

# 145mΩ, 1.5A Power Switch with Programmable Current Limit

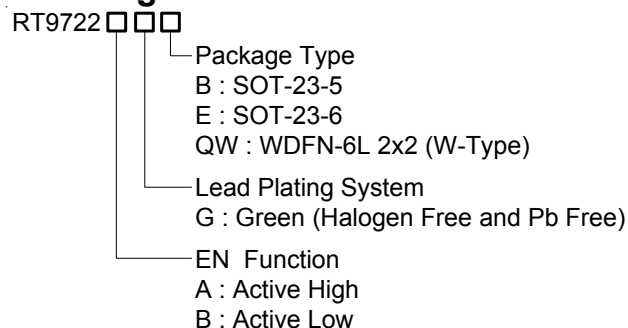
## General Description

The RT9722 is a cost effective, low voltage, single P-MOSFET high side power switch IC. Typical 145mΩ switch on resistance and 10μA quiescent current are realized in this IC. In order to fit different application, a SET pin is offered for current limit point setting, a resistor from SET to Ground sets the current limit for this switch.

In addition, the RT9722 integrates a thermal shutdown circuit and under voltage lockout circuit for overall protection, and a FLAG output with delay is available to indicate fault conditions to the local controller.

The RT9722 is an ideal solution for high side power load switch and can support flexible applications since it is available in various package such as WDFN-6L 2x2, SOT-23-5 and SOT-23-6.

## Ordering Information



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

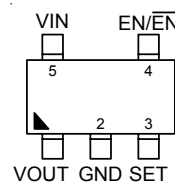
- Programmable Current Limit : 0.2A to 1.5A
- Low Quiescent Current : 10μA
- Low Shutdown Current : 0.1μA
- 145mΩ Switch On Resistance
- Operating Voltage Range : 2.4V to 5.5V
- Under Voltage Lockout
- Thermal Shutdown Protection
- RoHS Compliant and Halogen Free

## Applications

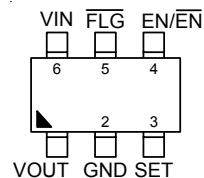
- Handheld Devices
- Hot Swap Supplies
- Notebooks
- Peripheral Ports
- Personal Communication Devices

## Pin Configurations

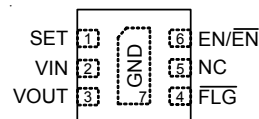
(TOP VIEW)



SOT-23-5



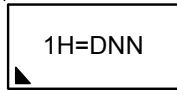
SOT-23-6



WDFN-6L 2x2

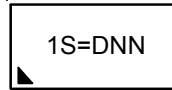
## Marking Information

RT9722AGB



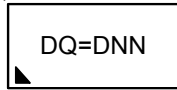
1H= : Product Code  
DNN : Date Code

RT9722BGB



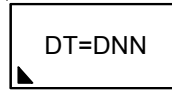
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RT9722AGE



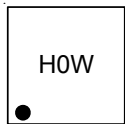
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RT9722BGE



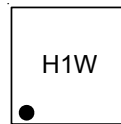
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RT9722AGQW



H0 : Product Code  
W : Date Code

RT9722BGQW



H1 : Product Code  
W : Date Code

## Typical Application Circuit

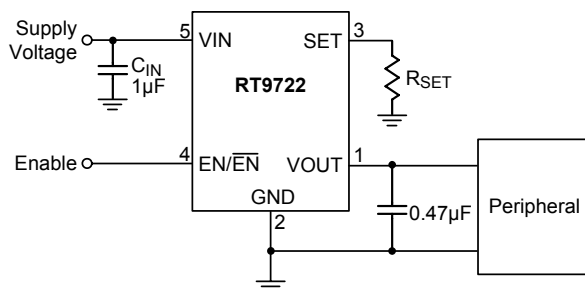


Figure 1. Typical Application Circuit for SOT-23-5 Package

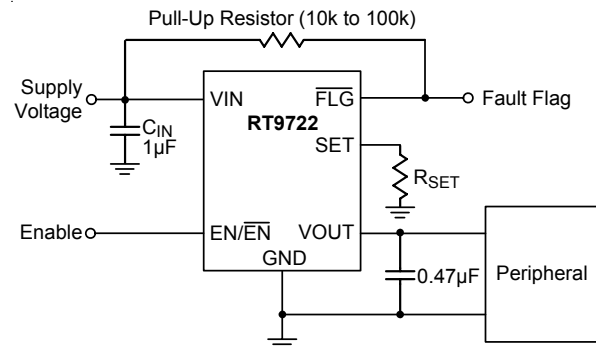
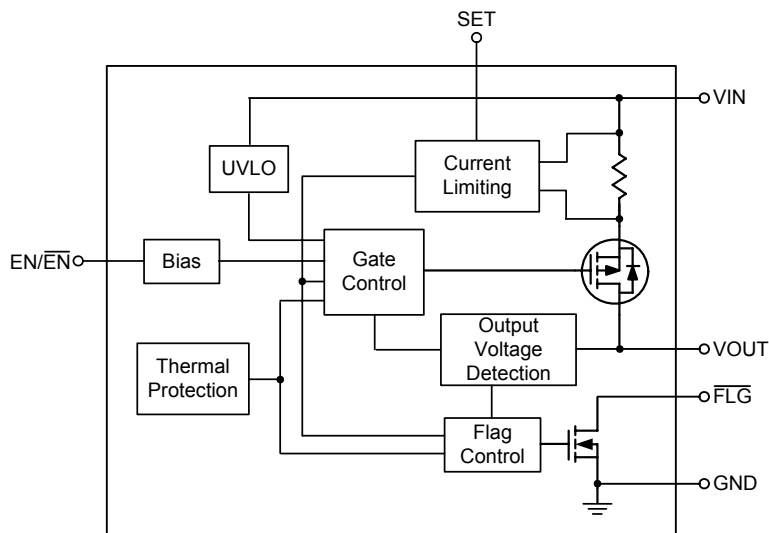


