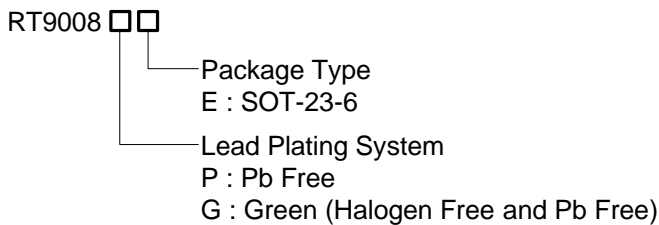


# Low Dropout Linear Regulator Controller with Soft-Start

## General Description

The RT9008 is a wide input range, low dropout voltage regulator controller with soft-start function. The part drives an external N-MOSFET and can operate with VCC power range from 4.5V to 13.5V. With this flexible topology and wide input voltage range, the RT9008 is suitable for various applications. The soft-start function can reduce the input inrush current by adjusting the external capacitor. The RT9008 uses the small footprint package of the SOT-23-6.

## Ordering Information



Note :

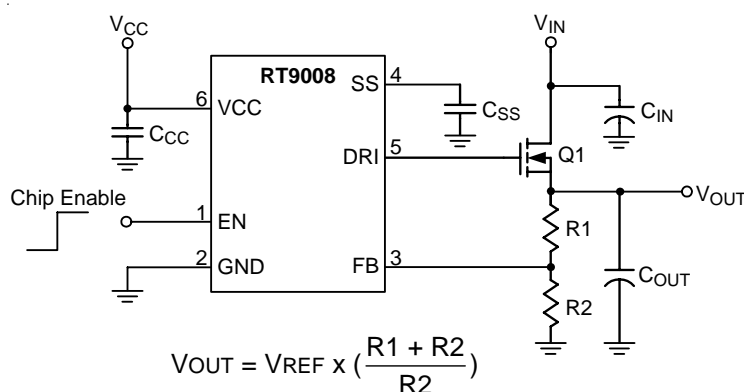
Richtek products are :

- ▶ RoHS compliant and compatible with the current requirements of IPC/JEDEC J-STD-020.
- ▶ Suitable for use in SnPb or Pb-free soldering processes.

## Marking Information

For marking information, contact our sales representative directly or through a Richtek distributor located in your area.

## Typical Application Circuit



## Features

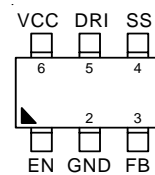
- Programmable Output Voltage
- High Current Driver for High Current FET
- Adjustable Soft Start Time
- High Accuracy ±2% Reference Voltage
- Quick Line and Load Transient Response
- Enable Control
- Small Footprint Package SOT-23-6
- RoHS Compliant and 100% Lead (Pb)-Free

## Applications

- Desktop/Notebook PC
- DSC
- Processor Power Sequencing

## Pin Configurations

(TOP VIEW)



