

# 200mA/500mA Fixed Output Voltage LDO Regulator

## General Description

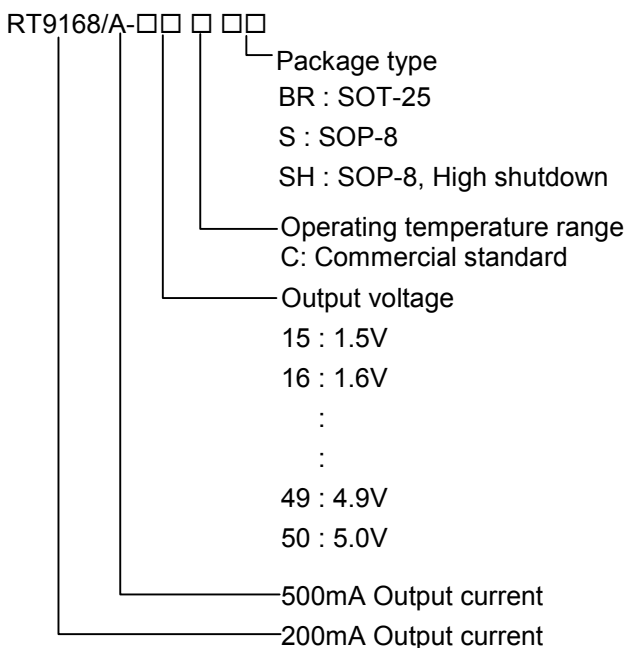
The RT9168/A is a 200mA/500mA low dropout and micropower regulator suitable for portable applications. The output voltages range from 1.5V to 5.0V in 100mV increments and 2% accuracy. The RT9168/A is designed for use with very low ESR capacitors. The output remains stable even with a 1 $\mu$ F ceramic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

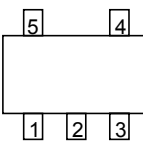
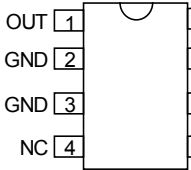
## Ordering Information



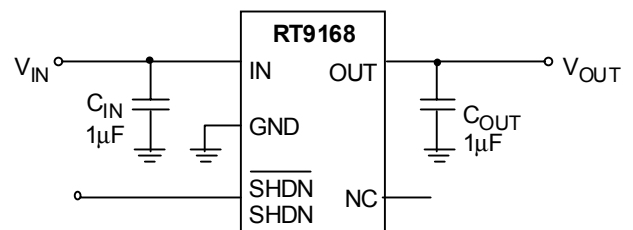
## Features

- Stable with Low-ESR Output Capacitor
- Low Dropout Voltage (220mV at 200mA)
- Low Operation Current - 80 $\mu$ A 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)	<p>TOP VIEW</p>  <p>1. OUT 2. GND 3. IN 4. SHDN 5. NC</p>
RT9168/A-□□CS RT9168/A-□□CSH (Plastic SOP-8)	<p>TOP VIEW</p>  <p>OUT 1, 8 IN GND 2, 7 GND GND 3, 6 GND NC 4, 5 SHDN/SHDN</p>