Figure 2. Typical Application Circuit for SOT-23-6 and WDFN-6L 2x2 Package

**Functional Pin Description**

Pin No.			Pin Name	Pin Function
SOT-23-5	SOT-23-6	WDFN-6L 2x2		
1	1	3	VOUT	Switch Output Voltage.
2	2	7 (Exposed Pad)	GND	Ground. The exposed pad must be soldered to a large PCB and connected to GND for maximum power dissipation.
3	3	1	SET	Current Limit Set Input. A resistor from SET to GND sets the current limit of the switch.
4	4	6	EN/EN	Chip Enable (Active High for RT9722A / Active Low for RT9722B).
--	5	4	FLG	Fault Flag Open-Drain Output.
5	6	2	VIN	Power Input Voltage.
--	--	5	NC	No Internal Connection.

**Function Block Diagram**



## Absolute Maximum Ratings (Note 1)

• Supply Input Voltage, $V_{IN}$ -----	6V
• EN Voltage-----	-0.3V to 6V
• FLAG, SET Voltage-----	6V
• Power Dissipation, $P_D$ @ $T_A = 25^\circ\text{C}$	
SOT-23-5/SOT-23-6-----	0.4W
WDFN-6L 2x2-----	0.606W
• Package Thermal Resistance (Note 2)	
SOT-23-5/SOT-23-6-----	250°C/W
WDFN-6L 2x2, $\theta_{JA}$ -----	165°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-----	2kV
MM-----	200V

## Recommended Operating Conditions (Note 4)

• Supply Input Voltage, $V_{IN}$ -----	2.4V to 5.5V
• EN Voltage-----	0V to 5.5V
• Junction Temperature Range-----	-40°C to 125°C
• Ambient Temperature Range-----	-40°C to 85°C

## Electrical Characteristics

( $V_{IN} = 5V$ ,  $C_{IN} = 1\mu\text{F}$ ,  $C_{OUT} = 0.47\mu\text{F}$ ,  $T_A = 25^\circ\text{C}$ , unless otherwise specified)

Parameter	Symbol	Test Conditions	Min	Typ	Max	Unit
Switch On Resistance	$R_{DS(ON)}$	$V_{IN} = 5V$ , $R_{SET} = 20k\Omega$ , $I_{OUT} = 100\text{mA}$	--	145	180	m $\Omega$
Quiescent Current	$I_Q$	EN = Active, SET Pin Open, $I_{OUT} = 0$	--	10	25	$\mu\text{A}$
Shutdown Current	$I_{SHDN}$	EN = Inactive, $V_{OUT} = \text{Open}$	--	0.1	1	$\mu\text{A}$
EN/ $\overline{\text{EN}}$ Threshold Voltage	Logic-Low	$V_{IL}$	--	--	0.6	V
	Logic-High	$V_{IH}$	1.4	--	--	
EN/ $\overline{\text{EN}}$ Input Current	$I_{EN/\overline{\text{EN}}}$	$V_{EN/\overline{\text{EN}}} = 5V$	--	0.01	0.1	$\mu\text{A}$
Output Leakage Current	$I_{LEAKAGE}$	Switch Off, $V_{OUT} = 0V$	--	0.01	1	$\mu\text{A}$
Turn On Time	$t_{ON}$	$V_{IN} = 5V$ , $R_{LOAD} = 10\Omega$	--	12	200	$\mu\text{s}$
Turn Off Time	$t_{OFF}$	$V_{IN} = 5V$ , $R_{LOAD} = 10\Omega$	--	10	--	$\mu\text{s}$
Current Limit	$I_{LIM}$	$R_{SET} = 6.8k\Omega$ , $V_{OUT} = 4V$	0.75	1	1.25	A
Minimum Current Limit	$I_{LIM(MIN)}$		--	0.2	--	A
Current Limit Response Time	$t_{Response}$	$R_{LOAD} = 0\Omega$	--	10	--	$\mu\text{s}$

To be continued

Parameter	Symbol	Test Conditions	Min	Typ	Max	Unit
FLG Output Resistance	$R_{\overline{FLG}}$	$I_{SINK} = 1mA$	--	20	--	$\Omega$
FLG Off Current	$I_{\overline{FLG\_off}}$	$V_{\overline{FLG}} = 5V$	--	0.01	1	$\mu A$
FLG Delay Time	$t_D$	From Fault Condition to FLG Assertion	5	12	20	ms
Under Voltage Lockout Threshold	$V_{UVLO}$	$V_{IN}$ Increasing	--	2	2.4	V
Under Voltage Hysteresis	$\Delta V_{UVLO}$	$V_{IN}$ Increasing	--	0.1	--	V
Thermal Shutdown Protection	$T_{SD}$		--	150	--	$^{\circ}C$
Thermal Shutdown Hysteresis	$\Delta T_{SD}$		--	20	--	$^{\circ}C$