SOT-23-6

Test Circuit

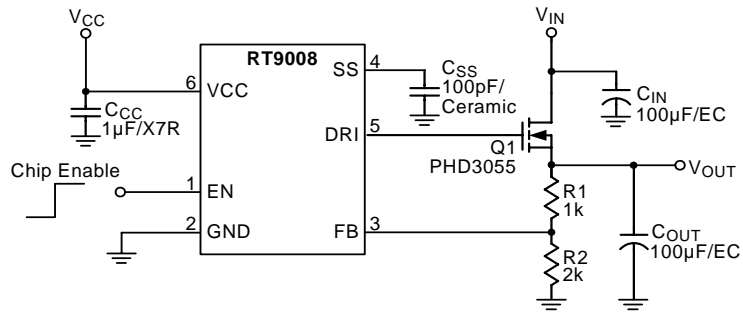


Figure 1. Typical Test Circuit

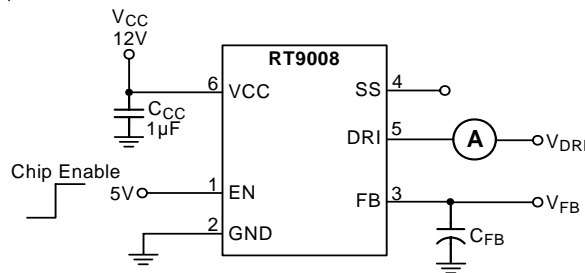
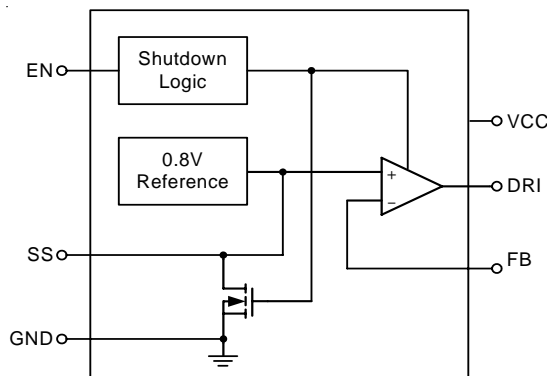


Figure 2. DRI Source/Sink Current Test Circuit

Functional Pin Description

Pin No.	Pin Name	Pin Function
1	EN	Enable Input Pin. (Active High)
2	GND	Ground.
3	FB	Output Voltage Feedback Reference Input.
4	SS	Soft Start Control.
5	DRI	Driver Output.
6	VCC	Power Supply Input.

Function Block Diagram



**Absolute Maximum Ratings** (Note 1)

- Supply Input Voltage,  $V_{CC}$  ----- 15V
- Enable Voltage ----- 7V
- Power Dissipation,  $P_D$  @  $T_A = 25^\circ\text{C}$   
   SOT-23-6 ----- 0.4W
- Package Thermal Resistance (Note 2)  
   SOT-23-6,  $\theta_{JA}$  ----- 250°C/W
- Lead Temperature (Soldering, 10 sec.) ----- 260°C
- Junction Temperature Range ----- 150°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,  $V_{CC}$  ----- 4.5V to 13.5V
- Enable Voltage ----- 0V to 5.5V
- Junction Temperature Range ----- -40°C to 125°C
- Ambient Temperature Range ----- -40°C to 85°C

**Electrical Characteristics**

( $V_{CC} = 12\text{V}$ ,  $T_A = 25^\circ\text{C}$ , unless otherwise specified).

Parameter	Symbol	Test Condition	Min	Typ	Max	Unit
POR Threshold Voltage	$V_{CC\_POR}$	$V_{CC}$ Rising	4.0	4.2	4.5	V
POR Hysteresis	$V_{CC\_PORHY}$		--	0.2	--	V
$V_{CC}$ Quiescent Current	$I_Q$	$V_{CC} = 12\text{V}$	--	0.3	0.8	mA
Driver Source Current	$I_{DRI\_SR}$	$V_{CC} = 12\text{V}$ , $V_{DRI} = 6\text{V}$	5	--	--	mA
Driver Sink Current	$I_{DRI\_SK}$	$V_{CC} = 12\text{V}$ , $V_{DRI} = 6\text{V}$	5	--	--	mA
Feedback Reference Voltage	$V_{REF}$	$V_{CC} = 12\text{V}$ , $V_{DRI} = 5\text{V}$	0.784	0.8	0.816	V
Reference Line Regulation	$V_{REF\_Line}$	$V_{CC} = 4.5\text{V}$ to $15\text{V}$	--	3	6	mV
Amplifier Voltage Gain		$V_{CC} = 12\text{V}$ , No Load	--	70		dB
PSRR at 100Hz, No Load	PSRR	$V_{CC} = 12\text{V}$ , No Load	50	--		dB
<b>Chip Enable</b>						
EN Threshold	Logic-High Voltage	$V_{IH}$	1.4	--	5.5	V
	Logic-Low Voltage	$V_{IL}$	0	--	0.4	
Shutdown Current	$I_{SHDN}$	$V_{CC} = 12\text{V}$ , $V_{EN} = 0\text{V}$	--	--	5	$\mu\text{A}$
<b>Soft-Start</b>						
SS pin Source Current	$I_{SS}$	$V_{SS} = 0\text{V}$	2	5	10	$\mu\text{A}$
Output Turn-On Rise Time		$V_{OUT} = 1.2\text{V}$ , $C_{OUT} = 1000\mu\text{F}$ , $C_{SS} = 4.7\text{nF}$	--	1	--	ms

