## 200mA/500mA Fixed Output Voltage LDO Regulator

## General Description

The RT9168/A is a 200mA/500mA low dropout and micropower regulator suitable for portable applications. The output voltages range from 1.5V to 5.0V in 100mV increments and 2% accuracy. The RT9168/A is designed for use with very low ESR capacitors. The output remains stable even with a 1μF ceramic output capacitor.

The RT9168/A uses an internal PMOS as the pass device, which does not cause extra GND current in heavy load and dropout conditions. The shutdown mode of nearly zero operation current makes the IC suitable for battery-powered devices. Other features include current limiting and over temperature protection. The SOP-8 and SOT-25 packages are also available for larger power dissipation and design flexibility.

## Applications

- Cellular Telephones
- Laptop, Notebook, and Palmtop Computers
- Battery-powered Equipment
- Hand-held Equipment

## Features

- **Stable with Low-ESR Output Capacitor**
- **Low Dropout Voltage (220mV at 200mA)**
- **Low Operation Current - 80μA Typical**
- **Shutdown Function**
- **Low Temperature Coefficient**
- **Current and Thermal Limiting**
- **Custom Voltage Available**
- **SOT-25 and SOP-8 Packages**

## Pin Configurations

| Part Number | Pin Configurations |
|---|---|
| RT9168/A-□□CBR (Plastic SOT-25) | TOP VIEW<br>5  4<br>1  2  3<br>1. OUT<br>2. GND<br>3. IN<br>4. $\overline{\text{SHDN}}$<br>5. NC |
| RT9168/A-□□CS RT9168/A-□□CSH (Plastic SOP-8) | TOP VIEW<br>OUT 1 — 8 IN<br>GND 2 — 7 GND<br>GND 3 — 6 GND<br>NC 4 — 5 $\overline{\text{SHDN}}$/SHDN |

## Ordering Information

RT9168/A-□□ □ □□

Package type
BR : SOT-25
S : SOP-8
SH : SOP-8, High shutdown

Operating temperature range
C: Commercial standard

Output voltage
15 : 1.5V
16 : 1.6V
:
:
49 : 4.9V
50 : 5.0V
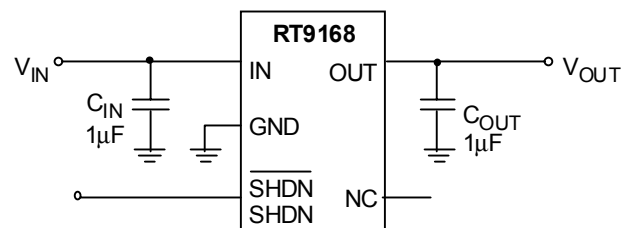
500mA Output current
200mA Output current

## Typical Application Circuit

RichTek

## Marking Information

| Part Number | Marking | Part Number | Marking |
|---|---|---|---|
| RT9168-15CBR | L0 | RT9168A-15CBR | M0 |
| RT9168-16CBR | L1 | RT9168A-16CBR | M1 |
| RT9168-17CBR | L2 | RT9168A-17CBR | M2 |
| RT9168-18CBR | L3 | RT9168A-18CBR | M3 |
| RT9168-19CBR | L4 | RT9168A-19CBR | M4 |
| RT9168-20CBR | L5 | RT9168A-20CBR | M5 |
| RT9168-21CBR | L6 | RT9168A-21CBR | M6 |
| RT9168-22CBR | L7 | RT9168A-22CBR | M7 |
| RT9168-23CBR | L8 | RT9168A-23CBR | M8 |
| RT9168-24CBR | L9 | RT9168A-24CBR | M9 |
| RT9168-25CBR | LA | RT9168A-25CBR | MA |
| RT9168-26CBR | LB | RT9168A-26CBR | MB |
| RT9168-27CBR | LC | RT9168A-27CBR | MC |
| RT9168-28CBR | LD | RT9168A-28CBR | MD |
| RT9168-29CBR | LE | RT9168A-29CBR | ME |
| RT9168-30CBR | LF | RT9168A-30CBR | MF |
| RT9168-31CBR | LG | RT9168A-31CBR | MG |
| RT9168-32CBR | LH | RT9168A-32CBR | MH |
| RT9168-33CBR | LJ | RT9168A-33CBR | MJ |
| RT9168-34CBR | LK | RT9168A-34CBR | MK |
| RT9168-35CBR | LL | RT9168A-35CBR | ML |
| RT9168-36CBR | LM | RT9168A-36CBR | MM |
| RT9168-37CBR | LN | RT9168A-37CBR | MN |
| RT9168-38CBR | LP | RT9168A-38CBR | MP |
| RT9168-39CBR | LQ | RT9168A-39CBR | MQ |
| RT9168-40CBR | LR | RT9168A-40CBR | MR |
| RT9168-41CBR | LS | RT9168A-41CBR | MS |
| RT9168-42CBR | LT | RT9168A-42CBR | MT |
| RT9168-43CBR | LU | RT9168A-43CBR | MU |
| RT9168-44CBR | LV | RT9168A-44CBR | MV |
| RT9168-45CBR | LW | RT9168A-45CBR | MW |
| RT9168-46CBR | LX | RT9168A-46CBR | MX |
| RT9168-47CBR | LY | RT9168A-47CBR | MY |
| RT9168-48CBR | LZ | RT9168A-48CBR | MZ |
| RT9168-49CBR | CL | RT9168A-49CBR | CN |
| RT9168-50CBR | CM | RT9168A-50CBR | CP |