## Typical Application Circuit



## Marking Information

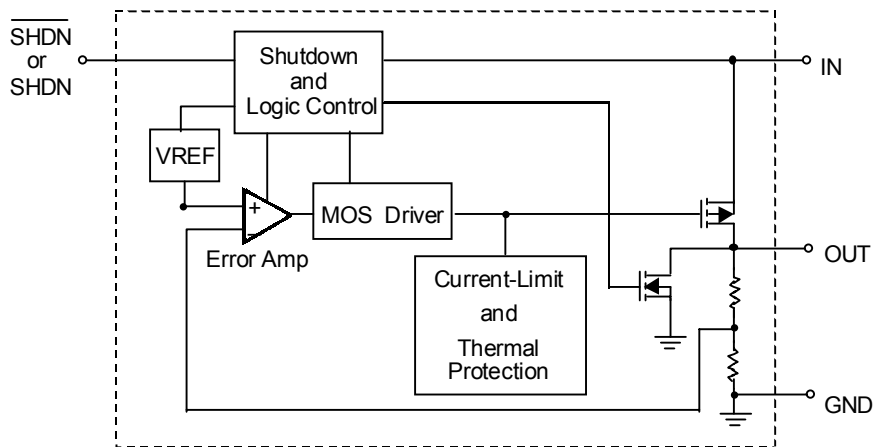
Part Number	Marking
RT9168-15CBR	L0
RT9168-16CBR	L1
RT9168-17CBR	L2
RT9168-18CBR	L3
RT9168-19CBR	L4
RT9168-20CBR	L5
RT9168-21CBR	L6
RT9168-22CBR	L7
RT9168-23CBR	L8
RT9168-24CBR	L9
RT9168-25CBR	LA
RT9168-26CBR	LB
RT9168-27CBR	LC
RT9168-28CBR	LD
RT9168-29CBR	LE
RT9168-30CBR	LF
RT9168-31CBR	LG
RT9168-32CBR	LH
RT9168-33CBR	LJ
RT9168-34CBR	LK
RT9168-35CBR	LL
RT9168-36CBR	LM
RT9168-37CBR	LN
RT9168-38CBR	LP
RT9168-39CBR	LQ
RT9168-40CBR	LR
RT9168-41CBR	LS
RT9168-42CBR	LT
RT9168-43CBR	LU
RT9168-44CBR	LV
RT9168-45CBR	LW
RT9168-46CBR	LX
RT9168-47CBR	LY
RT9168-48CBR	LZ
RT9168-49CBR	CL
RT9168-50CBR	CM

Part Number	Marking
RT9168A-15CBR	M0
RT9168A-16CBR	M1
RT9168A-17CBR	M2
RT9168A-18CBR	M3
RT9168A-19CBR	M4
RT9168A-20CBR	M5
RT9168A-21CBR	M6
RT9168A-22CBR	M7
RT9168A-23CBR	M8
RT9168A-24CBR	M9
RT9168A-25CBR	MA
RT9168A-26CBR	MB
RT9168A-27CBR	MC
RT9168A-28CBR	MD
RT9168A-29CBR	ME
RT9168A-30CBR	MF
RT9168A-31CBR	MG
RT9168A-32CBR	MH
RT9168A-33CBR	MJ
RT9168A-34CBR	MK
RT9168A-35CBR	ML
RT9168A-36CBR	MM
RT9168A-37CBR	MN
RT9168A-38CBR	MP
RT9168A-39CBR	MQ
RT9168A-40CBR	MR
RT9168A-41CBR	MS
RT9168A-42CBR	MT
RT9168A-43CBR	MU
RT9168A-44CBR	MV
RT9168A-45CBR	MW
RT9168A-46CBR	MX
RT9168A-47CBR	MY
RT9168A-48CBR	MZ
RT9168A-49CBR	CN
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,  $P_D$  @  $T_A = 25^\circ\text{C}$ 
  - SOT-25 ..... 0.25W
  - SOP-8 ..... 0.625W
- Operating Junction Temperature Range .....  $-40^\circ\text{C}$  to  $125^\circ\text{C}$
- Storage Temperature Range .....  $-65^\circ\text{C}$  to  $150^\circ\text{C}$
- Package Thermal Resistance
  - SOT-25,  $\theta_{JA}$  .....  $250^\circ\text{C/W}$
  - SOP-8,  $\theta_{JA}$  .....  $160^\circ\text{C/W}$
- Lead Temperature (Soldering, 5 sec.) .....  $260^\circ\text{C}$

## Electrical Characteristics

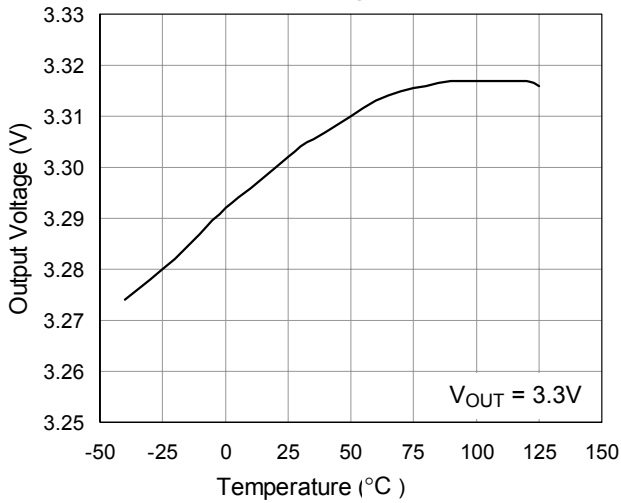
( $V_{IN} = 5.0\text{V}$ ,  $C_{IN} = 1\mu\text{F}$ ,  $C_{OUT} = 1\mu\text{F}$ ,  $T_A = 25^\circ\text{C}$ , unless otherwise specified)