**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.

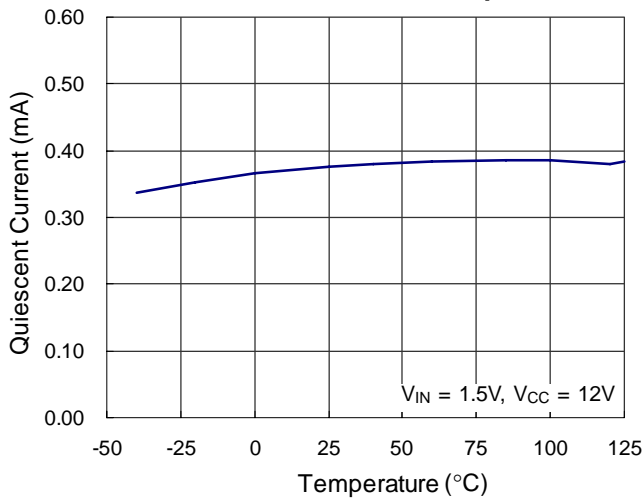
**Note 2.**  $\theta_{JA}$  is measured in the natural convection at  $T_A = 25^\circ\text{C}$  on a low effective thermal conductivity single layer test board of JEDEC 51-3 thermal measurement standard.

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

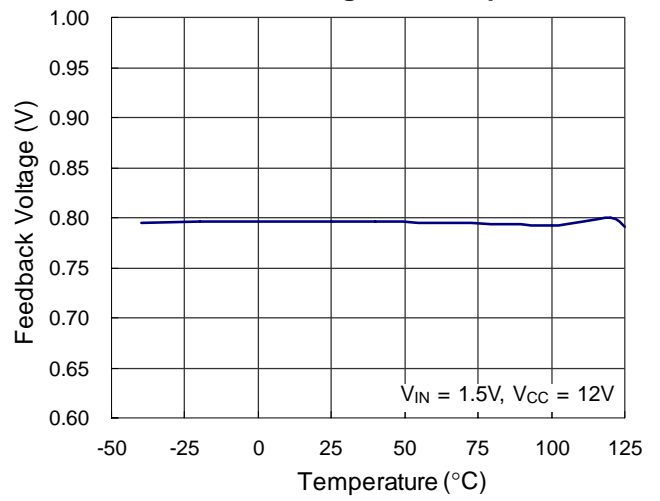
**Note 4.** The device is not guaranteed to function outside its operating conditions.

