

# Ultra-Low-Noise 200mA LDO Regulator

## General Description

The RT9177 is a 200mA low dropout and low noise micro-power regulator suitable for portable RF applications. The output voltage accuracy is within  $\pm 2\%$  and range from 2.4V to 3.2V in 100mV increments could be selected. It is designed for using very low ESR output capacitor. Its output remains stable even when using a  $1\mu\text{F}$  ceramic as its output capacitor.

With an internal PMOS as the pass device, it does not need extra GND current in heavy load and dropout conditions. In shutdown mode, nearly zero operation current makes the IC suitable for battery-powered devices. Other features including current limiting and over temperature protection. The noise performance can be improved by connecting a capacitor to the bypass pin.

## Ordering Information

RT9177-□□□□	
□□□□	Package type B : SOT-25 Type I BR : SOT-25 Type II
□□	Operating temperature range C : Commercial standard
□□	Output voltage 24 : 2.4V 25 : 2.5V : : 31 : 3.1V 32 : 3.2V

## Features

- Ultra-Low-Noise ( $150\text{nV}/\sqrt{\text{Hz}}$ ) for RF Application
- $1\mu\text{F}$  Ceramic  $C_{\text{OUT}}$  Stable
- Low Dropout Voltage ( $220\text{mV}$  @  $200\text{mA}$ )
- Low Operation Current -  $80\mu\text{A}$  Typical
- Shutdown Function
- Low Temperature Coefficient
- Current and Thermal Limiting
- Customized Voltage Available
- SOT-25 Package

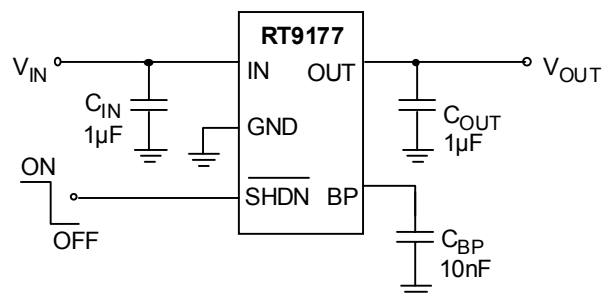
## Applications

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

## Pin Configurations

Part Number	Pin Configurations
RT9177-□□CB (Plastic SOT-25)	<p>TOP VIEW</p> <p>1. IN 2. <u>GND</u> 3. SHDN 4. BP 5. OUT</p>
RT9177-□□CBR (Plastic SOT-25)	<p>TOP VIEW</p> <p>1. OUT 2. GND 3. <u>IN</u> 4. SHDN 5. BP</p>

## Typical Application Circuit



**Marking Information**

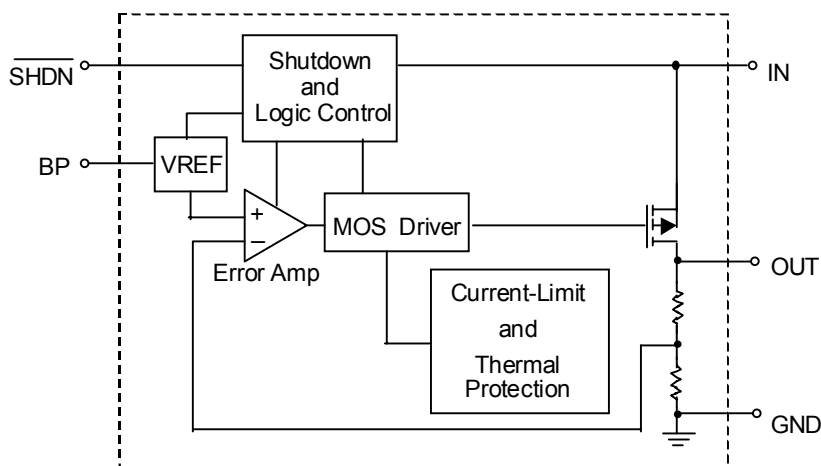
Part Number	Marking
RT9177-24CB	H9
RT9177-25CB	HA
RT9177-26CB	HB
RT9177-27CB	HC
RT9177-28CB	HD
RT9177-29CB	HE
RT9177-30CB	HF
RT9177-31CB	HG
RT9177-32CB	HH