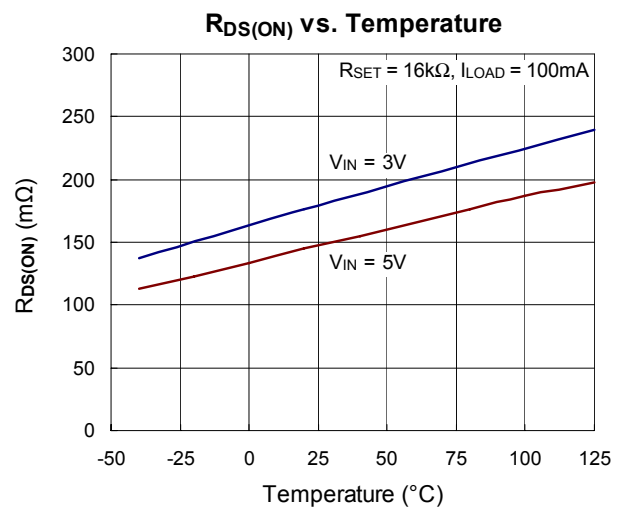
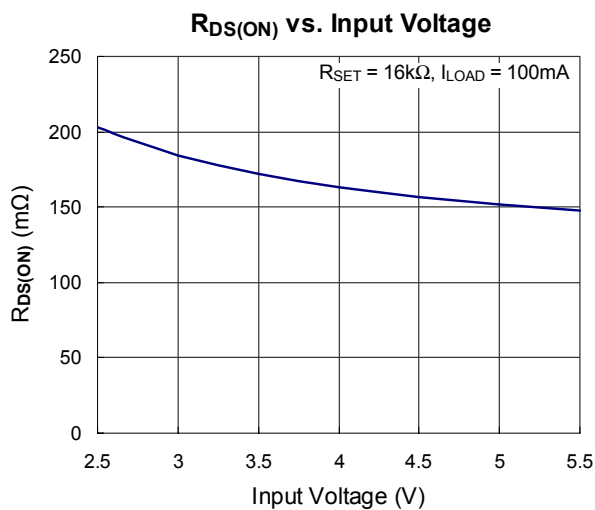
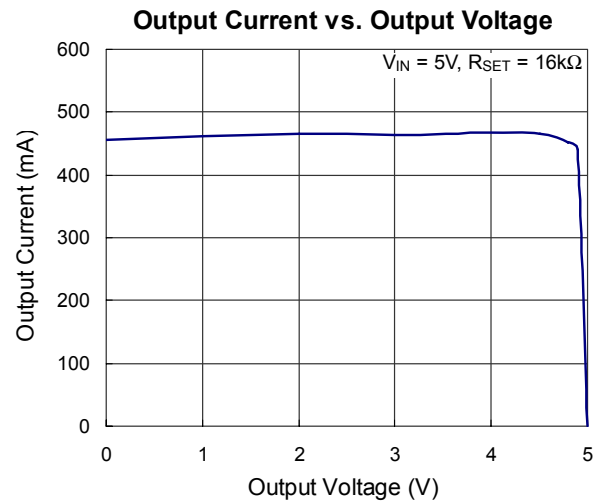
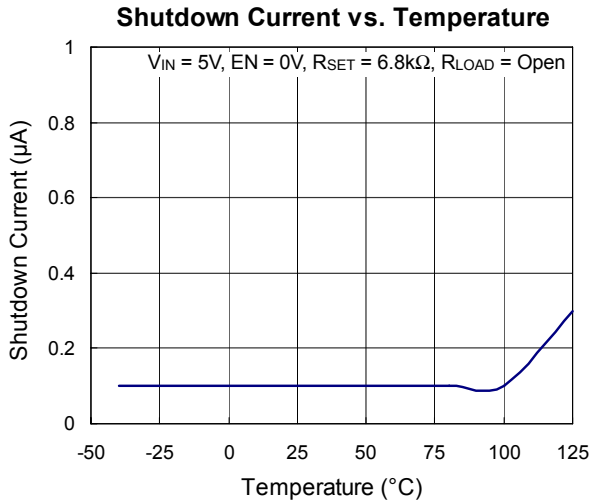
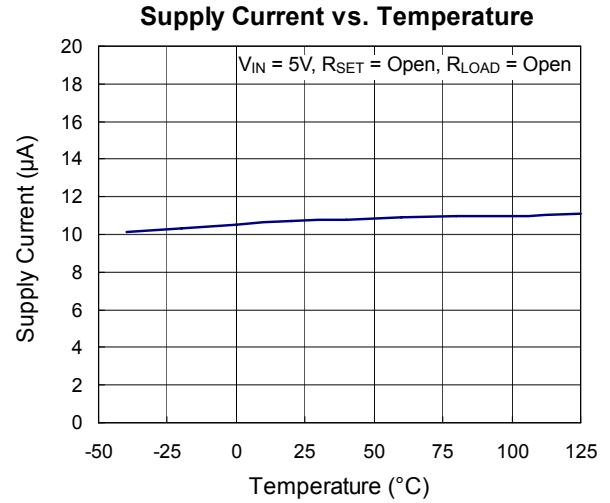
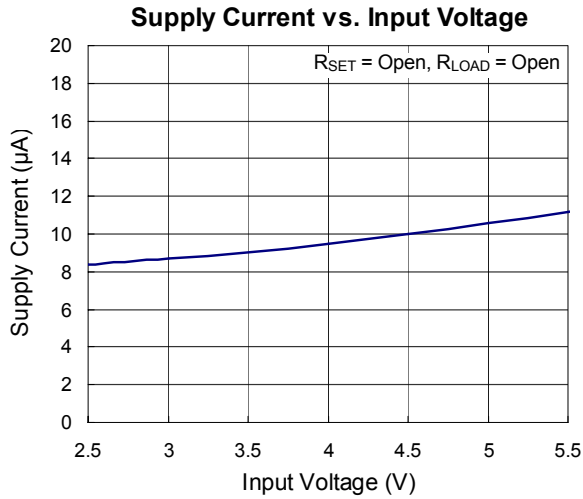
**Note 1.** Stresses listed as the above "Absolute Maximum Ratings" may cause permanent damage to the device. These are for stress ratings. Functional operation of the device at these or any other conditions beyond those indicated in the operational sections of the specifications is not implied. Exposure to absolute maximum rating conditions for extended periods may remain possibility to affect device reliability.