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

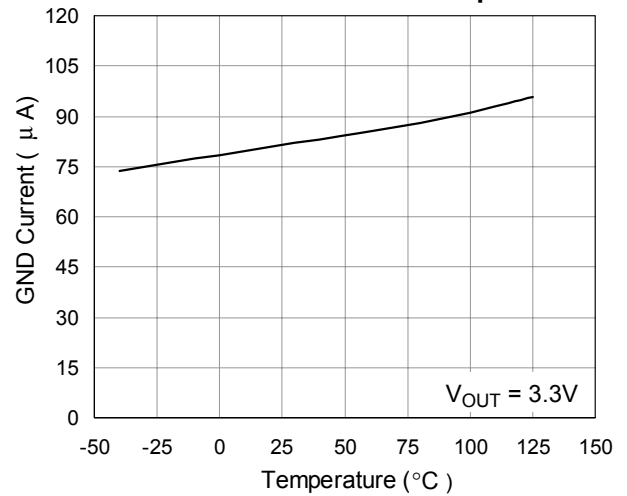
Notes: Dropout voltage definition:  $V_{IN} - V_{OUT}$  when  $V_{OUT}$  is 50 mV below the value of  $V_{OUT}$  at  $V_{IN} = V_{OUT} + 0.5\text{V}$