## Pin Description

| Pin Name | Pin Function |
|---|---|
| IN | Input |
| GND | Ground |
| $\overline{\text{SHDN}}$ (SHDN) | Active Low (High) Shutdown Input |
| NC | No Connection |
| OUT | Output |

## Function Block Diagram
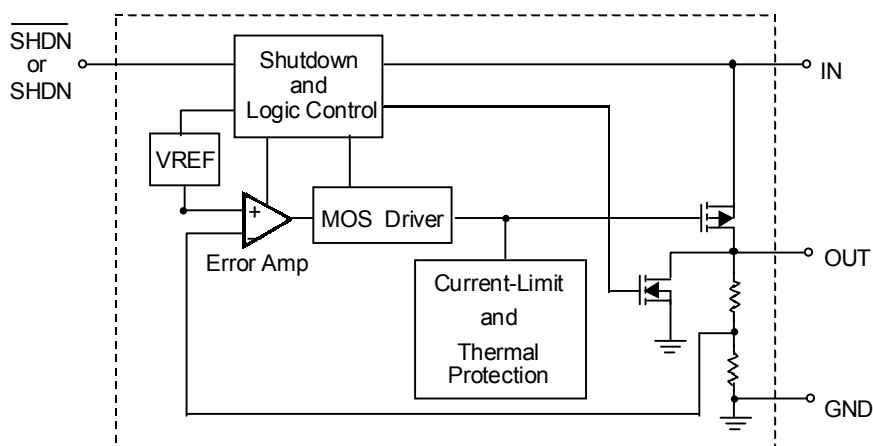
## Absolute Maximum Ratings

- Input Voltage ⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯ 8V
- Power Dissipation, $P_D$ @ $T_A$ = 25°C
  - SOT-25 ⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯ 0.25W
  - SOP-8 ⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯ 0.625W
- Operating Junction Temperature Range ⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯ −40°C to 125°C
- Storage Temperature Range ⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯ −65°C to 150°C
- Package Thermal Resistance
  - SOT-25, $\theta_{JA}$ ⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯ 250°C/W
  - SOP-8, $\theta_{JA}$ ⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯ 160°C/W
- Lead Temperature (Soldering, 5 sec.) ⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯ 260°C

## Electrical Characteristics

($V_{IN}$ = 5.0V, $C_{IN}$ = 1µF, $C_{OUT}$ = 1µF, $T_A$ = 25°C, unless otherwise specified)