Part Number	Marking
RT9177-24CBR	P9
RT9177-25CBR	PA
RT9177-26CBR	PB
RT9177-27CBR	PC
RT9177-28CBR	PD
RT9177-29CBR	PE
RT9177-30CBR	PF
RT9177-31CBR	PG
RT9177-32CBR	PH

**Pin Description**

Pin Name	Pin Function
IN	Input
GND	Ground
$\overline{\text{SHDN}}$	Active Low Shutdown Input
BP	Reference Noise Bypass
OUT	Output

**Function Block Diagram**



**Absolute Maximum Ratings**

- Input Voltage ----- 7V
- Power Dissipation,  $P_D$  @  $T_A = 25^\circ\text{C}$   
   SOT-25 ----- 0.25W
- 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,  $\theta_{JA}$  -----  $250^\circ\text{C/W}$
- Lead Temperature (Soldering, 5 sec.) -----  $260^\circ\text{C}$

**Electrical Characteristics**

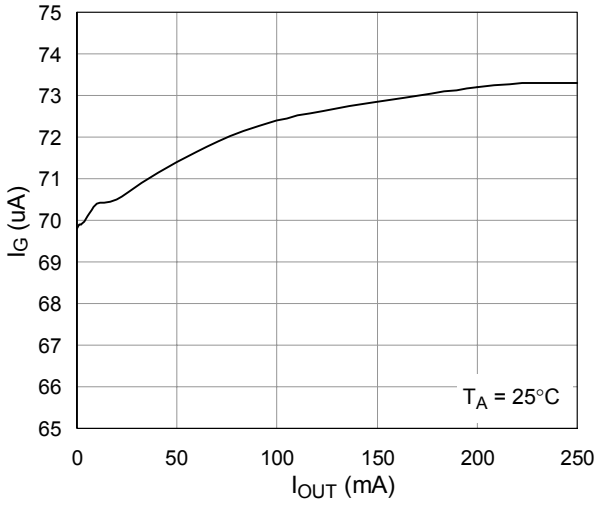
( $V_{IN} = 5.0\text{V}$ ,  $C_{IN} = 1\mu\text{F}$ ,  $C_{OUT} = 1\mu\text{F}$ ,  $T_A = 25^\circ\text{C}$ , unless otherwise specified)

Parameter	Symbol	Test Conditions	Min	Typ	Max	Units
Input Voltage Range	$V_{IN}$		2.5	--	6	V
Output Voltage Accuracy	$\Delta V_{OUT}$	$I_L = 1\text{mA}$	-2	--	+2	%
Maximum Output Current	$I_{MAX}$		200	--	--	mA
Current Limit	$I_{LIMIT}$	$R_{LOAD} = 1\Omega$	--	300	--	mA
GND Pin Current	$I_G$	No Load	--	80	150	$\mu\text{A}$
		$I_{OUT} = 200\text{mA}$	--	90	150	
Dropout Voltage <sup>(Note)</sup> ( $V_{OUT}(\text{Nominal}) \geq 3.0\text{V}$ Version)	$V_{DROP}$	$I_{OUT} = 1\text{mA}$	--	1.1	5	mV
		$I_{OUT} = 50\text{mA}$	--	55	100	
		$I_{OUT} = 200\text{mA}$	--	220	300	
Line Regulation	$\Delta V_{LINE}$	$V_{IN} = (V_{OUT} + 0.15)$ to $6\text{V}$ , $I_{OUT} = 1\text{mA}$	-0.2	--	+0.2	%/V
Load Regulation	$\Delta V_{LOAD}$	$I_{OUT} = 0\text{mA}$ to $200\text{mA}$	--	0.01	0.04	%/mA
$\overline{\text{SHDN}}$ Input High Threshold	$V_{IH}$	$V_{IN} = 3\text{V}$ to $5.5\text{V}$	1.0	--	--	V
$\overline{\text{SHDN}}$ Input Low Threshold	$V_{IL}$	$V_{IN} = 3\text{V}$ to $5.5\text{V}$	--	--	0.4	V
$\overline{\text{SHDN}}$ 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	$T_{SD}$		--	150	--	$^\circ\text{C}$
Output Noise	$e_{NO}$	$C_{BP} = 10\text{nF}$ , $C_{OUT} = 10\mu\text{F}$	--	150	--	$\text{nV}/\sqrt{\text{Hz}}$
Ripple Rejection	PSRR	$F = 100\text{Hz}$ , $C_{BP} = 10\text{nF}$ , $C_{OUT} = 10\mu\text{F}$	--	68	--	dB

