

## **Peak 3A Bus Termination Regulator**

### **General Description**

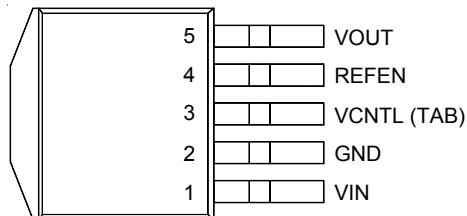
The RT9173/A regulator is designed to convert voltage supplies ranging from 1.6V to 6V into a desired output voltage which adjusted by two external voltage divider resistors. The regulator is capable of sourcing or sinking up to 3A of peak current while regulating an output voltage to within 2% (DDR 1) and 3% (DDR 2) or less.

The RT9173/A, used in conjunction with series termination resistors, provides an excellent voltage source for active termination schemes of high speed transmission lines as those seen in high speed memory buses and distributed backplane designs. The voltage output of the regulator can be used as a termination voltage for DDR SDRAM.

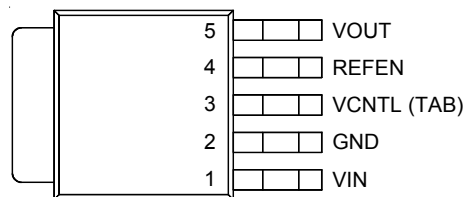
Current limits in both sourcing and sinking mode, plus on-chip thermal shutdown make the circuit tolerant of the output fault conditions.

### **Pin Configuration**

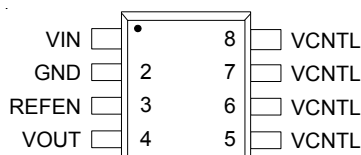
(TOP VIEW)



TO-263-5 (RT9173A)



TO-252-5 (RT9173A)



SOP-8 (RT9173)

### **Features**

- Support Both DDR 1 (1.25V<sub>TT</sub>) and DDR 2 (0.9V<sub>TT</sub>) Requirements
- SOP-8, TO-252-5 and TO-263-5 Packages
- Capable of Sourcing and Sinking 3A Peak Current
- Current-limiting Protection
- Thermal Protection
- Integrated Power MOSFETs
- Generates Termination Voltages for SSTL-2
- High Accuracy Output Voltage at Full-Load
- Adjustable V<sub>OUT</sub> by External Resistors
- Minimum External Components
- Shutdown for Standby or Suspend Mode Operation with High-impedance Output
- RoHS Compliant and 100% Lead (Pb)-Free

### **Applications**

- DDR Memory Termination
- Active Termination Buses
- Supply Splitter

### **Marking Information**

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

## Ordering Information

| Part No    | Status   | Sink & Source (A) | Package  | Lead Plating System                  |
|------------|----------|-------------------|----------|--------------------------------------|
| RT9173PM5  | Obsolete | 1.5               | TO-263-5 | P : Pb Free                          |
| RT9173PL5  | Obsolete | 1.5               | TO-252-5 | P : Pb Free                          |
| RT9173PS   | Active   | 1.5               | SOP-8    | P : Pb Free                          |
| RT9173GM5  | Obsolete | 1.5               | TO-263-5 | G : Green (Halogen Free and Pb Free) |
| RT9173GL5  | Obsolete | 1.5               | TO-252-5 | G : Green (Halogen Free and Pb Free) |
| RT9173GS   | Active   | 1.5               | SOP-8    | G : Green (Halogen Free and Pb Free) |
| RT9173APM5 | Obsolete | 3                 | TO-263-5 | P : Pb Free                          |
| RT9173APL5 | Active   | 3                 | TO-252-5 | P : Pb Free                          |
| RT9173APS  | Obsolete | 3                 | SOP-8    | P : Pb Free                          |
| RT9173AGM5 | Active   | 3                 | TO-263-5 | G : Green (Halogen Free and Pb Free) |
| RT9173AGL5 | Obsolete | 3                 | TO-252-5 | G : Green (Halogen Free and Pb Free) |
| RT9173AGS  | Obsolete | 3                 | SOP-8    | G : Green (Halogen Free and Pb Free) |

The part status values are defined as below :

**Active** : Device is in production and is recommended for new designs.

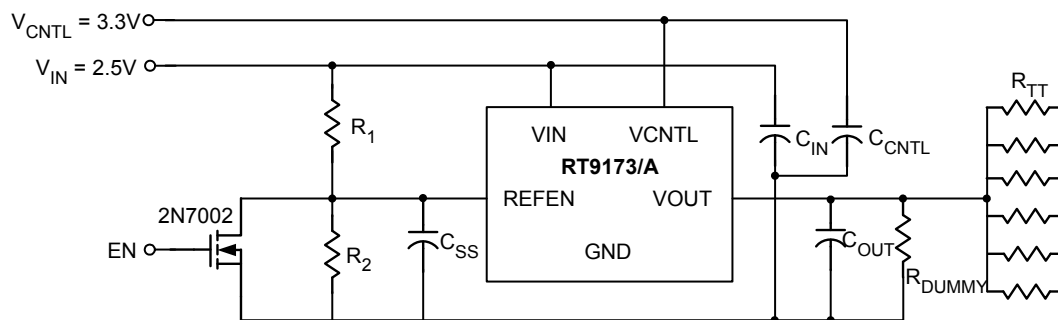
**Lifebuy** : The device will be discontinued, and a lifetime-buy period is in effect.