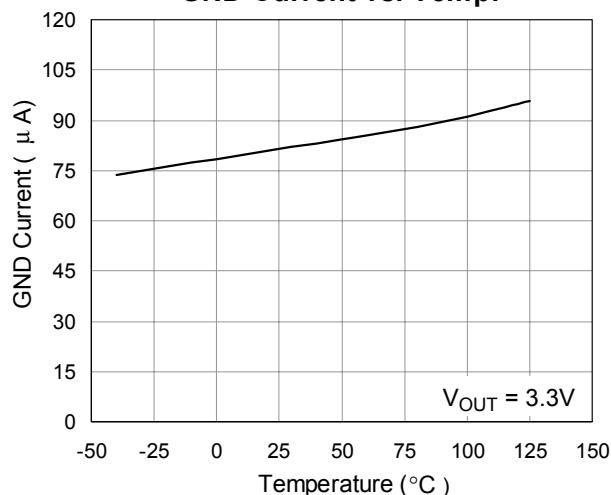| Parameter | | Symbol | Test Conditions | Min | Typ | Max | Units |
|---|---|---|---|---|---|---|---|
| Input Voltage Range | | $V_{IN}$ | | 2.9 | -- | 7 | V |
| | | | $I_L$ = 50mA | 2.7 | -- | 7 | |
| Output Voltage Accuracy | | $\Delta V_{OUT}$ | $I_L$ = 1mA | -2 | -- | +2 | % |
| Maximum Output Current | RT9168 | $I_{MAX}$ | | 200 | -- | -- | mA |
| | RT9168A | | | 500 | -- | -- | mA |
| Current Limit | RT9168 | $I_{LIMIT}$ | $R_{LOAD}$ = 1 Ohm | -- | 300 | -- | mA |
| | RT9168A | | | -- | 700 | -- | mA |
| GND Pin Current | RT9168/A | $I_G$ | No Load | -- | 80 | 150 | µA |
| | RT9168 | | $I_{OUT}$ = 200mA | -- | 90 | 150 | |
| | RT9168A | | $I_{OUT}$ = 500mA | -- | 90 | 150 | |
| Dropout Voltage (Note) ($V_{OUT}$(Nominal)≥3.0V Version) | RT9168/A | $V_{DROP}$ | $I_{OUT}$ = 1mA | -- | 1.1 | 5 | mV |
| | RT9168/A | | $I_{OUT}$ = 50mA | -- | 55 | 100 | mV |
| | RT9168/A | | $I_{OUT}$ = 200mA | -- | 220 | 300 | mV |
| | RT9168A | | $I_{OUT}$ = 500mA | -- | 600 | 750 | mV |
| Line Regulation | | $\Delta V_{LINE}$ | $V_{IN}$ = ($V_{OUT}$+0.15) to 7V, $I_{OUT}$ = 1mA | -0.2 | -- | +0.2 | %/V |
| Load Regulation | | $\Delta V_{LOAD}$ | $I_{OUT}$ = 0mA to 200mA | -- | 0.01 | 0.04 | %/mA |
| | | | $I_{OUT}$ = 0mA to 500mA | -- | 0.01 | 0.04 | |
| $\overline{SHDN}$, SHDN Input High Threshold | | $V_{IH}$ | $V_{IN}$ = 3V to 5.5V | 2.2 | -- | -- | V |
| $\overline{SHDN}$, SHDN Input Low Threshold | | $V_{IL}$ | $V_{IN}$ = 3V to 5.5V | -- | -- | 0.4 | V |
| $\overline{SHDN}$, SHDN Bias Current | | $I_{SD}$ | | -- | -- | 100 | nA |
| Shutdown Supply Current | | $I_{GSD}$ | $V_{OUT}$ = 0V | -- | 0.01 | 1 | µA |
| Thermal Shutdown Temperature | | $T_{SD}$ | | -- | 155 | -- | °C |
| Ripple Rejection | | PSRR | F = 100Hz, $C_{BP}$ = 10nF, $C_{OUT}$ = 10µF | -- | 58 | -- | dB |

Notes: Dropout voltage definition: $V_{IN}$ - $V_{OUT}$ when $V_{OUT}$ is 50 mV below the value of $V_{OUT}$ at $V_{IN}$ = $V_{OUT}$ + 0.5V
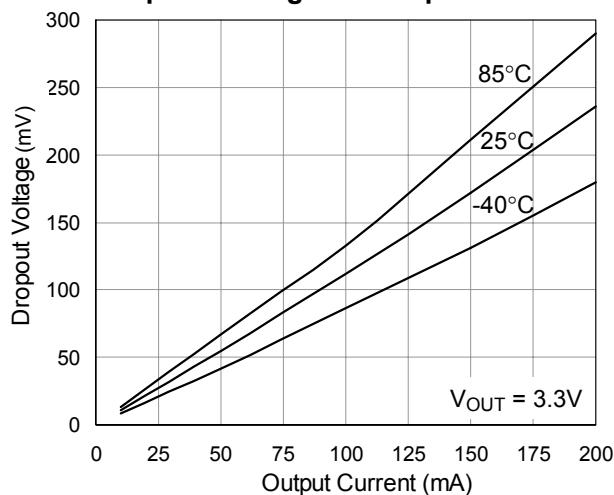
## Typical Operating Charateristics
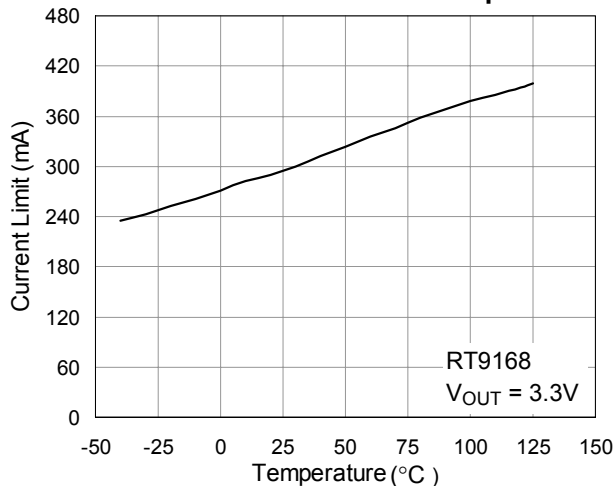
**Output Voltage vs. Temp.**