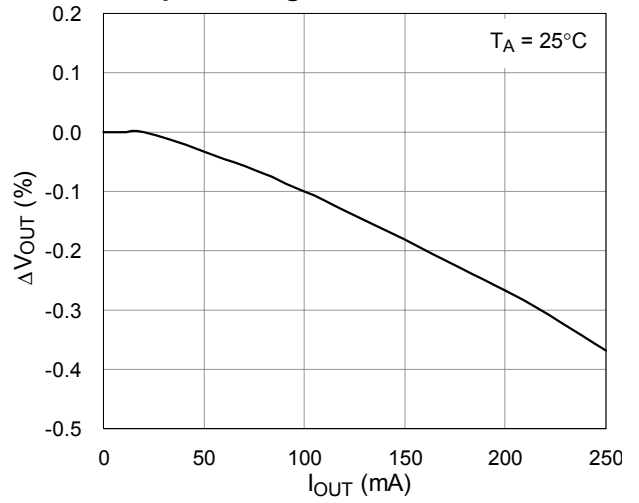
Notes: Dropout voltage definition:  $V_{IN} - V_{OUT}$  when  $V_{OUT}$  is 50 mV below the value of  $V_{OUT}$  at  $V_{IN} = V_{OUT} + 0.5\text{V}$

**Typical Operating Characteristics**

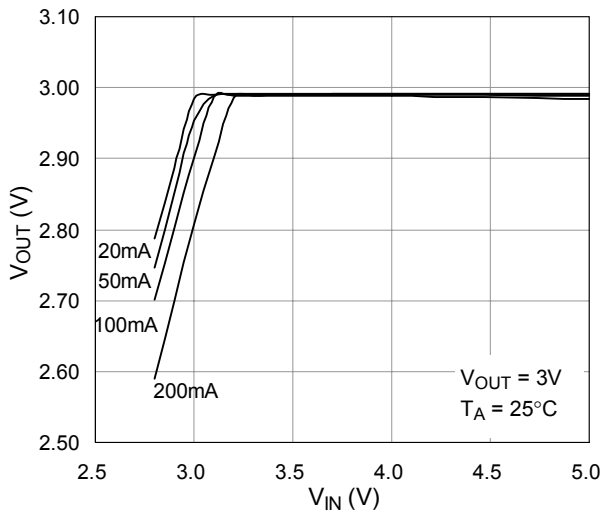