**NRND** : Not recommended for new designs.

**Preview** : Device has been announced but is not in production.

**Obsolete** : Richtek has discontinued the production of the device.

## Typical Application Circuit



$$R_1 = R_2 = 100\text{k}\Omega, R_{TT} = 50\Omega / 33\Omega / 25\Omega$$

$$C_{OUT(MIN)} = 10\mu\text{F (Ceramic)} + 1000\mu\text{F under the worst case testing condition}$$

$$R_{DUMMY} = 1\text{k}\Omega \text{ as for VOUT discharge when V_IN is not present but V_CNTL is present}$$

$$C_{SS} = 1\mu\text{F}, C_{IN} = 470\mu\text{F (Low ESR)}, C_{CNTL} = 47\mu\text{F}$$

## Test Circuit

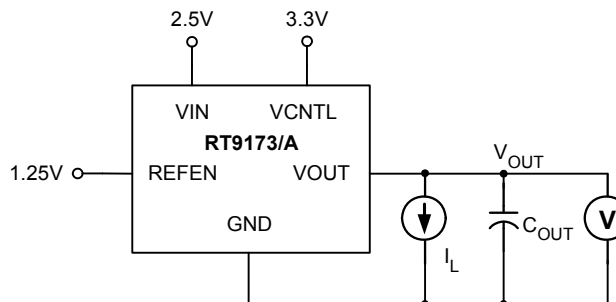


Figure 1. Output Voltage Tolerance,  $\Delta V_{LOAD}$

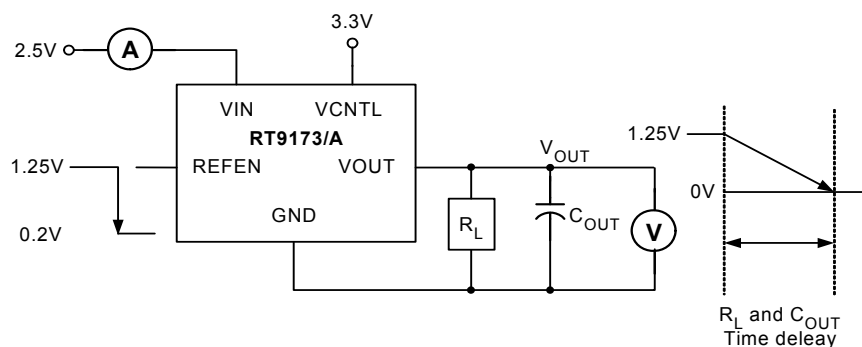


Figure 2. Current in Shutdown Mode,  $I_{SHDN}$

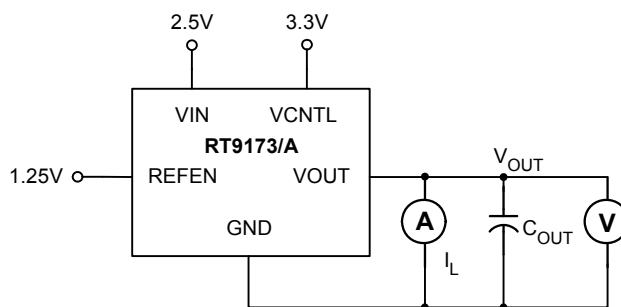


Figure 3. Current Limit for High Side,  $I_{LIMIT}$

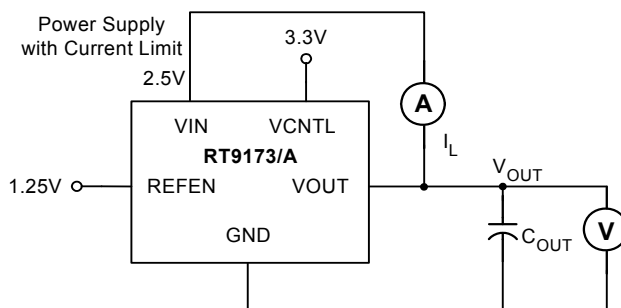


Figure 4. Current Limit for Low Side,  $I_{LIMIT}$

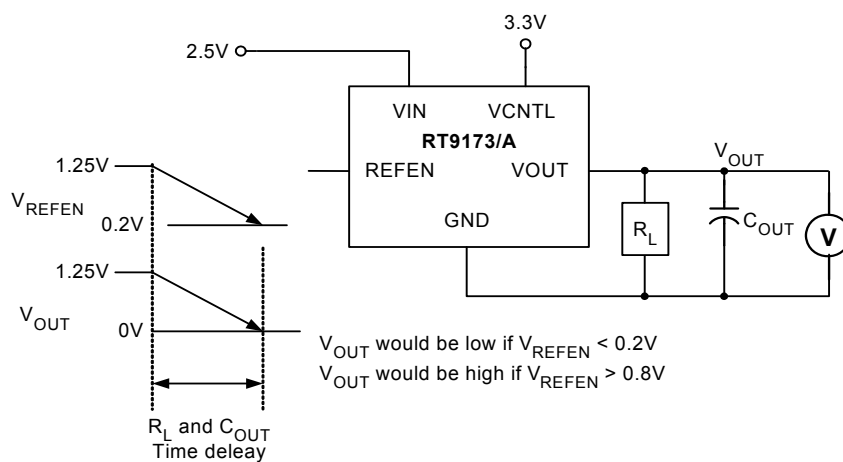
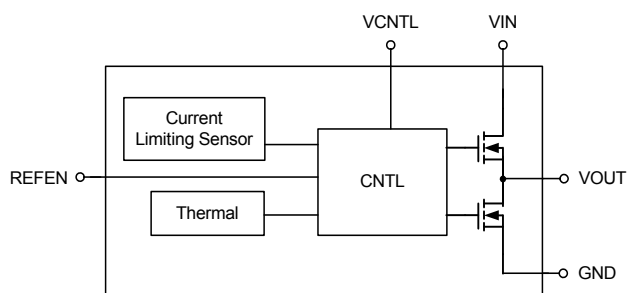


Figure 5. REFEN Pin Shutdown Threshold,  $V_{TRIGGER}$

## Functional Pin Description

| Pin Name | Pin Function                             |
|----------|------------------------------------------|
| VIN      | Power input voltage.                     |
| GND      | Ground.                                  |
| VCNTL    | Gate drive voltage.                      |
| REFEN    | Reference voltage input and chip enable. |
| VOUT     | Output voltage.                          |

## Functional Block Diagram



## Absolute Maximum Ratings

- Input Voltage ----- 7V
- Power Dissipation ----- Internally Limited
- ESD Rating ----- 2kV
- Storage Temperature Range ----- -65°C to 150°C
- Lead Temperature (Soldering, 10 sec.) ----- 260°C
- Power Dissipation,  $P_D$  @  $T_A = 25^\circ\text{C}$ 
  - TO-263-5 ----- 1.923W
  - TO-252-5 ----- 1.471W
  - SOP-8 ----- 0.625W
- Package Thermal Resistance (Note 1)
  - TO-263-5,  $\theta_{JC}$  ----- 7.7°C/W
  - TO-252-5,  $\theta_{JC}$  ----- 8°C/W
  - SOP-8,  $\theta_{JC}$  ----- 23.2°C/W
  - TO-263-5,  $\theta_{JA}$  ----- 52°C/W
  - TO-252-5,  $\theta_{JA}$  ----- 68°C/W
  - SOP-8,  $\theta_{JA}$  ----- 160°C/W