$V_{OUT}$ = 3.3V
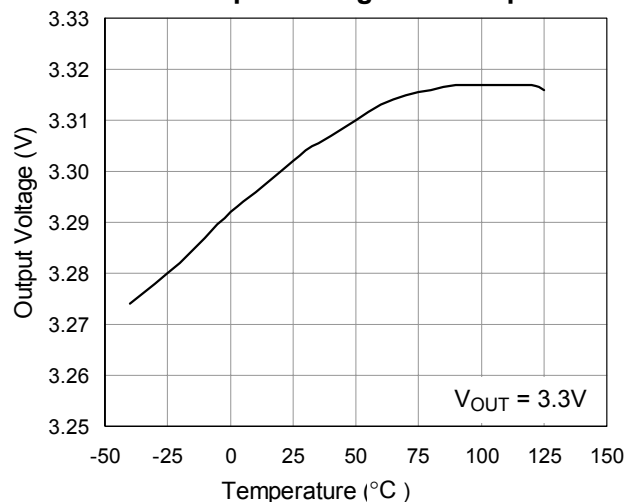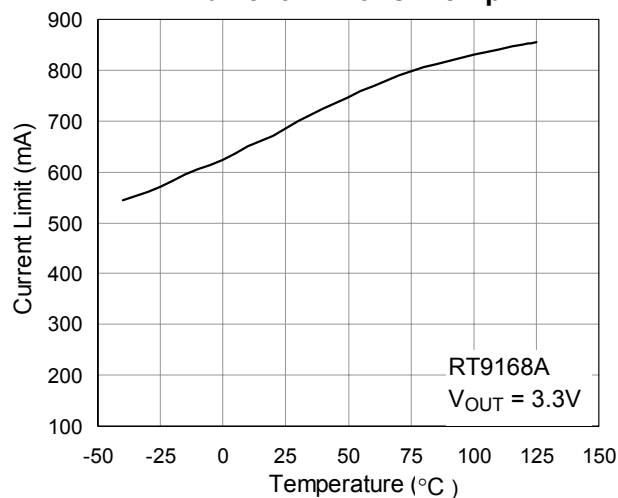
**GND Current vs. Temp.**



$V_{OUT}$ = 3.3V

**Dropout Voltage vs. Output Current**
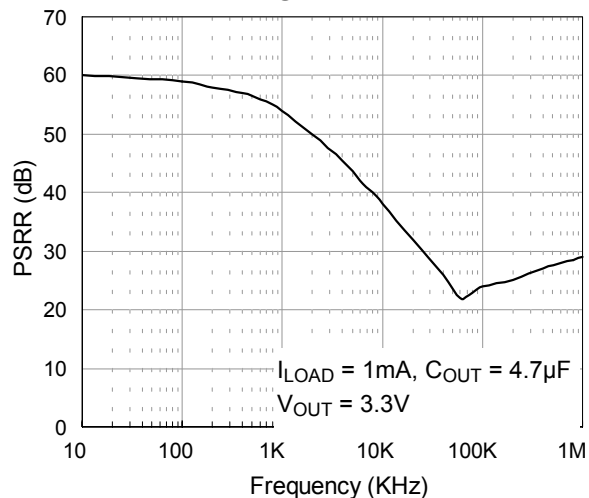


85°C
25°C
-40°C

$V_{OUT}$ = 3.3V

**Current Limit vs. Temp.**



RT9168
$V_{OUT}$ = 3.3V

**Current Limit vs. Temp.**



RT9168A
$V_{OUT}$ = 3.3V

**PSRR**



$I_{LOAD}$ = 1mA, $C_{OUT}$ = 4.7μF
$V_{OUT}$ = 3.3V

**Load Transient Response**

$C_{OUT}$ = 1µF
$C_{IN}$ = 10µF
$V_{OUT}$ = 3.0V
$V_{IN}$ = 4V

Time (50µS/Div)

**Load Transient Response**

$C_{OUT}$ = 4.7µF
$C_{IN}$ = 10µF
$V_{OUT}$ = 3.0V
$V_{IN}$ = 4V

Time (50µS/Div)

**Line Transient Response**

$C_{OUT}$ = 1µF
$V_{OUT}$ = 3.0V
Loading = 1mA

Time (1mS/Div)