**Typical Operating Characteristics**

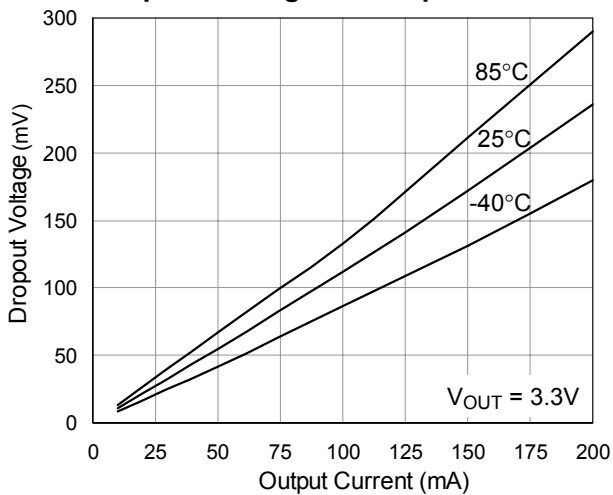
**Output Voltage vs. Temp.**



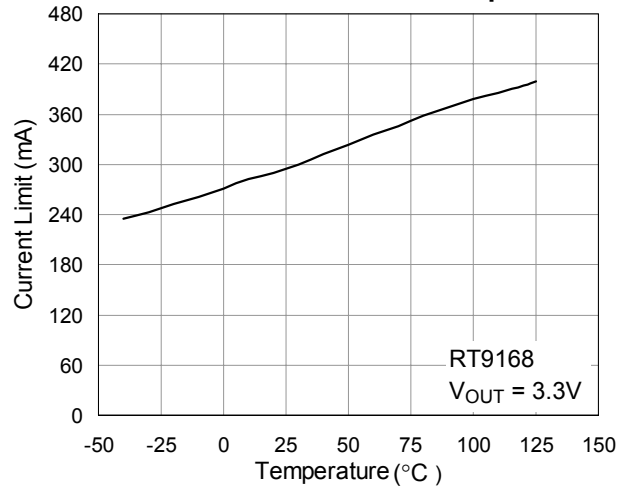
**GND Current vs. Temp.**



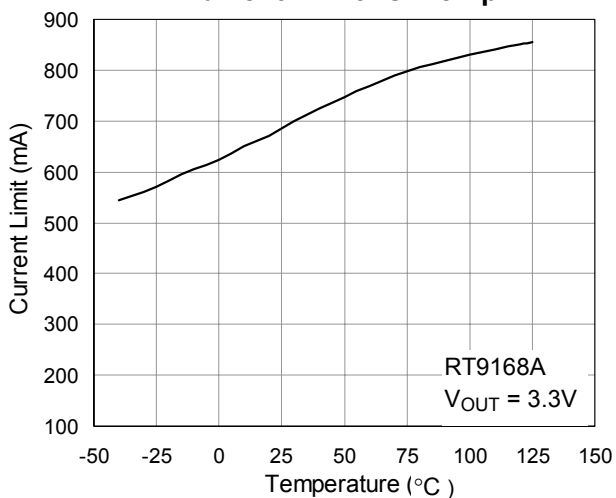
**Dropout Voltage vs. Output Current**



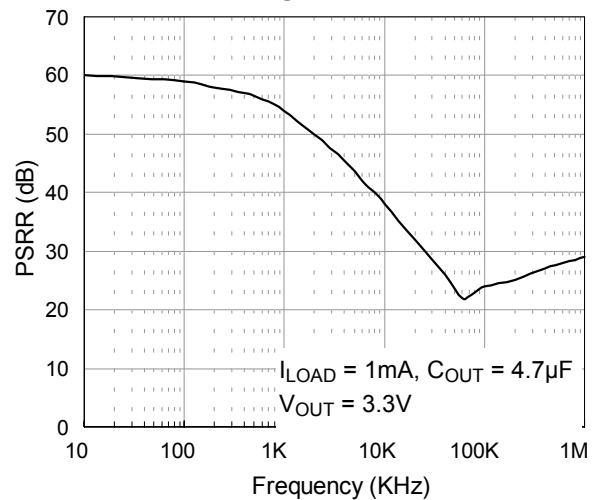
**Current Limit vs. Temp.**



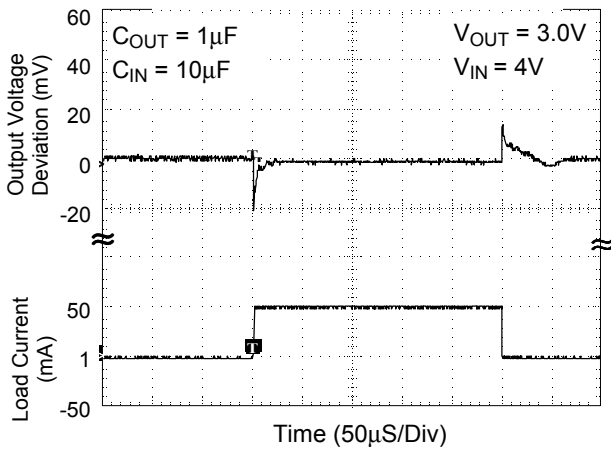
**Current Limit vs. Temp.**



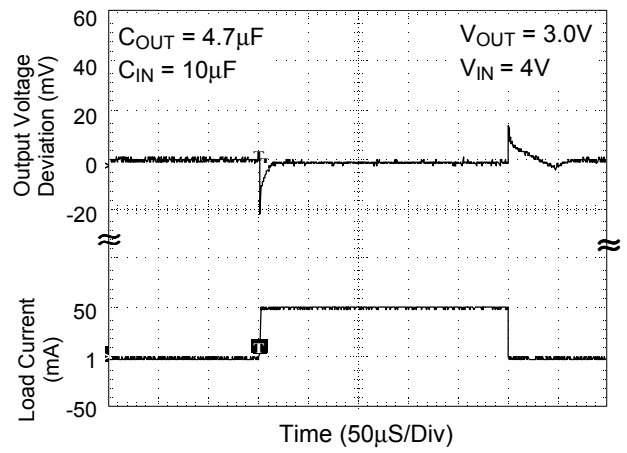
**PSRR**



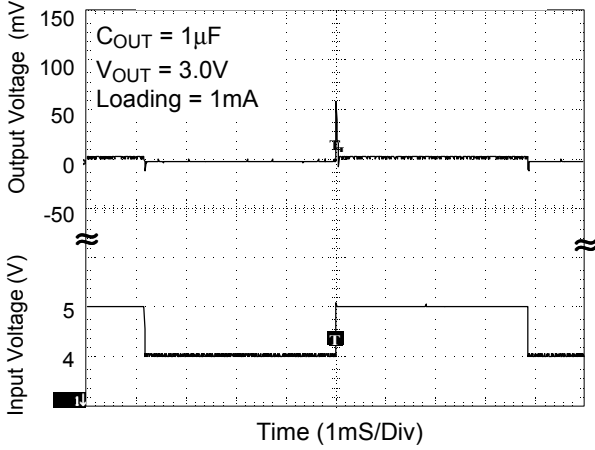
Load Transient Response



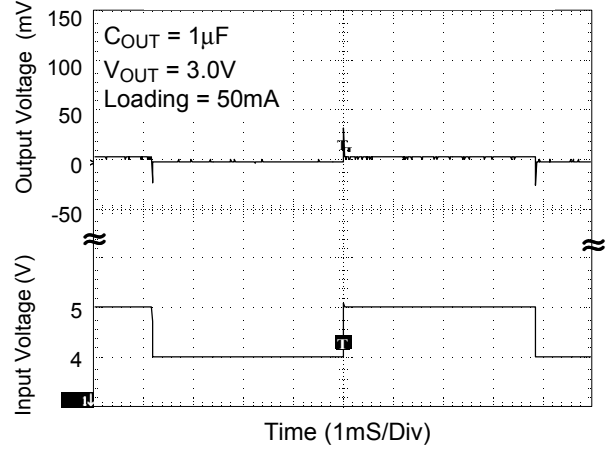
Load Transient Response



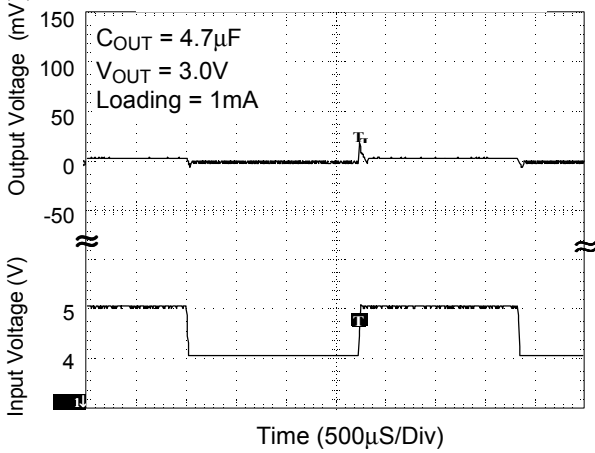
Line Transient Response



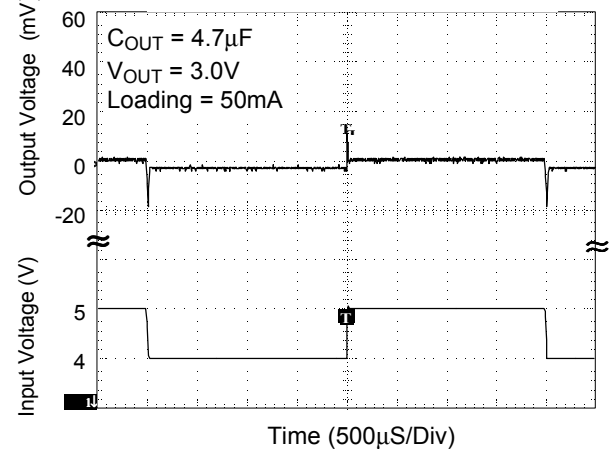
Line Transient Response



