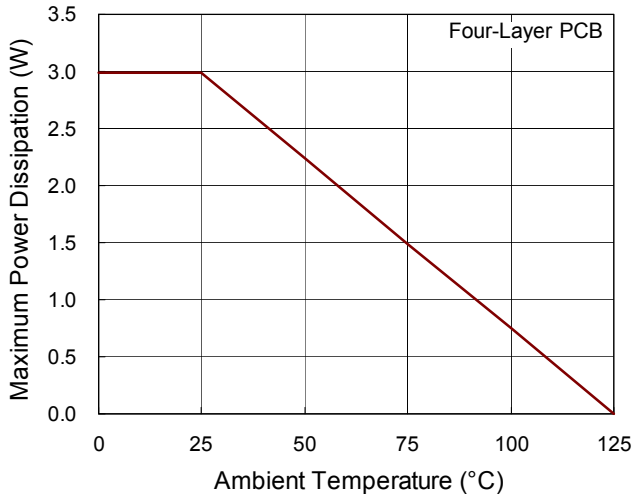


Figure 2. Derating Curve of Maximum Power Dissipation

**Layout Consideration**

Follow the PCB layout guidelines for optimal performance of the device.

- ▶ Place the  $R_{ILIM}$  resistor as close to the device as possible. To reduce parasitic effects on the current limit accuracy.
- ▶ For better thermal performance, to design a wide and thick plane for PCB ground or to add a lot of vias to GND plane.

An example of PCB layout guide is shown from Figure 3.

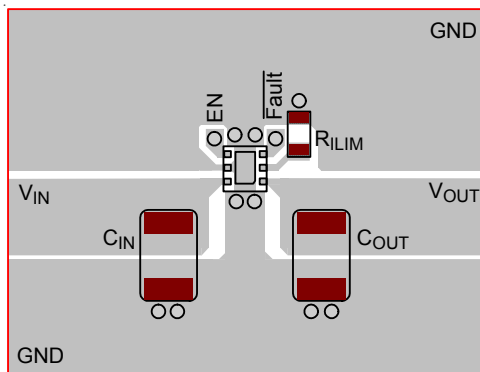
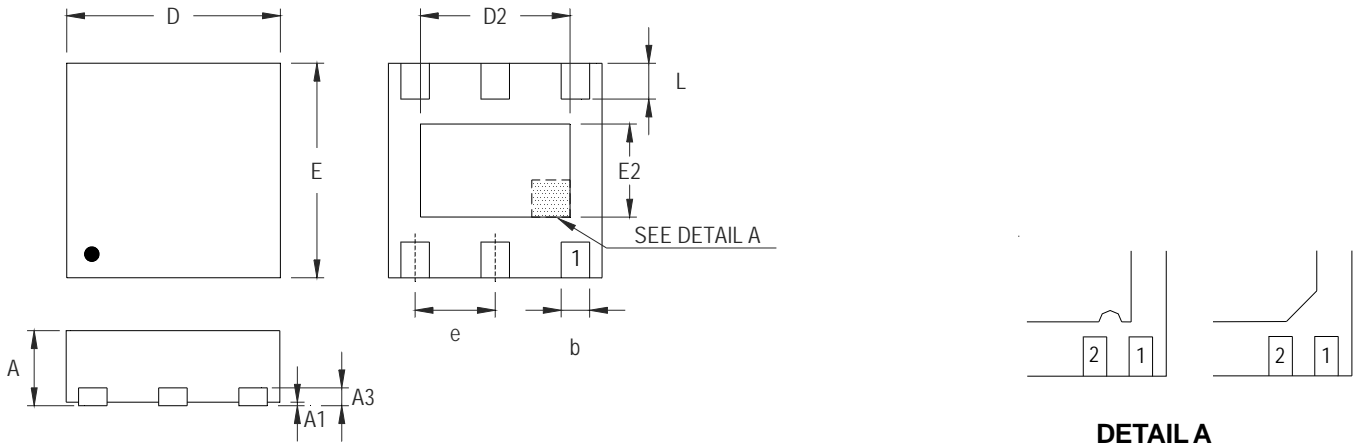


Figure 3. PCB Layout Guide

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	0.200	0.350	0.008	0.014
D	1.900	2.100	0.075	0.083
D2	1.550	1.650	0.061	0.065
E	1.900	2.100	0.075	0.083
E2	0.950	1.050	0.037	0.041
e	0.650		0.026	
L	0.200	0.300	0.008	0.012

W-Type 6SL DFN 2x2 Package



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