**Line Transient Response**

$C_{OUT}$ = 1µF
$V_{OUT}$ = 3.0V
Loading = 50mA

Time (1mS/Div)

**Line Transient Response**

$C_{OUT}$ = 4.7µF
$V_{OUT}$ = 3.0V
Loading = 1mA

Time (500µS/Div)

**Line Transient Response**

$C_{OUT}$ = 4.7µF
$V_{OUT}$ = 3.0V
Loading = 50mA

Time (500µS/Div)
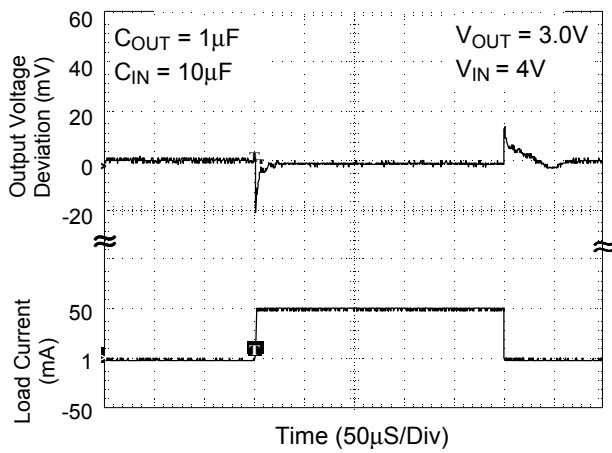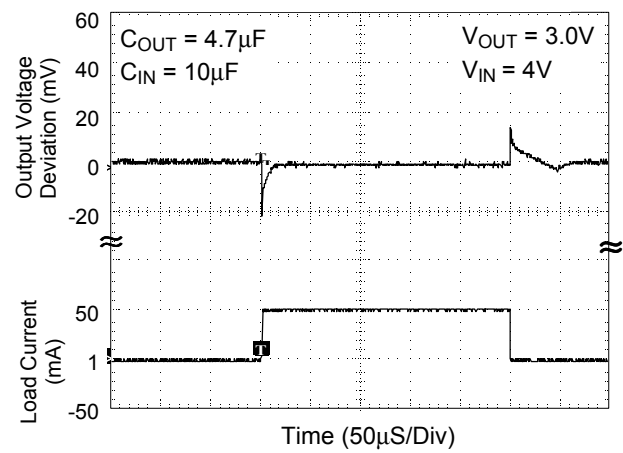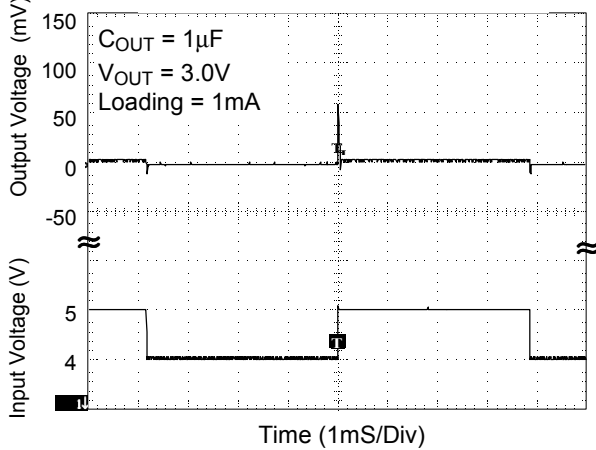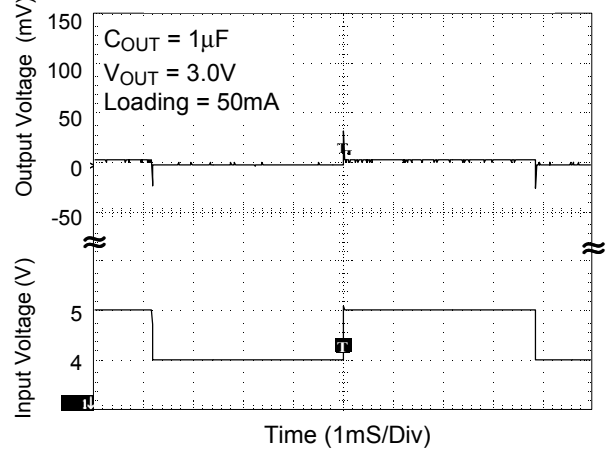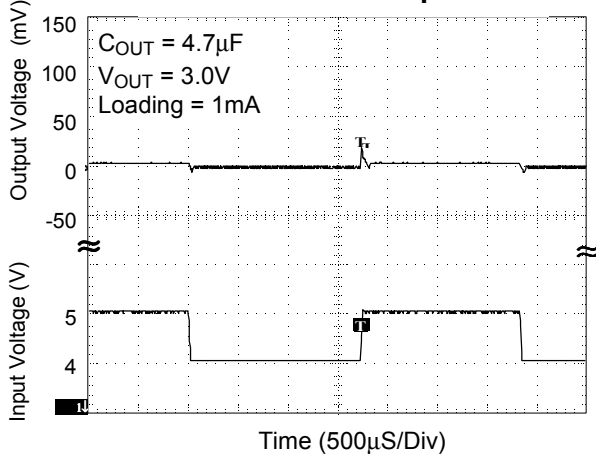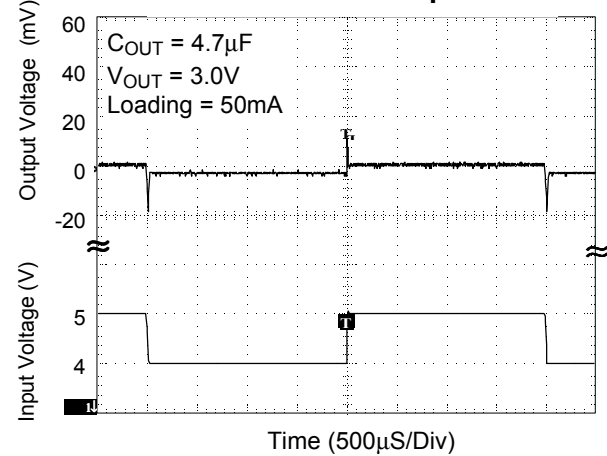
## Applications Guides