Typical Operating Characteristics

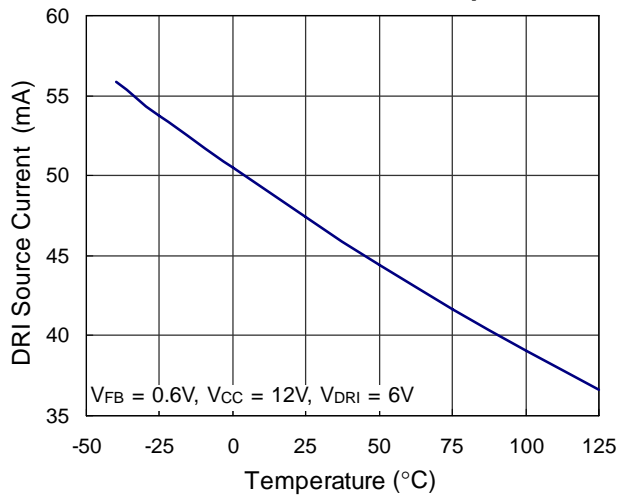
Quiescent Current vs. Temperature



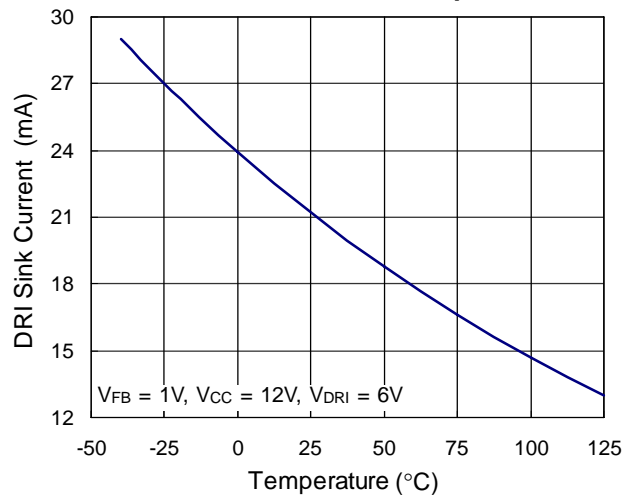
Feedback Voltage vs. Temperature



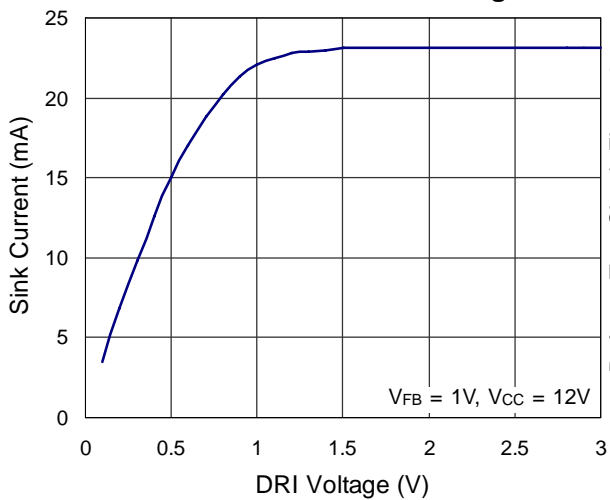
DRI Source Current vs. Temperature



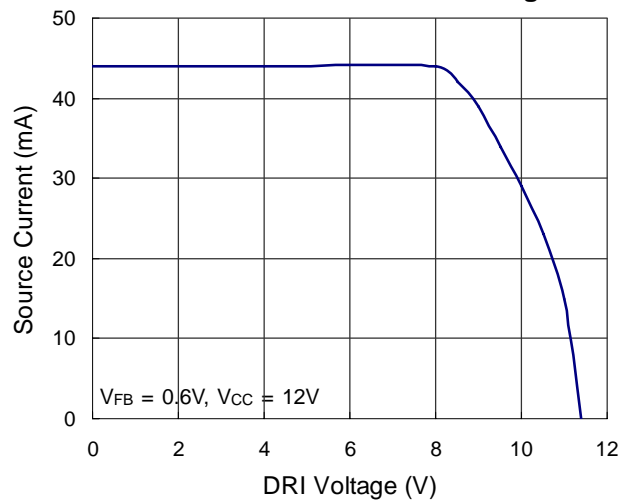
DRI Sink Current vs. Temperature



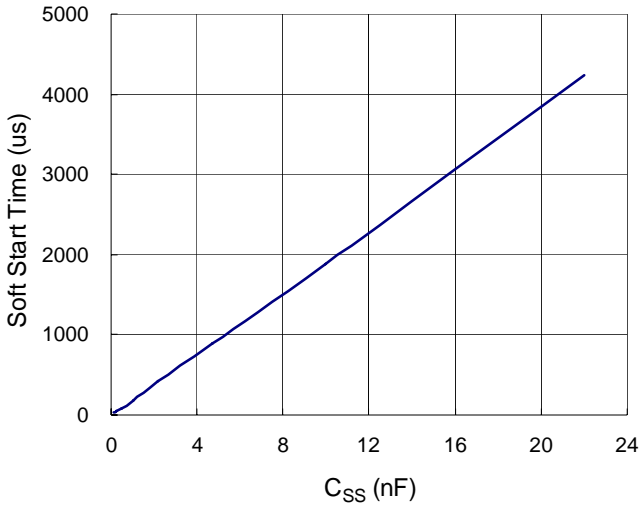
Sink Current vs. DRI Voltage



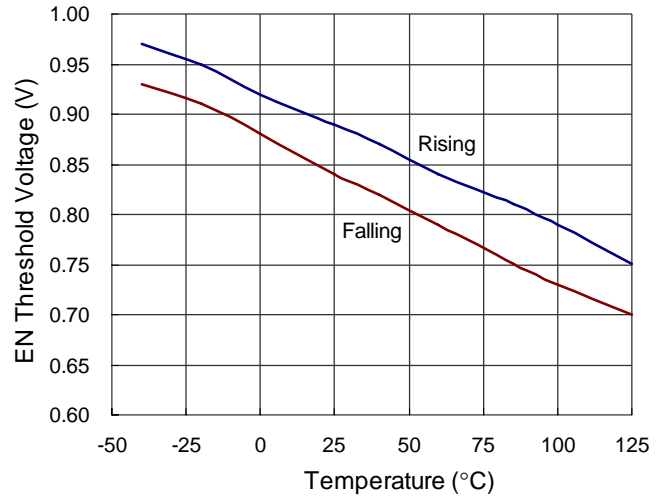
Source Current vs. DRI Voltage