## Recommended Operating Conditions (Note 4)

- Input Voltage,  $V_{IN}$  ----- 2.5V to 1.5V  $\pm 3\%$
- Control Voltage,  $V_{CNTL}$  ----- 5V or 3.3V  $\pm 5\%$
- Junction Temperature Range ----- -40°C to 125°C
- Ambient Temperature Range ----- -40°C to 85°C

## Electrical Characteristics

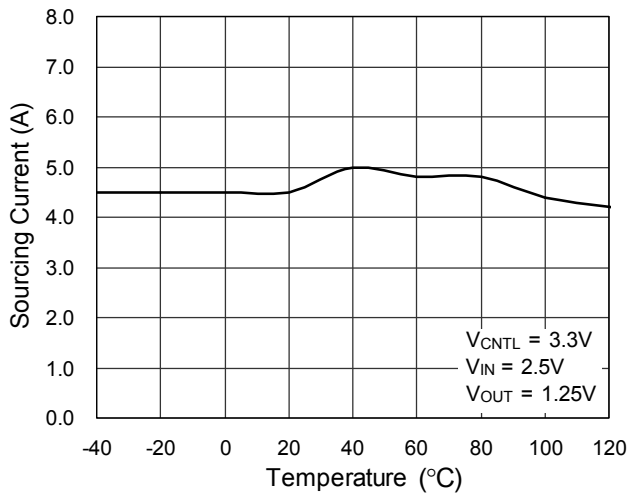
( $V_{IN} = 2.5\text{V}$ ,  $V_{CNTL} = 3.3\text{V}$ ,  $V_{REFEN} = 1.25\text{V}$ ,  $C_{OUT} = 10\mu\text{F}$  (Ceramic),  $T_A = 25^\circ\text{C}$ , unless otherwise specified.)

| Parameter                                 | Symbol            | Test Conditions                                                           | Min | Typ     | Max | Unit             |
|-------------------------------------------|-------------------|---------------------------------------------------------------------------|-----|---------|-----|------------------|
| Output Offset Voltage                     | $V_{OS}$          | $I_{OUT} = 0\text{A}$ , Figure 1 (Note 2)                                 | -20 | 0       | 20  | mV               |
| Load Regulation (DDR 1/2)                 | $\Delta V_{LOAD}$ | $I_L : 0\text{A} \rightarrow 1.5\text{A}$ , Figure 1                      | --  | 0.8/1.2 | 2/3 | %                |
|                                           |                   | $I_L : 0\text{A} \rightarrow -1.5\text{A}$                                | --  | 0.8/1.2 | 2/3 |                  |
| Input Voltage Range (DDR 1/2)<br>(Note 3) | $V_{IN}$          | Keep $V_{CNTL} \geq V_{IN}$ on operation power on and power off sequences | 1.6 | 2.5/1.8 | --  | V                |
|                                           | $V_{CNTL}$        |                                                                           | --  | 3.3     | 6   |                  |
| Operating Current of $V_{CNTL}$           | $I_{CNTL}$        | No Load                                                                   | --  | 6.5     | 10  | mA               |
| Current In Shutdown Mode                  | $I_{SHDN}$        | $V_{REFEN} < 0.2\text{V}$ , $R_L = 180\Omega$ , Figure 2                  | --  | 50      | 90  | $\mu\text{A}$    |
| <b>Short Circuit Protection</b>           |                   |                                                                           |     |         |     |                  |
| Current limit                             | $I_{LIMIT}$       | Figure 3,4                                                                | 3.0 | --      | --  | A                |
| <b>Over Temperature Protection</b>        |                   |                                                                           |     |         |     |                  |
| Thermal Shutdown Temperature              | $T_{SD}$          | $3.3\text{V} \leq V_{CNTL} \leq 5\text{V}$                                | 125 | 150     | --  | $^\circ\text{C}$ |
| Thermal Shutdown Hysteresis               |                   | Guaranteed by design                                                      | --  | 50      | --  | $^\circ\text{C}$ |
| <b>Shutdown Function</b>                  |                   |                                                                           |     |         |     |                  |
| Shutdown Threshold Trigger                | $V_{TRIGGER}$     | Output = High, Figure 5                                                   | 0.8 | --      | --  | V                |
|                                           | $V_{TRIGGER}$     | Output = Low, Figure 5                                                    | --  | --      | 0.2 |                  |

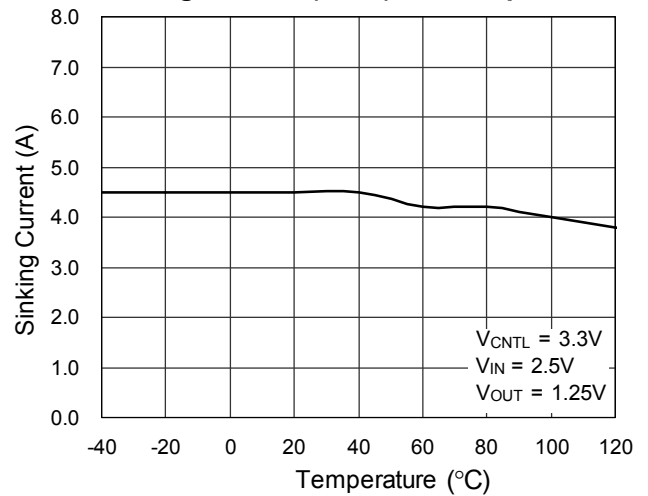
- Note 1.**  $\theta_{JA}$  is measured in the natural convection at  $T_A = 25^\circ\text{C}$  on a low effective thermal conductivity test board (single Layers, 1S) of JEDEC 51-3 thermal measurement standard. The case point of  $\theta_{JC}$  is on the on the center of  $V_{CTRL}$  pins (Lead 6 & 7) for SOP-8 packages, the center of heat sink (tab) for TO-252-5 and TO-263-5 packages.
- Note 2.**  $V_{OS}$  offset is the voltage measurement defined as  $V_{OUT}$  subtracted from  $V_{REFEN}$ .
- Note 3.** For safely operate your system, the 3.3V rail MUST be tied to  $V_{CNTL}$  rather than 5V rail, especially for the new part of RT9173ACL5.
- Note 4.** The device is not guaranteed to function outside its operating conditions.