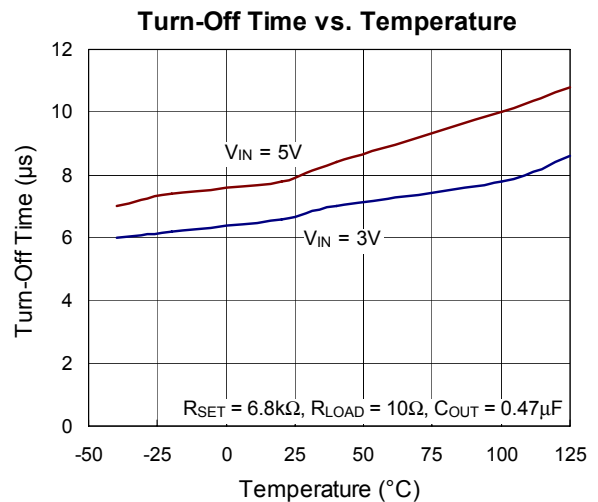
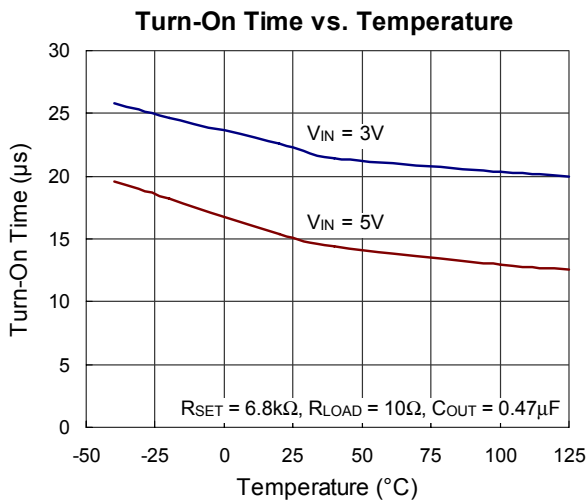
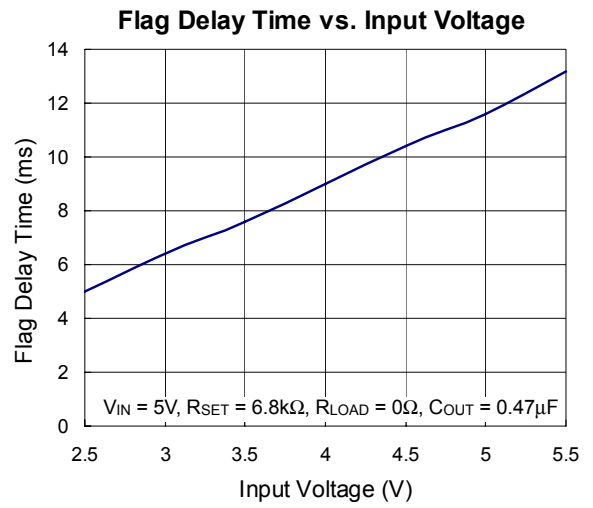
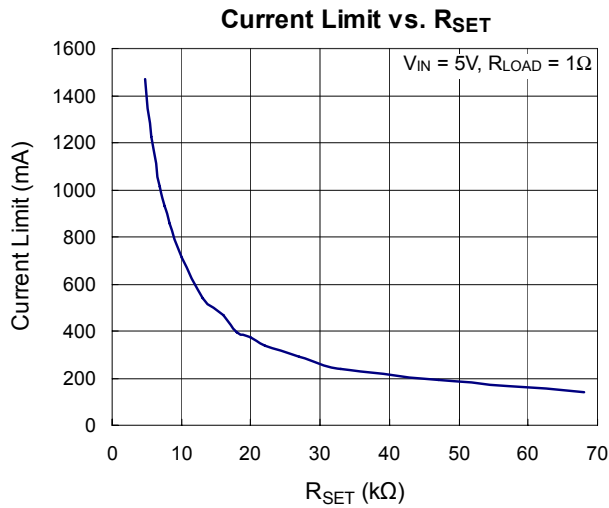
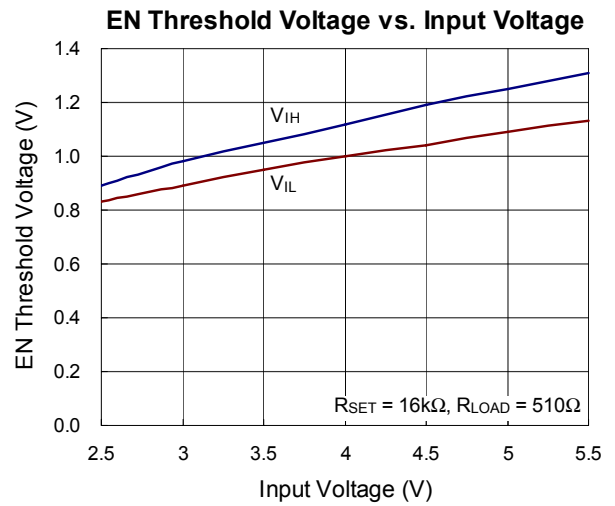
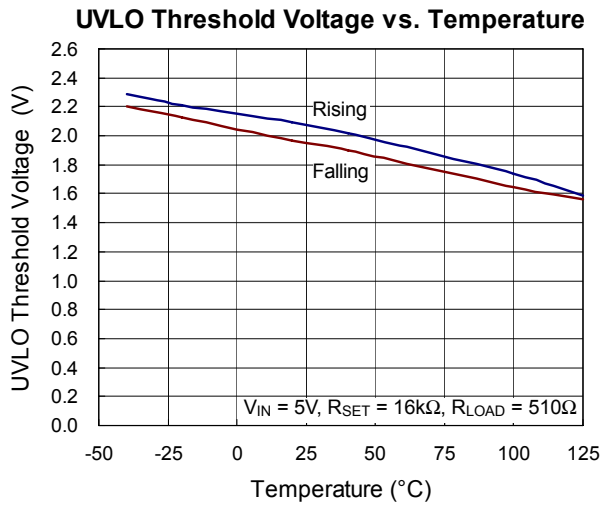
**Note 2.**  $\theta_{JA}$  is measured in the natural convection at  $T_A = 25^{\circ}C$  on a low effective thermal conductivity single layer test board of JEDEC 51-3 thermal measurement standard.