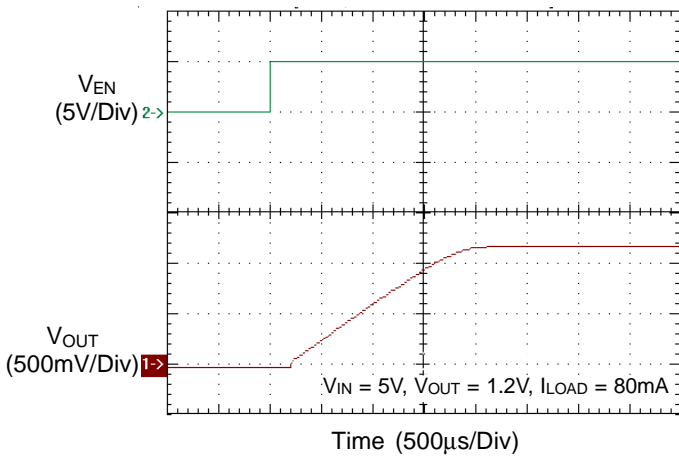
Soft Start Time vs. C<sub>SS</sub>



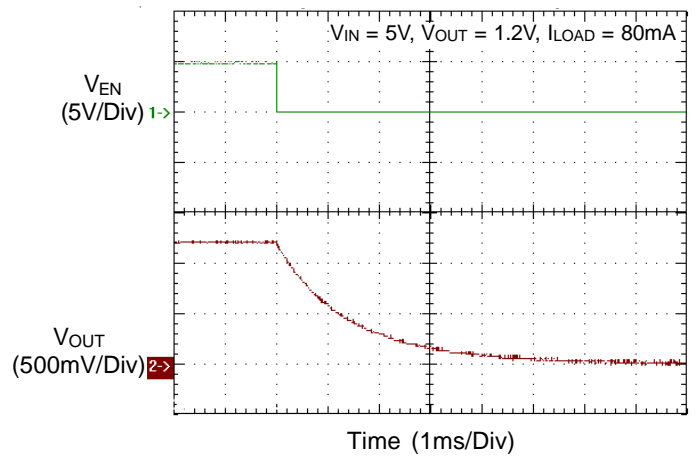
EN Threshold Voltage vs. Temperature



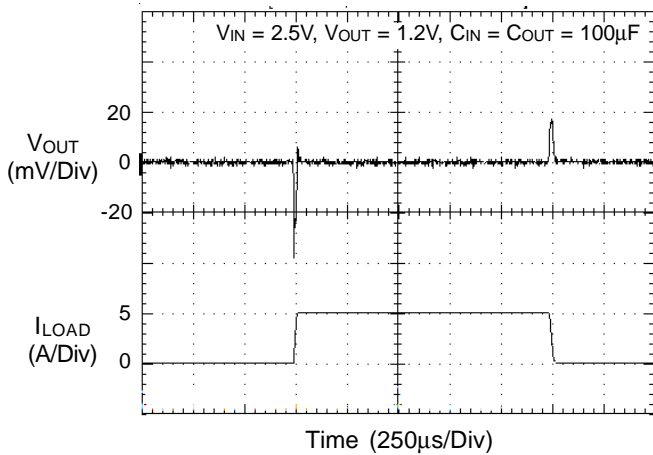
Power On from EN



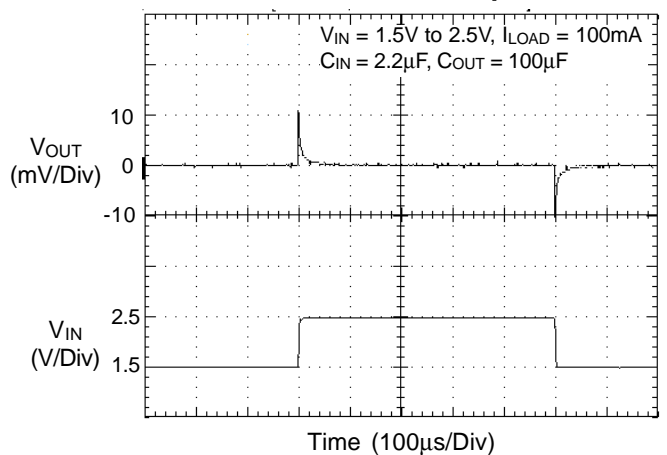
Power Off from EN



Load Transient Response



Line Transient Response



## Application Information

### Output Voltage Setting

As shown in application circuit, the output voltage can be easily set by the external resistor divider of R1 and R2.