## Typical Operating Characteristics

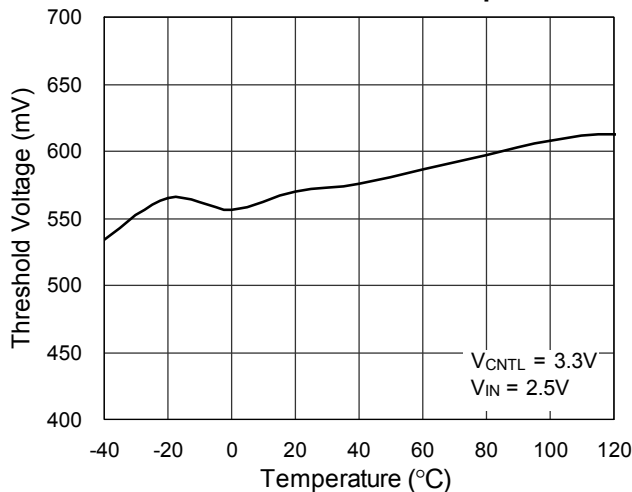
### Sourcing Current (Peak) vs. Temperature



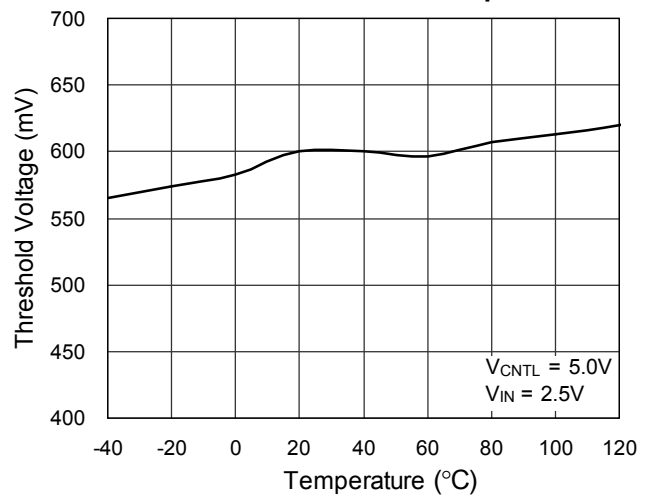
### Sinking Current (Peak) vs. Temperature



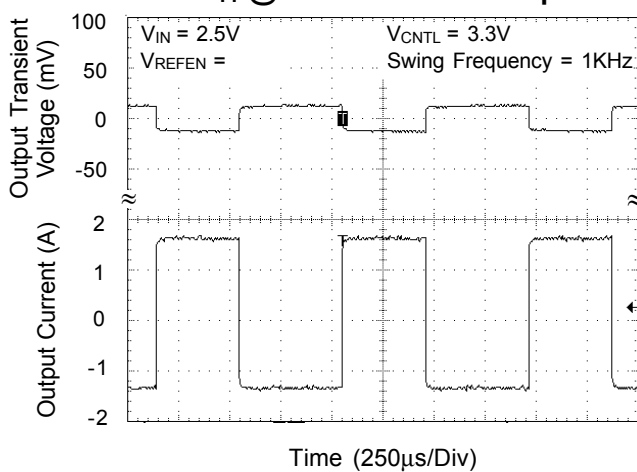
### Turn-On Threshold vs. Temperature



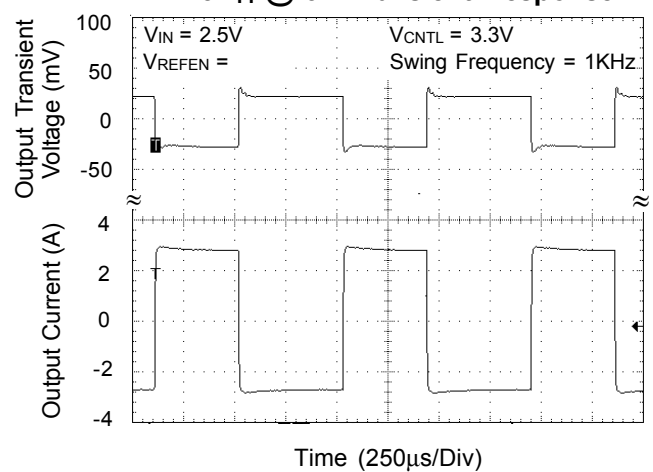
### Turn-On Threshold vs. Temperature



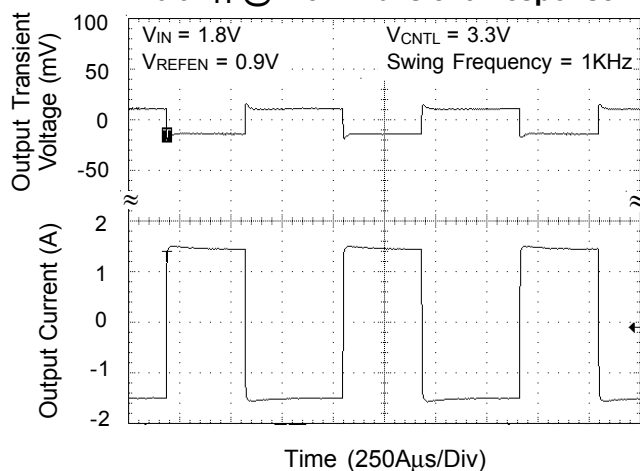
### 1.25V<sub>TT</sub> @ 1.5A Transient Response



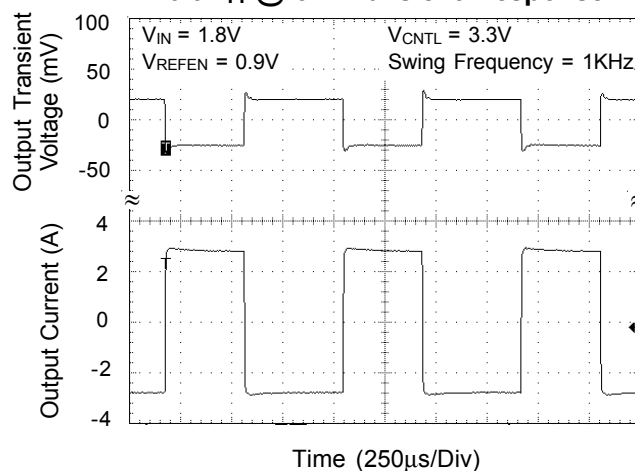
### 1.25V<sub>TT</sub> @ 3A Transient Response