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

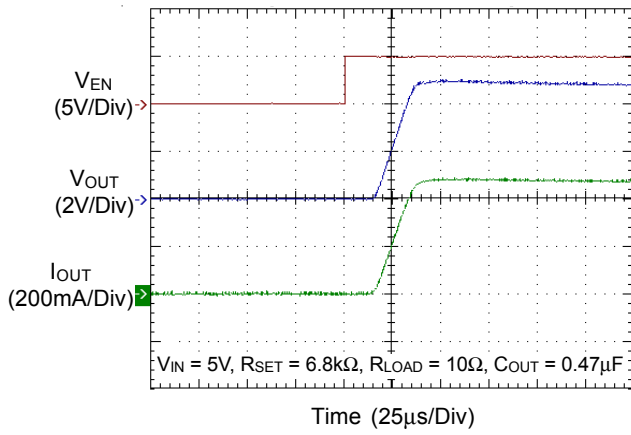
**Note 4.** The device is not guaranteed to function outside its operating conditions.

Typical Operating Characteristics

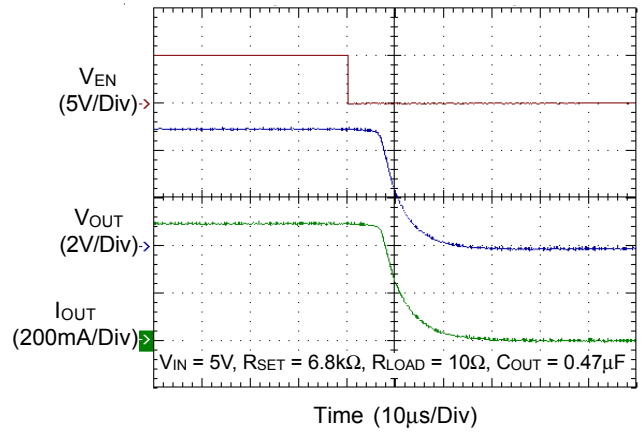




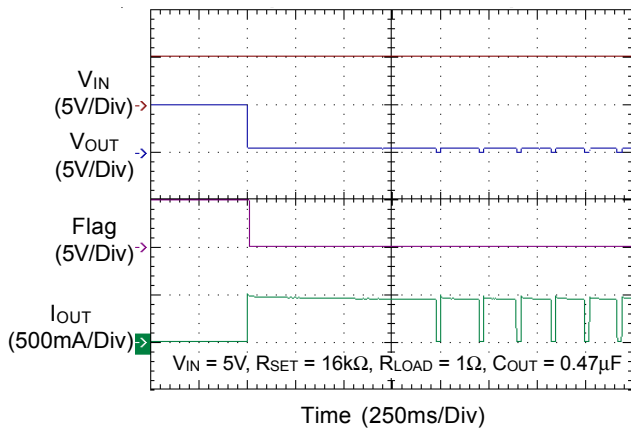
Power On from EN



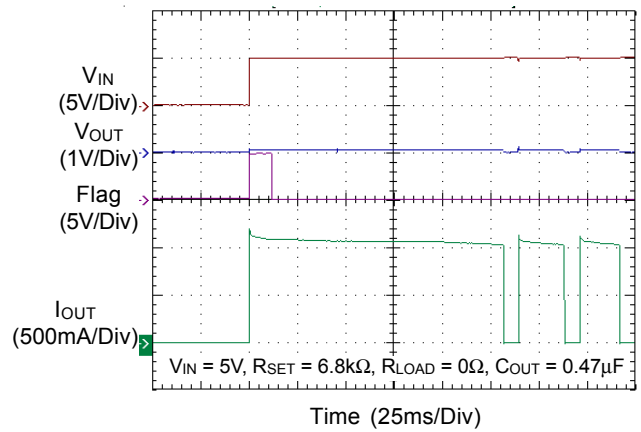
Power Off from EN



Current Limit with Thermal Shutdown



Short Circuit Protection





## Application Information

The RT9722 is a high-side power switch with programmable current limit function. The RT9722 provides active-high (RT9722A) and active-low (RT9722B) enable input and full protection functions make it optimized to replace complex discrete on/off control circuitry.

### Current Limit Setting

The current limit value  $I_{LIM}$ , can be set by an external resistor between SET and GND. Figure 3 shows the typical current limit value under various setting resistance,  $R_{SET}$ .

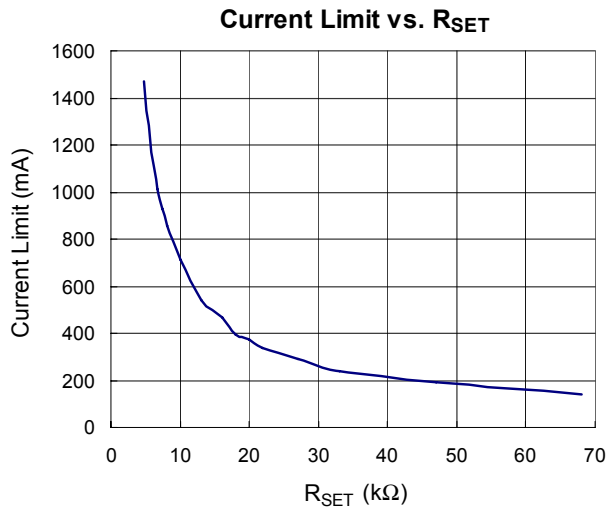


Figure 3. Current Limit vs.  $R_{SET}$  Resistance

The accuracy of current limit set point may vary with operating temperature and supply voltage, see “Typical Operating Characteristics” graph for further details.

A few standard resistor values of the  $R_{SET}$  and its typical current limit set point with  $\pm 25\%$  tolerance are listed in Table 1.

### Input and Output

$V_{IN}$  (input) is the power source connected to the internal circuitry and the source of the MOSFET.  $V_{OUT}$  (output) is the drain of the MOSFET. In a typical application, current flows through the switch from  $V_{IN}$  to  $V_{OUT}$  toward the load. If  $V_{OUT}$  is greater than  $V_{IN}$ , current will flow from  $V_{OUT}$  to  $V_{IN}$  since the MOSFET is bidirectional when on. The RT9722 is designed to control current flowing from  $V_{IN}$  to  $V_{OUT}$ . If a voltage applied to  $V_{OUT}$  is greater than the voltage on  $V_{IN}$ , large currents may flow and cause damage to the device.

Table 1. Current Limit vs.  $R_{SET}$  Resistance

$R_{SET}$ (kΩ)	Design Current Limit (mA)		
	Min	Typ	Max
4.7	1125.0	1500	1875.0
5.49	937.5	1250	1562.5
6.8	750.0	1000	1250.0
7.32	675.0	900	1125.0
8.66	600.0	800	1000.0
10.5	525.0	700	875.0
13	450.0	600	750.0
16	375.0	500	625.0
18	337.5	450	562.5
20	300.0	400	500.0
22.6	262.5	350	437.5
30	225.0	300	375.0
34.8	187.5	250	312.5
47	150.0	200	250.0

### Chip Enable Input

The switch will be disabled when the  $\overline{EN/EN}$  pin is in a logic low/high condition. During this condition, the internal circuitry and MOSFET are turned off, reducing the supply current to 0.1μA typically. The maximum guaranteed voltage for a logic low at the EN pin is 0.6V. A minimum guaranteed voltage of 1.4V at the EN pin will turn on the RT9722 again. Floating the input may cause unpredictable operation. EN should not be allowed to go negative with respect to GND. The EN pin can be directly tied to  $V_{IN}$  to keep the part on.

### Soft-Start for Hot Plug-In Applications

In order to eliminate the upstream voltage droop caused by the large inrush current during hot-plug events, the “soft-start” feature effectively isolates the power source from extremely large capacitive loads.