### Capacitor Selection and Regulator Stability

Like any low-dropout regulator, the external capacitors used with the RT9168/A must be carefully selected for regulator stability and performance.

Using a capacitor whose value is > 1μF on the RT9168/A input and the amount of capacitance can be increased without limit. The input capacitor must be located not more than 0.5" from the input pin of the IC and returned to a clean analog ground. Any good quality ceramic or tantalum can be used for this capacitor. The capacitor with larger value and lower ESR (equivalent series resistance) provides better PSRR and line-transient response.

The output capacitor must meet both requirements for minimum amount of capacitance and ESR in all LDO applications. The RT9168/A is designed specifically to work with low ESR ceramic output capacitor in space-saving and performance consideration. Using a ceramic capacitor whose value is at least 1μF with ESR is > 5mΩ on the RT9168/A output ensures stability. The RT9168/A still works well with output capacitor of other types due to the wide stable ESR range. Fig.1 shows the curves of allowable ESR range as a function of load current for various output voltages and capacitor values. Output capacitor of larger capacitance can reduce noise and improve load-transient response, stability, and PSRR. The output capacitor should be located not more than 0.5" from the $V_{OUT}$ pin of the RT9168/A and returned to a clean analog ground.

Note that some ceramic dielectrics exhibit large capacitance and ESR variation with temperature. It may be necessary to use 2.2μF or more to ensure stability at temperatures below -10°C in this case. Also, tantalum capacitors, 2.2μF or more may be needed to maintain capacitance and ESR in the stable region for strict application environment.

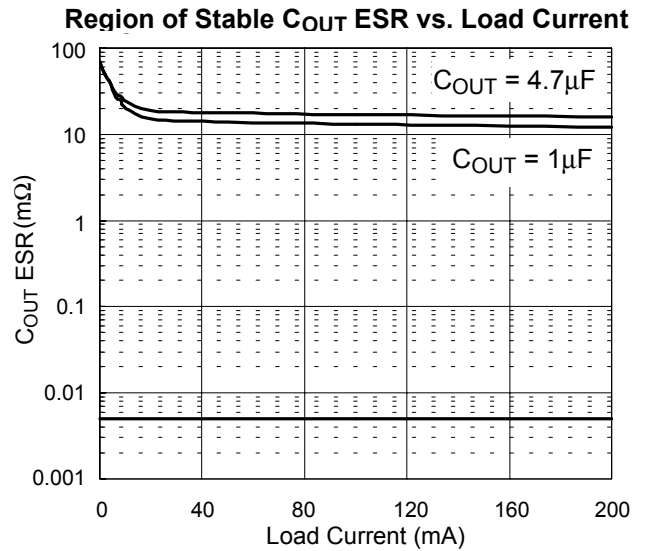**Region of Stable $C_{OUT}$ ESR vs. Load Current**



**Fig. 1**

Tantalum capacitors maybe suffer failure due to surge current when it is connected to a low-impedance source of power (like a battery or very large capacitor). If a tantalum capacitor is used at the input, it must be guaranteed to have a surge current rating sufficient for the application by the manufacture.