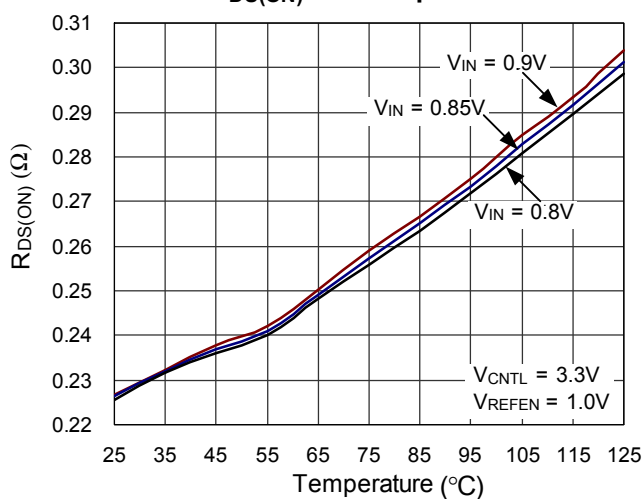
**0.9V<sub>TT</sub> @ 1.5A Transient Response**



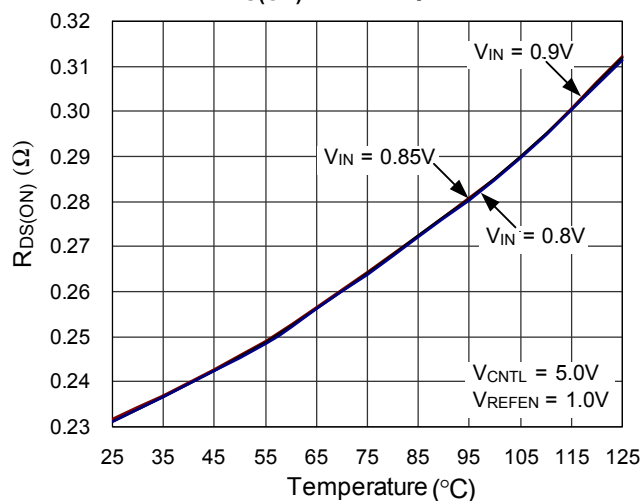
**0.9V<sub>TT</sub> @ 3A Transient Response**



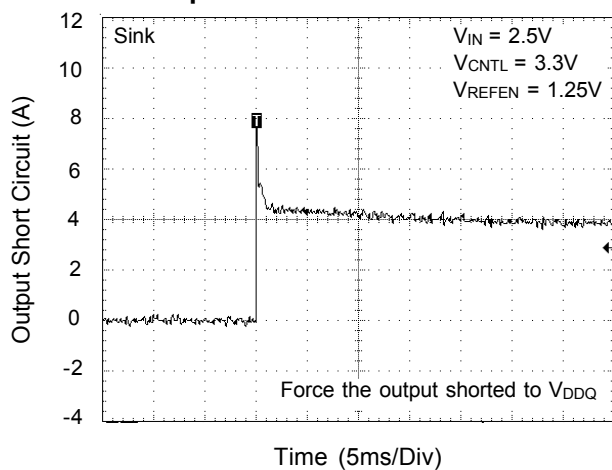
**R<sub>DS(ON)</sub> vs. Temperature**



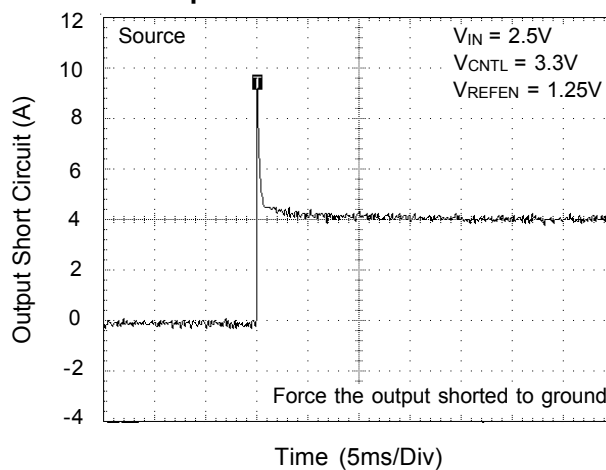
**R<sub>DS(ON)</sub> vs. Temperature**



**Output Short-Circuit Protection**



**Output Short-Circuit Protection**



## Application Information

### Internal Parasitic Diode

Avoid forward-bias internal parasitic diode,  $V_{OUT}$  to  $V_{CNTL}$ , and  $V_{OUT}$  to  $V_{IN}$ , the  $V_{OUT}$  should not be forced some voltage respect to ground on this pin while the  $V_{CNTL}$  or  $V_{IN}$  is disappeared.

### Consideration while Designs the Resistance of Voltage Divider

Make sure the sinking current capability of pull-down NMOS if the lower resistance was chosen so that the voltage on  $V_{REFEN}$  is below 0.2V.

In addition, the capacitor and voltage divider form the low-pass filter. There are two reasons doing this design; one is for output voltage soft-start while another is for noise immunity.

### How to reduce power dissipation on Notebook PC or the dual channel DDR SDRAM application?

In notebook application, using RichTek's Patent "Distributed Bus Terminator Topology" with choosing RichTek's product is encouraged.