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

Where  $V_{REF}$  is the feedback reference voltage (0.8V typical).

### Chip Enable Operation

Pull the EN pin low (< 0.4V) to shutdown the device. During shutdown mode, the standby current is lower than 5μA. The external capacitor and load current determine the output voltage decay rate. Drive the EN pin high (> 1.4V) to turn on the device again.

### Soft-Start

Soft-Start provides for the monotonic, glitch-free turn-on of the regulator. Soft-start limits the input inrush current which may cause a glitch, especially if the source impedance is high. The soft-start is achieved by the controller ramping up to the error amplifier reference input. The RT9008 soft-start time is 190us when the soft-start capacitor is 1nF, 920μs for 4.7nF and 1.9ms for 10nF.

### Capacitors Selection

Careful selection of the external capacitors is highly recommended for the best performance of the RT9008.

Regarding the supply voltage capacitor ( $C_{CC}$ ) connecting a ceramic capacitor 1μF between the  $V_{CC}$  and GND is a must.

The capacitor  $C_{CC}$  improves the supply voltage stability to provide chip normal operation.

As to the input capacitor,  $C_{IN}$ , connecting a 100μF between the  $V_{IN}$ , and GND is recommended to increase stability. With large capacitor value could result in better performance for both PSRR and line transient response.

When driving external pass element, a 100μF electrolytic capacitor on the output capacitor ( $C_{OUT}$ ) is recommended for stability. With larger capacitor, the RT9008 can reduce noise, improve load transient response and PSRR.

### MOSFET Selection and Thermal Consideration

The RT9008 is designed to drive an external N-MOSFET pass element. MOSFET selection criteria include threshold voltage  $V_{GS}$  ( $V_{TH}$ ), maximum continuous drain current  $I_D$ , on-resistance  $R_{DS(ON)}$ , maximum drain-to-source voltage  $V_{DS}$  and package thermal resistance  $\theta_{JA}$ .

The most critical specification is the MOSFET  $R_{DS(ON)}$ . The maximum allowed  $R_{DS(ON)}$  can be calculated by the following formula :

$$R_{DS(ON)} = \frac{V_{IN} - V_{OUT}}{I_{LOAD}}$$

For example, if the maximum load current is 2A, the input voltage is 1.5V and the output voltage is 1.2V, then  $R_{DS(ON)} = (1.5V - 1.2V)/2A = 150m\Omega$ .

The MOSFET's  $R_{DS(ON)}$  have to be selected to be lower than 150mΩ. A Philips PHD3055E MOSFET with an  $R_{DS(ON)}$  of 120mΩ (typ.) is a good choice.

After that, consider the thermal resistance from junction to ambient  $\theta_{JA}$  of the MOSFET's package. The power dissipation is calculated by :

$$P_D = (V_{IN} - V_{OUT}) \times I_{LOAD}$$

The thermal resistance from junction to ambient  $\theta_{JA}$  can be calculated by :

$$\theta_{(JA)} = \frac{(T_J - T_A)}{P_D}$$

In this example,  $P_D = (1.5V - 1.2V) \times 2A = 0.6W$ . The PHD3055E's  $\theta_{JA}$  is 75°C/W for its D-PAK package, which translates to a 45°C temperature rise above ambient. The package provides exposed backsides that directly transfer heat to the PCB board.

The RT9008 maximum power dissipation depends on the thermal resistance of the 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  $\theta_{JA}$  is the junction to ambient resistance.

For recommended operating conditions specification of the RT9008, the maximum junction temperature is 125°C. The junction to ambient thermal resistance  $\theta_{JA}$  for SOT-23-6 package is 250°C/W on the standard JEDEC 51-3 single-layer thermal test board.