### Fault Flag

The RT9722 provides a  $\overline{FLG}$  signal pin which is an N-Channel open drain MOSFET output. This open drain output goes low when current limit  $V_{OUT} < V_{IN} - 1V$ , or the die temperature exceeds 150°C approximately. The  $\overline{FLG}$

pin requires a pull-up resistor, this resistor should be large in value to reduce energy drain. A 100k pull-up resistor works well for most applications. In the case of an over-current condition,  $\overline{\text{FLG}}$  will be asserted only after the flag response delay time,  $t_D$ , has elapsed. This ensures that  $\overline{\text{FLG}}$  is asserted only 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 a highly large capacitive load is connected and causes a high transient inrush current that exceeds the current limit threshold. The  $\overline{\text{FLG}}$  response delay time  $t_D$  is typically 12ms at  $V_{\text{IN}} = 5\text{V}$ .

### Under-Voltage Lockout

Under-voltage lockout (UVLO) prevents the MOSFET switch from turning on until input voltage exceeds approximately 2V. Under-voltage detection functions only when the chip enable input is enabled.

### Thermal Shutdown

Thermal shutdown is employed to protect the device from damage if the die temperature exceeds approximately 150°C. If enabled, the switch automatically restarts when the die temperature falls 20°C (typ.). The output will continue to cycle on and off until the device is disabled or the fault is removed.

### Short Circuit Protection

The current limit circuitry prevents damage to the MOSFET switch and external load. When a heavy load or short circuit is applied to an enabled switch, a large transient current may flow until the current limit circuitry responds. Once this current limit threshold is exceeded, the device enters constant current mode until the thermal shutdown occurred or the fault is removed.

### Supply Filter/Bypass Capacitor

A 1 $\mu\text{F}$  low-ESR ceramic capacitor from  $V_{\text{IN}}$  to GND (the amount of the capacitance may be increased without limit), located at the device is strongly recommended to prevent the input voltage drooping during hot-plug events. However, higher capacitor values will further reduce the voltage droop on the input. Furthermore, without the bypass capacitor, an output short may cause sufficient ringing on the input (from source lead inductance) to destroy the internal

control circuitry. An important note to be aware of is the parasitic inductance of PCB traces can cause over-voltage transients if the PCB trace has even a few tens of nH of inductance. The input transient must not exceed 6.0V of the absolute maximum supply voltage even for a short duration.

### Power Dissipation

The device's junction temperature depends on several factors such as the load, PCB layout, ambient temperature and package type. The maximum output current must be derated at higher ambient temperature to ensure the junction temperature does not exceed operating junction temperature 125°C. With all possible conditions, the junction temperature must be within the range specified under operating conditions. Power dissipation can be calculated based on the output current and the  $R_{\text{DS(ON)}}$  of switch as below.

$$P_D = R_{\text{DS(ON)}} \times I_{\text{OUT}}^2$$

The application may limit the amount of output current based on the total power dissipation and the ambient temperature.

### 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 junction to ambient. The maximum power dissipation can be calculated by following formula :

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

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

For recommended operating conditions specification of RT9722, the maximum operating junction temperature is 125°C. The junction to ambient thermal resistance  $\theta_{\text{JA}}$  for SOT-23-5/SOT-23-6 package is 250°C/W and WDFN-6L 2x2 package is 165°C/W on the standard JEDEC 51-3 single-layer thermal test board. The maximum power dissipation at  $T_{\text{A}} = 25^\circ\text{C}$  can be calculated by following formula :

$$P_{\text{D(MAX)}} = (125^\circ\text{C} - 25^\circ\text{C}) / (250^\circ\text{C/W}) = 0.4\text{W for SOT-23-5/SOT-23-6 package}$$

$P_{D(MAX)} = (125^{\circ}\text{C} - 25^{\circ}\text{C}) / (165^{\circ}\text{C}/\text{W}) = 0.606\text{W}$  for WDFN-6L 2x2 package

The maximum power dissipation depends on operating ambient temperature for fixed  $T_{J(MAX)}$  and thermal resistance  $\theta_{JA}$ . For the RT9722 Figure 4 shows the maximum power dissipation allowed under various ambient temperatures.

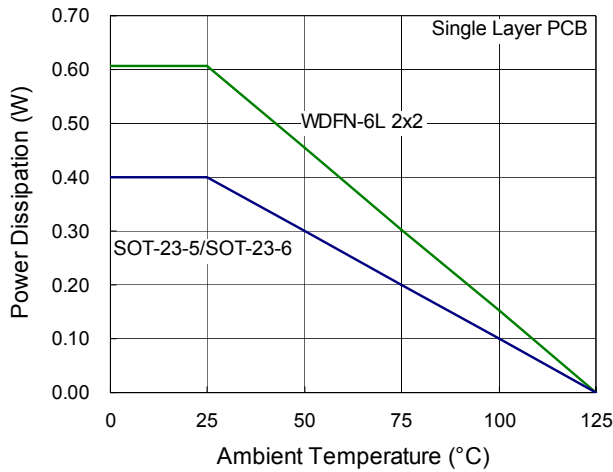


Figure 4. RT9722 Maximum Power Dissipation Derating Curve

**Layout Consideration**

For the best performance of the RT9722, careful PCB layout is necessary. The following guidelines must be considered:

- ▶ Keep all input and output traces as short and wide as possible.
- ▶ Locate the bypass capacitors as close as possible to the input and output pin of the RT9722.
- ▶ Avoid vias as much as possible. If vias are necessary, make them as large as feasible.
- ▶ Place a ground plane under all circuitry to lower both resistance and inductance and improve DC and transient performance (Use a separate ground and power plane if possible).