Distributed Bus Terminating Topology

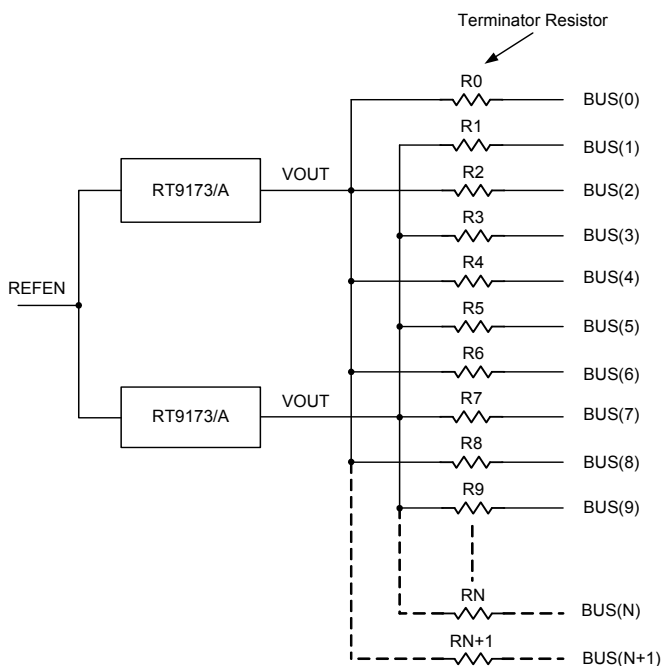


Figure 6

### Thermal Consideration

RT9173/A regulators have internal thermal limiting circuitry designed to protect the device during overload conditions. For continued operation, do not exceed absolute maximum operation junction temperature 125°C. The power dissipation definition in device is :

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

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 125°C,  $T_A$  is the ambient temperature and the  $\theta_{JA}$  is the junction to ambient thermal resistance. The junction to ambient thermal resistance  $\theta_{JA}$  highly depends on IC package, PCB layout, and the rate of surroundings airflow.  $\theta_{JA}$  for SOP-8 package is 160°C/W and TO-263-5 package is 52°C/W on standard JEDEC 51-3 (**single layer, 1S**) thermal test board. The maximum power dissipation at  $T_A = 25^\circ\text{C}$  can be calculated by following

formula :

$$P_{D(MAX)} = (125^\circ\text{C} - 25^\circ\text{C}) / (160^\circ\text{C/W}) = 0.625\text{W} \text{ (SOP-8 package)}$$

$$P_{D(MAX)} = (125^\circ\text{C} - 25^\circ\text{C}) / (52^\circ\text{C/W}) = 1.923\text{W} \text{ (TO-263-5 package)}$$

Since the multiple  $V_{CTRL}$  pins of the SOP-8 package are internally fused and connected to lead frame, it is efficient to dissipate the heat by adding cooper area on  $V_{CTRL}$  footprint. Figure 7 shows the package sectional drawing of SOP-8. Every package has several thermal dissipation paths, as show in Figure 8, the thermal resistance equivalent circuit of SOP-8. The path 2 is the main path of thermal flow due to these materials thermal conductivity. We define the center of multiple  $V_{CTRL}$  pins are the case point of the path 2.

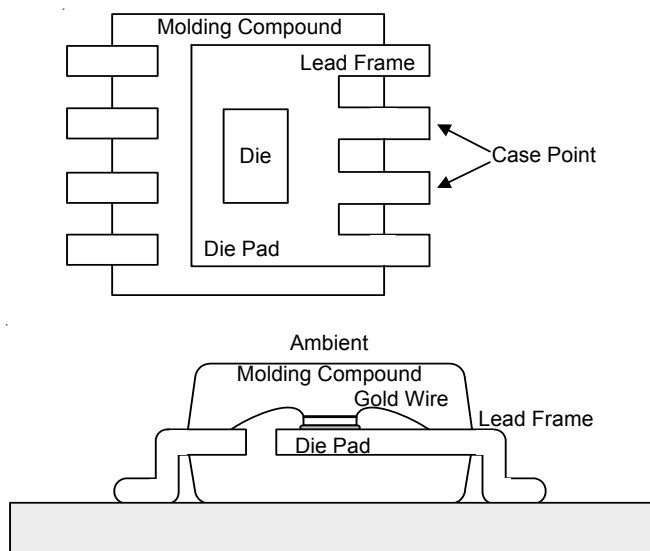


Figure 7. The Package Section Drawing of RT9173/A SOP-8 Package

The thermal resistance  $\theta_{JA}$  of IC package is determined by the package design and the PCB design. However, the package design has been decided. If possible, it's useful to increase thermal performance by the PCB design. The thermal resistance can be decreased efficiently by adding copper under the main path of thermal flow on the package.

The maximum power dissipation depends on operating ambient temperature for fixed  $T_{J(MAX)}$  and thermal resistance  $\theta_{JA}$ . For RT9173/A package, the Figure 9 and the Figure 10 show the thermal resistance  $\theta_{JA}$  vs. copper area of SOP-8 and TO-263-5 packages on single layer (1S) and 4-layer (2S2P) thermal test board at  $T_A = 25^\circ\text{C}$ , PCB copper thickness = 2oz.