The maximum allowed power dissipation at  $T_A = 25^\circ\text{C}$  can be calculated by following formula :

For SOT-23-6 package,

$$P_{D(MAX)} = (125^\circ\text{C} - 25^\circ\text{C}) / (250^\circ\text{C/W}) = 0.400 \text{ W}$$

The maximum power dissipation depends on operating ambient temperature for fixed  $T_{J(MAX)}$  and thermal resistance  $\theta_{JA}$ . For RT9008 package, the Figure 3 of derating curve allows the designer to see the effect of rising ambient temperature on the maximum power dissipation allowed.

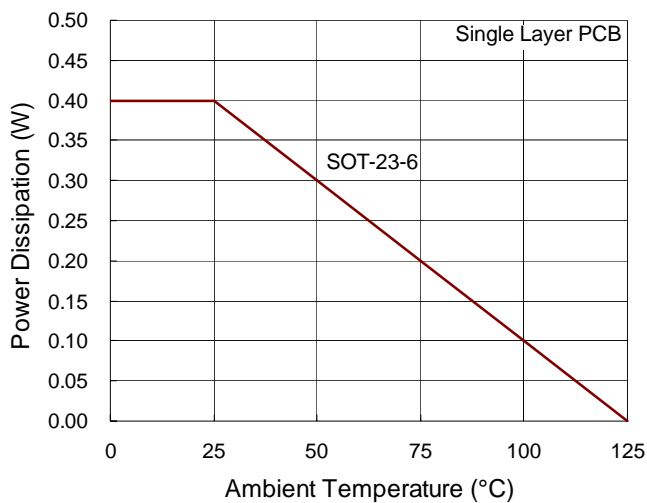


Figure 3. Derating Curves for RT9008 Package

## Layout Considerations

There are three critical layout considerations. One is the divider resistors should be located as close to the RT9008 FB pin as possible to minimize noise

The second is the placement of capacitors. The  $C_{IN}$  and  $C_{OUT}$  have to be placed near the N-MOSFET for improving performance.

The third is the copper area for pass element, it should be as large as possible when the pass element operating under high power situation that could rise the junction temperature. Considering the package thermal resistance limitation, the copper area should be large enough to handle the power dissipation shown as Figure 4.

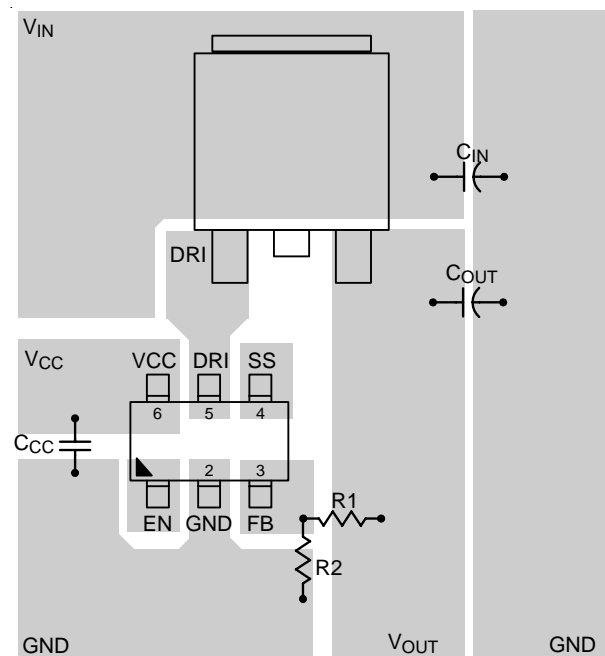
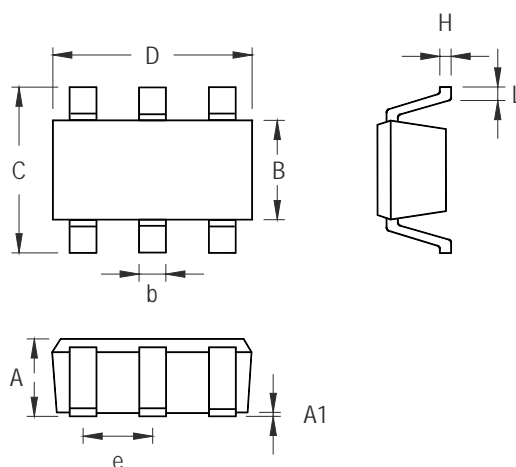


Figure 4. PCB Layout Guide



**Outline Dimension**



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**

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