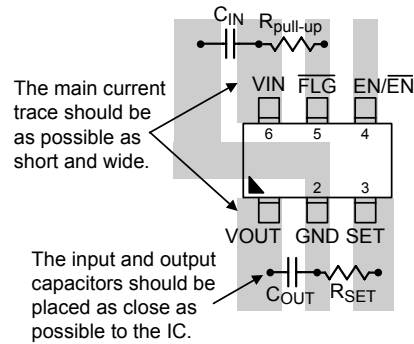
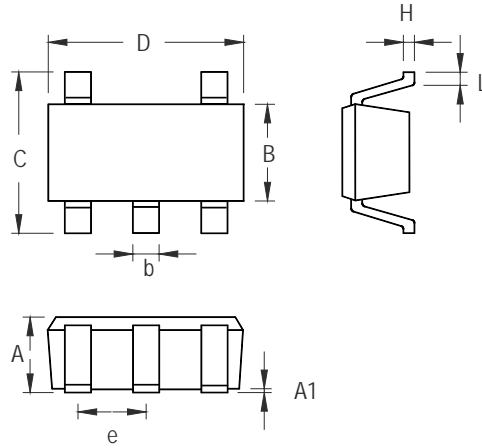


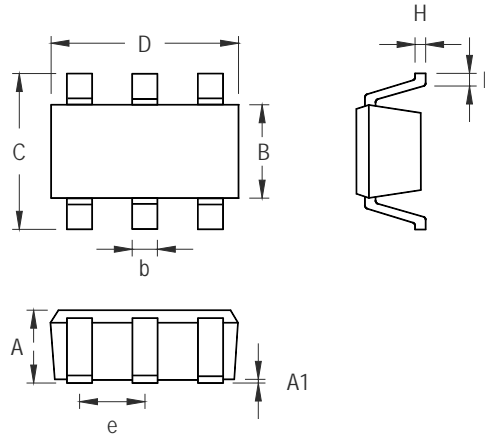
Figure 5. PCB Layout Guide

Outline Dimension



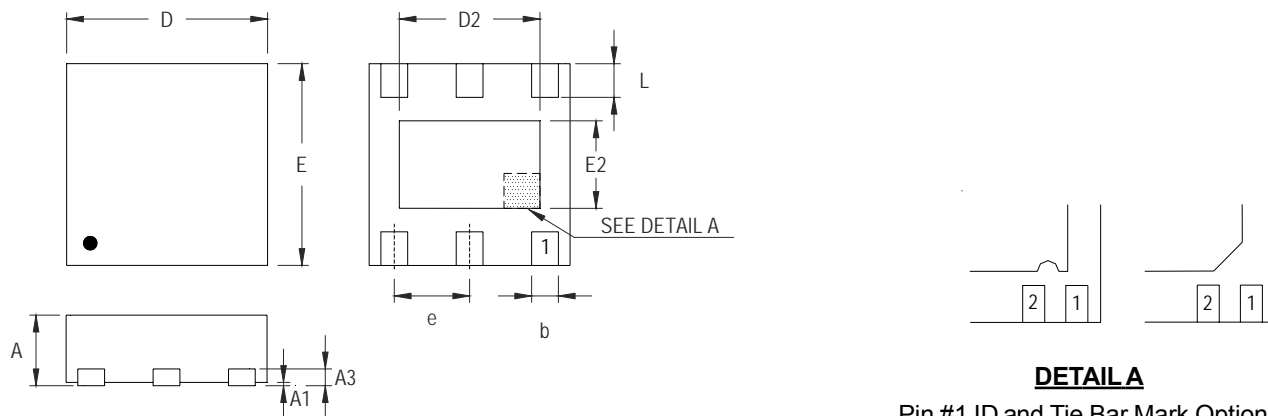
Symbol	Dimensions In Millimeters		Dimensions In Inches	
	Min	Max	Min	Max
A	0.889	1.295	0.035	0.051
A1	0.000	0.152	0.000	0.006
B	1.397	1.803	0.055	0.071
b	0.356	0.559	0.014	0.022
C	2.591	2.997	0.102	0.118
D	2.692	3.099	0.106	0.122
e	0.838	1.041	0.033	0.041
H	0.080	0.254	0.003	0.010
L	0.300	0.610	0.012	0.024

SOT-23-5 Surface Mount Package



Symbol	Dimensions In Millimeters		Dimensions In Inches	
	Min	Max	Min	Max
A	0.889	1.295	0.031	0.051
A1	0.000	0.152	0.000	0.006
B	1.397	1.803	0.055	0.071
b	0.250	0.560	0.010	0.022
C	2.591	2.997	0.102	0.118
D	2.692	3.099	0.106	0.122
e	0.838	1.041	0.033	0.041
H	0.080	0.254	0.003	0.010
L	0.300	0.610	0.012	0.024

**SOT-23-6 Surface Mount Package**



**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	1.950	2.050	0.077	0.081
D2	1.000	1.450	0.039	0.057
E	1.950	2.050	0.077	0.081
E2	0.500	0.850	0.020	0.033
e	0.650		0.026	
L	0.300	0.400	0.012	0.016

**W-Type 6L DFN 2x2 Package**

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