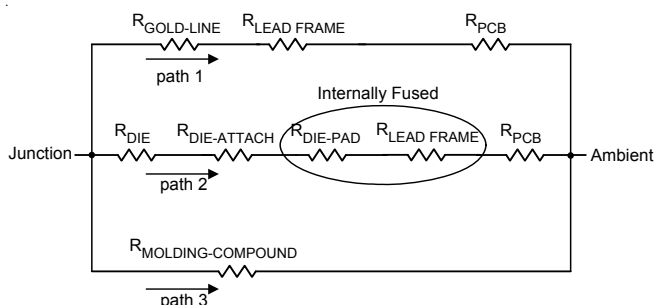


Figure 8. Thermal Resistance Equivalent Circuit of RT9173/A SOP-8 Package

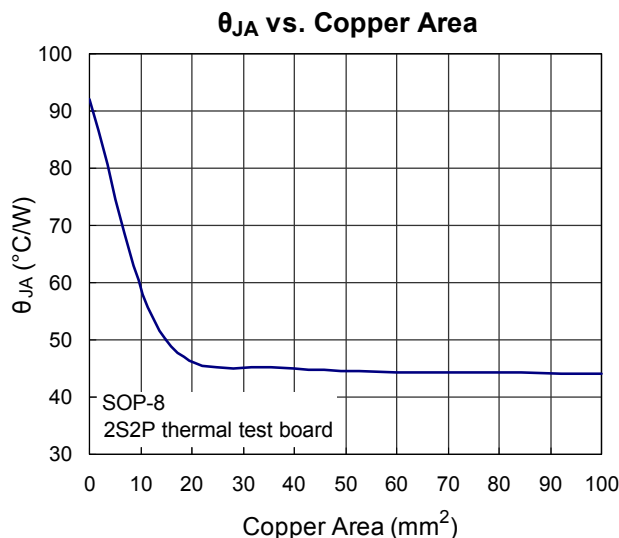


Figure 9. Thermal Resistance  $\theta_{JA}$  vs. Copper Area of SOP-8 Packages

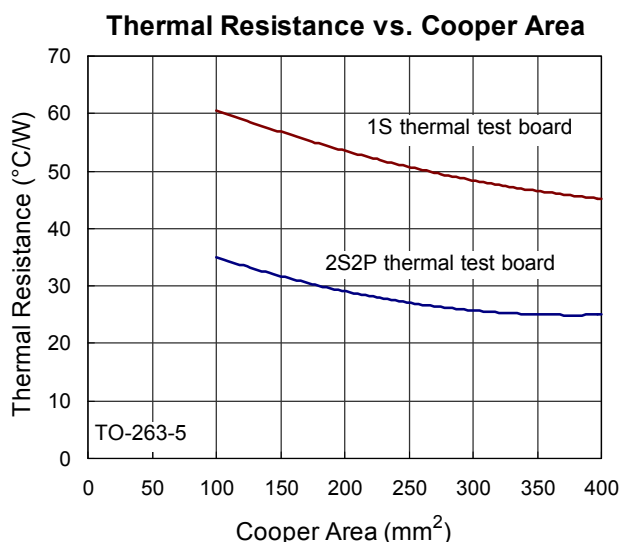


Figure 10. Thermal Resistance  $\theta_{JA}$  vs. Copper Area of TO-263-5 Packages

For example, as shown in Figure 9, RT9173/A SOP-8 with 10mm x 10mm copper area on 4-layers (2S2P) thermal test board at  $T_A = 25^\circ\text{C}$ , we can obtain the lower thermal resistance about  $45^\circ\text{C/W}$ . The power maximum dissipation can be calculated as :

$$P_{D(MAX)} = (125^\circ\text{C} - 25^\circ\text{C}) / (45^\circ\text{C/W}) = 2.22\text{W} \text{ (SOP-8)}$$

As shown in Figure 10, RT9173/A TO-263-5 with 15mm x 15mm copper area on 4-layers (2S2P) thermal test board at  $T_A = 25^\circ\text{C}$ , we can obtain the lower thermal resistance about  $29^\circ\text{C/W}$ . The power maximum dissipation

can be calculated as :

$$P_{D(MAX)} = (125^{\circ}\text{C} - 25^{\circ}\text{C}) / (29^{\circ}\text{C/W}) = 3.45\text{W (TO-263-5)}$$

Figure 11 and Figure 12 of power dissipation vs. copper area allow the designer to see the effect of rising ambient temperature on the maximum power allowed.

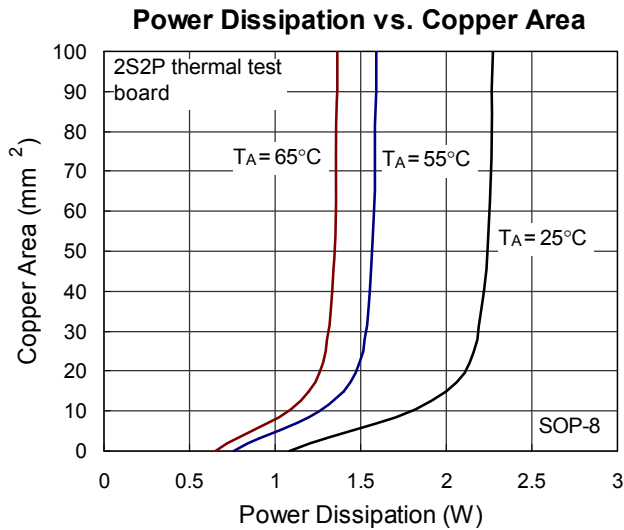


Figure 11. Power Dissipation vs. Copper Area of SOP-8 Package

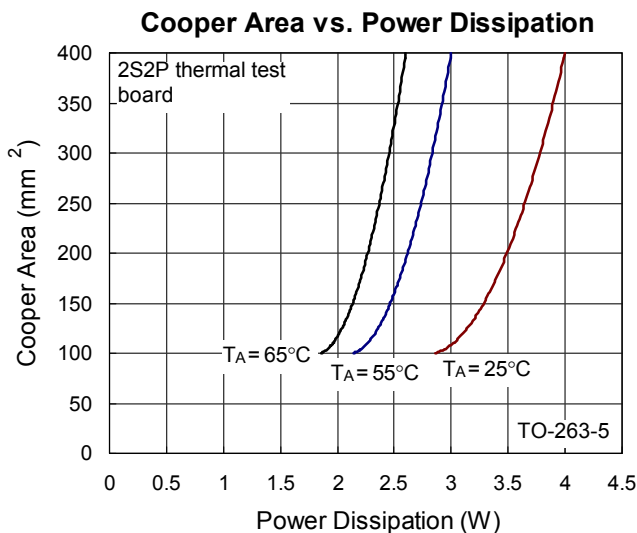
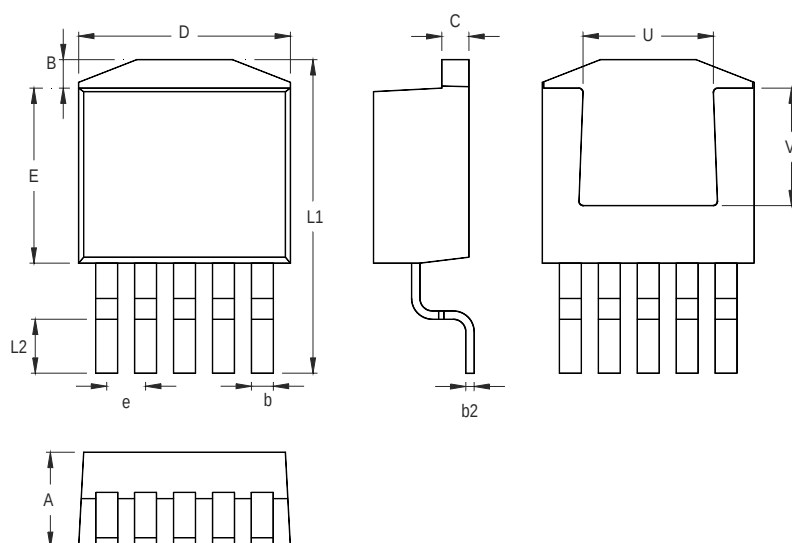