**GND Current vs. Load**



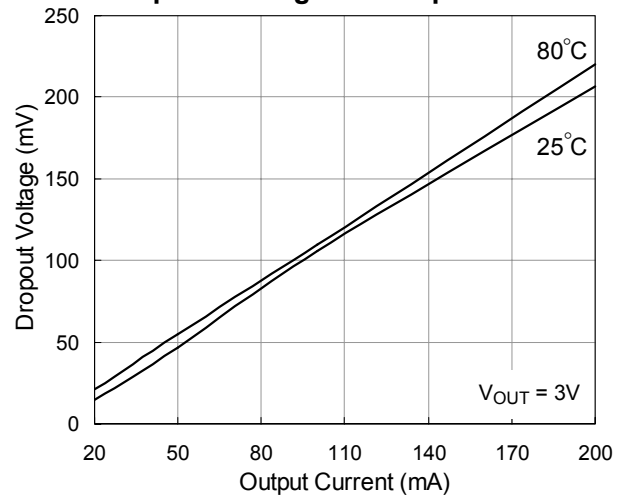
**Output Voltage Variation vs. Load**



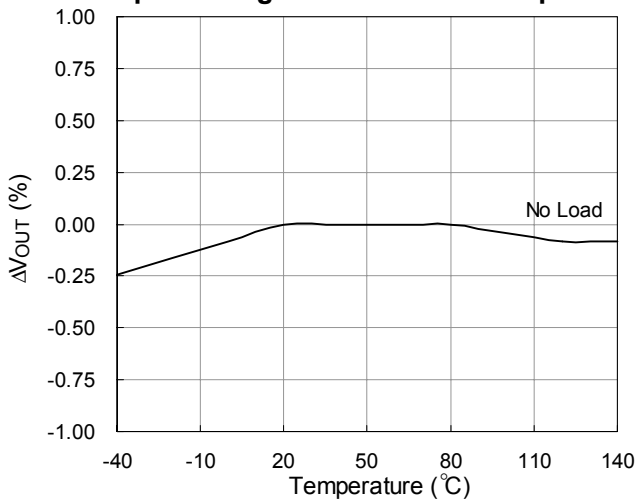
**$V_{OUT}$  vs.  $V_{IN}$**



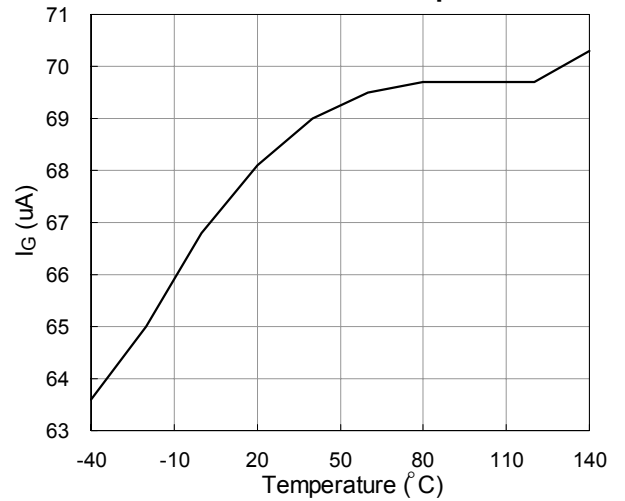