### Load-Transient Considerations

The RT9168/A load-transient response graphs (see Typical Operating Characteristics) show two components of the output response: a DC shift from the output impedance due to the load current change, and the transient response. The DC shift is quite small due to the excellent load regulation of the IC. Typical output voltage transient spike for a step change in the load current from 0mA to 50mA is tens mV, depending on the ESR of the output capacitor. Increasing the output capacitor's value and decreasing the ESR attenuates the overshoot.

### Shutdown Input Operation

The RT9168/A is shutdown by pulling the SHDN input low, and turned on by driving the input high. If this feature is not to be used, the SHDN input should be tied to VIN to keep the regulator on at all times (the SHDN input must **not** be left floating).

To ensure proper operation, the signal source used to drive the SHDN input must be able to swing above and below the specified turn-on/turn-off voltage thresholds which guarantee an ON or OFF state (see Electrical Characteristics). The ON/OFF signal may come from either CMOS output, or an open-collector output with pull-up resistor to the RT9168/A input voltage or another logic supply. The high-level voltage may exceed the RT9168/A input voltage, but must remain within the absolute maximum ratings for the SHDN pin.

**Internal P-Channel Pass Transistor**

The RT9168/A features a typical 1.1Ω P-channel MOSFET pass transistor. It provides several advantages over similar designs using PNP pass transistors, including longer battery life. The P-channel MOSFET requires no base drive, which reduces quiescent current considerably. PNP-based regulators waste considerable current in dropout when the pass transistor saturates. They also use high base-drive currents under large loads. The RT9168/A does not suffer from these problems and consume only 80μA of quiescent current whether in dropout, light-load, or heavy-load applications.

**Input-Output (Dropout) Voltage**

A regulator's minimum input-output voltage differential (or dropout voltage) determines the lowest usable supply voltage. In battery-powered systems, this will determine the useful end-of-life battery voltage. Because the RT9168/A uses a P-channel MOSFET pass transistor, the dropout voltage is a function of drain-to-source on-resistance [$R_{DS(ON)}$] multiplied by the load current.

**Reverse Current Path**

The power transistor used in the RT9168/A has an inherent diode connected between the regulator input and output (see Fig.2). If the output is forced above the input by more than a diode-drop, this diode will become forward biased and current will flow from the $V_{OUT}$ terminal to $V_{IN}$. This diode will also be turned on by abruptly stepping the input voltage to a value below the output voltage. To

prevent regulator mis-operation, a Schottky diode should be used in any applications where input/output voltage conditions can cause the internal diode to be turned on (see Fig.3). As shown, the Schottky diode is connected in parallel with the internal parasitic diode and prevents it from being turned on by limiting the voltage drop across it to about 0.3V. < 100 mA to prevent damage to the part.
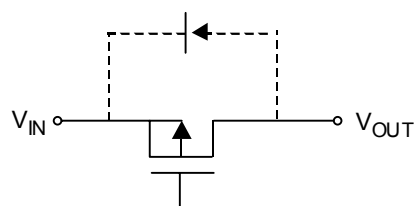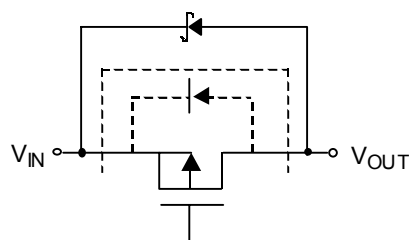


Fig. 2



Fig. 3

**Current Limit and Thermal Protection**

The RT9168 includes a current limit which monitors and controls the pass transistor's gate voltage limiting the output current to 300mA Typ. (700mA Typ. for RT9168A). Thermal-overload protection limits total power dissipation in the RT9168/A. When the junction temperature exceeds $T_J$ = +155°C, the thermal sensor signals the shutdown logic turning off the pass transistor and allowing the IC to cool. The thermal sensor will turn the pass transistor on again after the IC's junction temperature cools by 10°C, resulting in a pulsed output during continuous thermal-overload conditions. Thermal-overloaded protection is designed to protect the RT9168/A in the event of fault conditions. Do not exceed the absolute maximum junction-temperature rating of $T_J$ = +150°C for continuous operation. The output can be shorted to ground for an

indefinite amount of time without damaging the part by cooperation of current limit and thermal protection.