Line Transient Response



Line Transient Response



**Applications Guides**

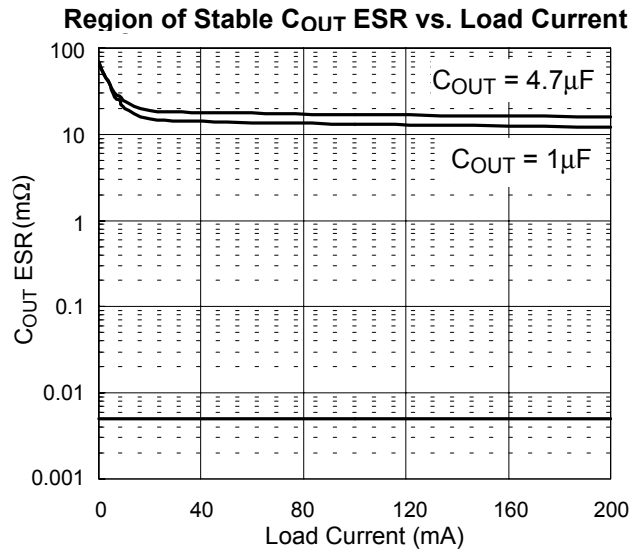
**Capacitor Selection and Regulator Stability**

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  $> 1\mu\text{F}$  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  $1\mu\text{F}$  with ESR is  $> 5\text{m}\Omega$  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  $V_{\text{OUT}}$  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  $2.2\mu\text{F}$  or more to ensure stability at temperatures below  $-10^\circ\text{C}$  in this case. Also, tantalum capacitors,  $2.2\mu\text{F}$  or more may be needed to maintain capacitance and ESR in the stable region for strict application environment.