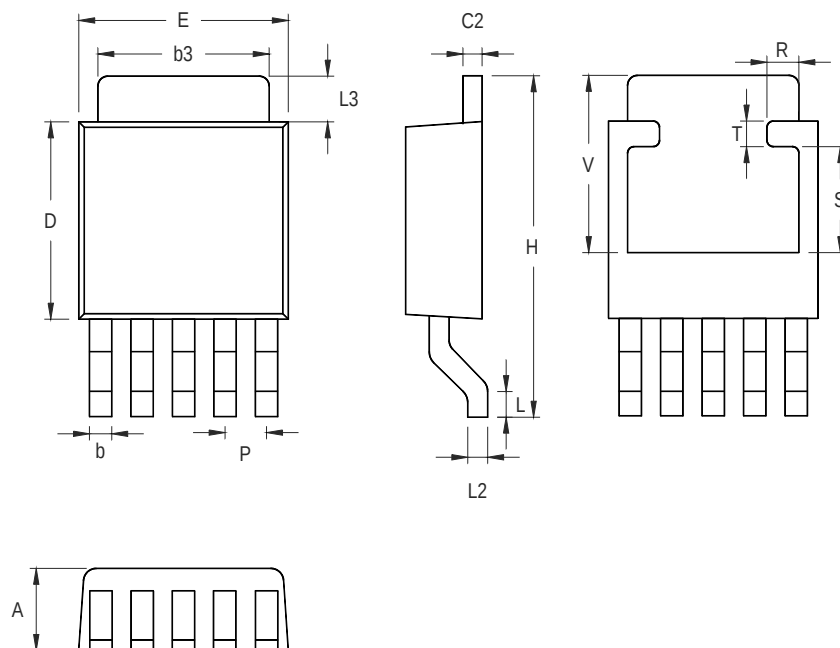
Figure 12. Power Dissipation vs. Copper Area of TO-263-5 Package

## **Outline Dimension**



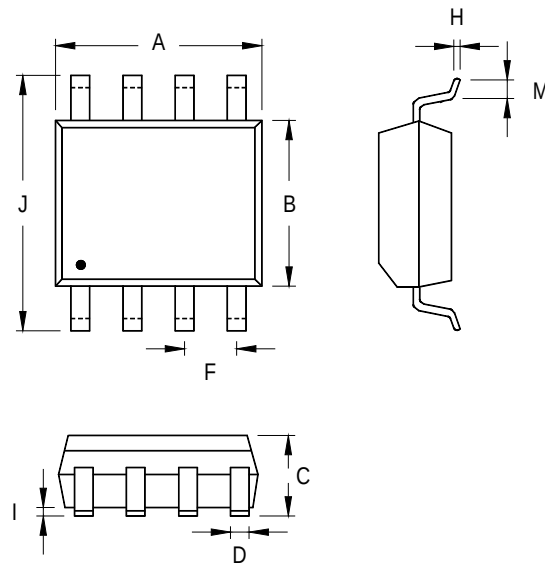
| Symbol | Dimensions In Millimeters |        | Dimensions In Inches |       |
|--------|---------------------------|--------|----------------------|-------|
|        | Min                       | Max    | Min                  | Max   |
| D      | 9.652                     | 10.668 | 0.380                | 0.420 |
| B      | 1.143                     | 1.676  | 0.045                | 0.066 |
| E      | 8.128                     | 9.652  | 0.320                | 0.380 |
| A      | 4.064                     | 4.826  | 0.160                | 0.190 |
| C      | 1.143                     | 1.397  | 0.045                | 0.055 |
| U      | 6.223 Ref.                |        | 0.245 Ref.           |       |
| V      | 7.620 Ref.                |        | 0.300 Ref.           |       |
| L1     | 14.605                    | 15.875 | 0.575                | 0.625 |
| L2     | 2.286                     | 2.794  | 0.090                | 0.110 |
| b      | 0.660                     | 0.914  | 0.026                | 0.036 |
| b2     | 0.305                     | 0.584  | 0.012                | 0.023 |
| e      | 1.524                     | 1.829  | 0.060                | 0.072 |

### **5-Lead TO-263 Plastic Surface Mount Package**



| Symbol | Dimensions In Millimeters |        | Dimensions In Inches |       |
|--------|---------------------------|--------|----------------------|-------|
|        | Min                       | Max    | Min                  | Max   |
| A      | 2.184                     | 2.388  | 0.086                | 0.094 |
| b      | 0.381                     | 0.889  | 0.015                | 0.035 |
| b3     | 4.953                     | 5.461  | 0.195                | 0.215 |
| C2     | 0.457                     | 0.889  | 0.018                | 0.035 |
| D      | 5.334                     | 6.223  | 0.210                | 0.245 |
| E      | 6.350                     | 6.731  | 0.250                | 0.265 |
| H      | 9.000                     | 10.414 | 0.354                | 0.410 |
| L      | 0.508                     | 1.780  | 0.020                | 0.070 |
| L2     | 0.508 Ref.                |        | 0.020 Ref.           |       |
| L3     | 0.889                     | 2.032  | 0.035                | 0.080 |
| P      | 1.270 Ref.                |        | 0.050 Ref.           |       |
| V      | 5.200 Ref.                |        | 0.205 Ref.           |       |
| R      | 0.200                     | 1.500  | 0.008                | 0.059 |
| S      | 2.500                     | 3.400  | 0.098                | 0.134 |
| T      | 0.500                     | 0.850  | 0.020                | 0.033 |

### 5-Lead TO-252 Surface Mount Package



| Symbol | Dimensions In Millimeters |       | Dimensions In Inches |       |
|--------|---------------------------|-------|----------------------|-------|
|        | Min                       | Max   | Min                  | Max   |
| A      | 4.801                     | 5.004 | 0.189                | 0.197 |
| B      | 3.810                     | 3.988 | 0.150                | 0.157 |
| C      | 1.346                     | 1.753 | 0.053                | 0.069 |
| D      | 0.330                     | 0.508 | 0.013                | 0.020 |
| F      | 1.194                     | 1.346 | 0.047                | 0.053 |
| H      | 0.170                     | 0.254 | 0.007                | 0.010 |
| I      | 0.050                     | 0.254 | 0.002                | 0.010 |
| J      | 5.791                     | 6.200 | 0.228                | 0.244 |
| M      | 0.400                     | 1.270 | 0.016                | 0.050 |

**8-Lead SOP Plastic Package**

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