**Operating Region and Power Dissipation**

The maximum power dissipation of RT9168/A depends on the thermal resistance of the case and circuit board, the temperature difference between the die junction and ambient air, and the rate of airflow. The power dissipation across the device is $P = I_{OUT} (V_{IN} - V_{OUT})$. The maximum power dissipation is: $PMAX = (T_J - T_A) /\theta_{JA}$

where $T_J - T_A$ is the temperature difference between the RT9168/A die junction and the surrounding environment, $\theta_{JA}$ is the thermal resistance from the junction to the surrounding environment. The GND pin of the RT9168/A performs the dual function of providing an electrical connection to ground and channeling heat away. Connect the GND pin to ground using a large pad or ground plane.

## Package Information
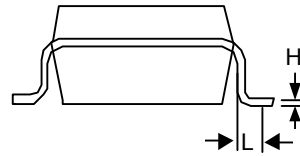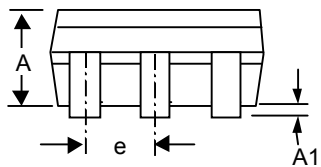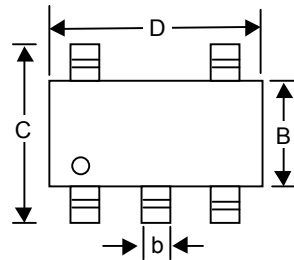


| Symbol | Dimensions In Millimeters | | Dimensions In Inches | |
|---|---|---|---|---|
| | **Min** | **Max** | **Min** | **Max** |
| A | 0.889 | 1.295 | 0.035 | 0.051 |
| A1 | 0.000 | 0.152 | 0.000 | 0.006 |
| B | 1.397 | 1.803 | 0.055 | 0.071 |
| b | 0.356 | 0.559 | 0.014 | 0.022 |
| C | 2.591 | 2.997 | 0.102 | 0.118 |
| D | 2.692 | 3.099 | 0.106 | 0.122 |
| e | 0.838 | 1.041 | 0.033 | 0.041 |
| H | 0.102 | 0.254 | 0.004 | 0.010 |
| L | 0.356 | 0.610 | 0.014 | 0.024 |

**SOT- 25 Surface Mount Package**
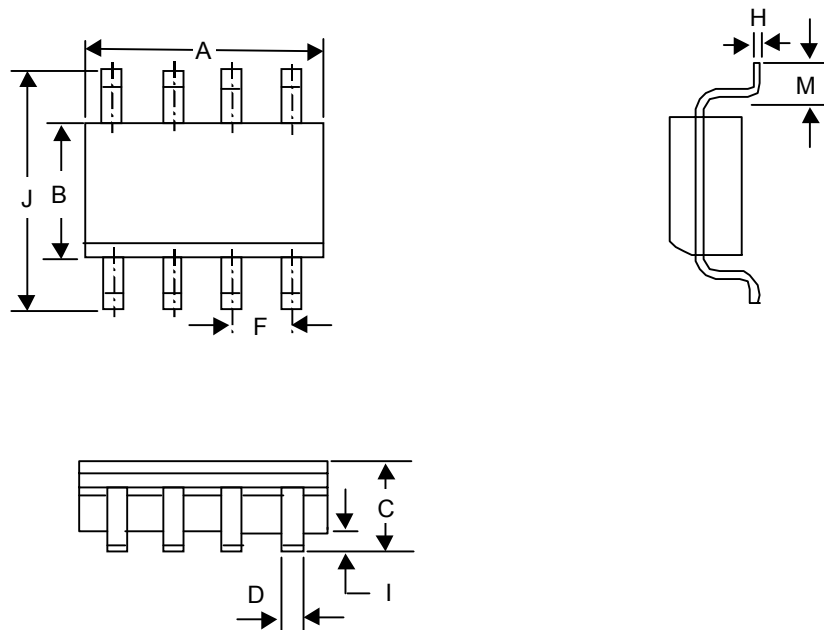
| Symbol | Dimensions In Millimeters | | Dimensions In Inches | |
|---|---|---|---|---|
| | **Min** | **Max** | **Min** | **Max** |
| A | 4.801 | 5.004 | 0.189 | 0.197 |
| B | 3.810 | 3.988 | 0.150 | 0.157 |
| C | 1.346 | 1.753 | 0.053 | 0.069 |
| D | 0.330 | 0.508 | 0.013 | 0.020 |
| F | 1.194 | 1.346 | 0.047 | 0.053 |
| H | 0.178 | 0.254 | 0.007 | 0.010 |
| I | 0.102 | 0.254 | 0.004 | 0.010 |
| J | 5.791 | 6.198 | 0.228 | 0.244 |
| M | 0.406 | 1.270 | 0.016 | 0.050 |

**8–Lead SOP Plastic Package**

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