**Fig. 1**

Tantalum capacitors may 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  $V_{\text{IN}}$  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  $1.1\Omega$  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  $80\mu\text{A}$  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  $0.3\text{V}$ .  $< 100\text{ mA}$  to prevent damage to the part.

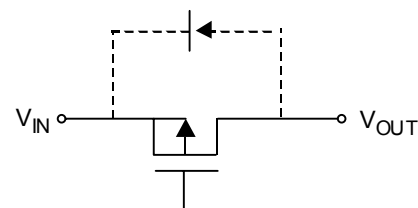


Fig. 2

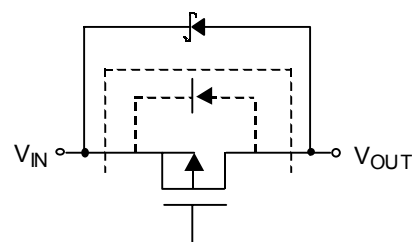


Fig. 3

### 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  $300\text{mA Typ.}$  ( $700\text{mA Typ.}$  for RT9168A). Thermal-overload protection limits total power dissipation in the RT9168/A. When the junction temperature exceeds  $T_J = +155^\circ\text{C}$ , 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  $10^\circ\text{C}$ , 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  $T_J = +150^\circ\text{C}$  for continuous operation. The output can be shorted to ground for an



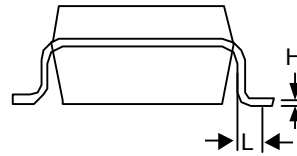
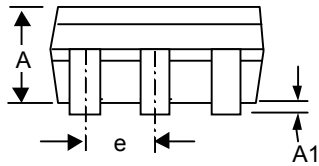
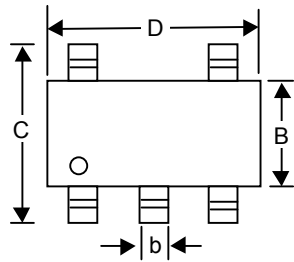
indefinite amount of time without damaging the part by cooperation of current limit and thermal protection.

#### **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:  $P_{MAX} = (T_J - T_A) / \theta_{JA}$

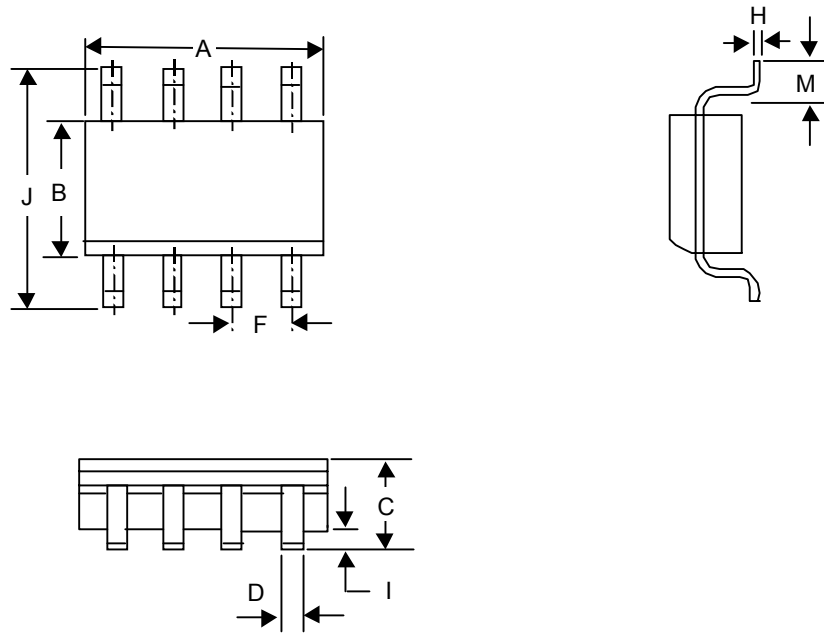
where  $T_J - T_A$  is the temperature difference between the RT9168/A die junction and the surrounding environment,  $\theta_{JA}$  is the thermal resistance from the junction to the surrounding environment. The GND pin of the RT9168/A performs the dual function of providing an electrical connection 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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