**Dropout Voltage vs. Output Current**

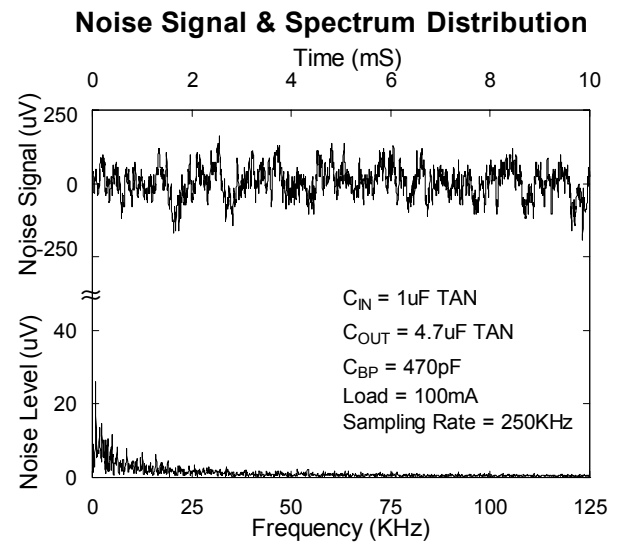
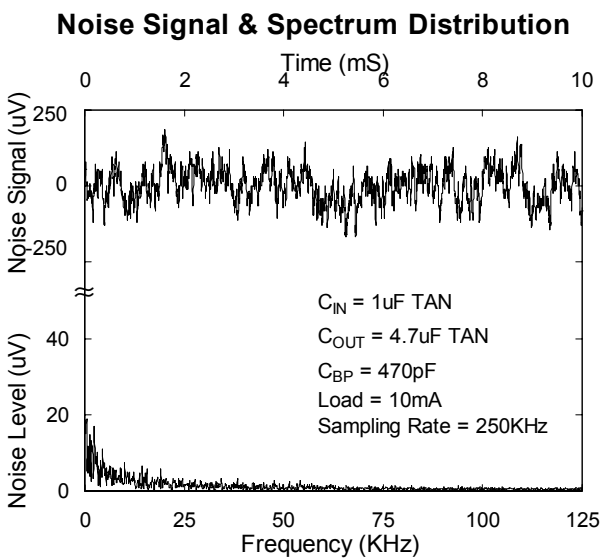
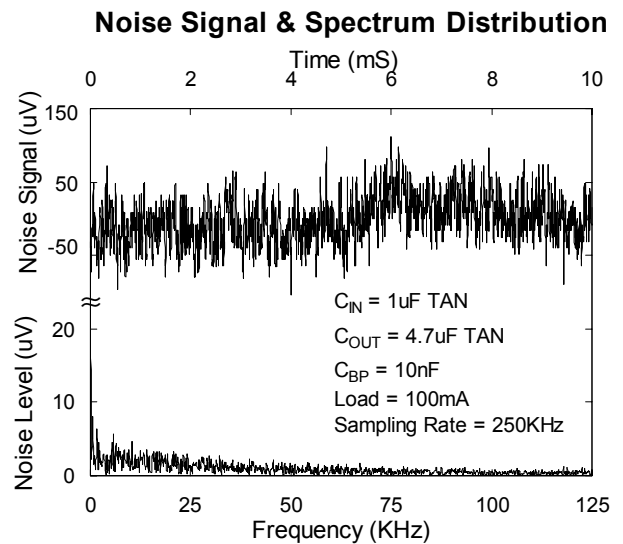
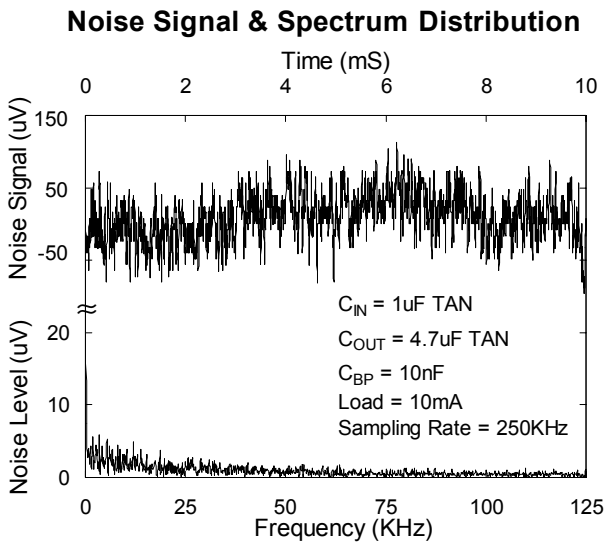
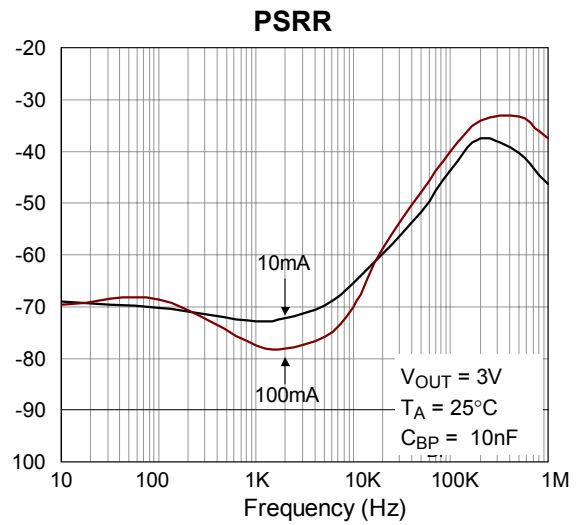
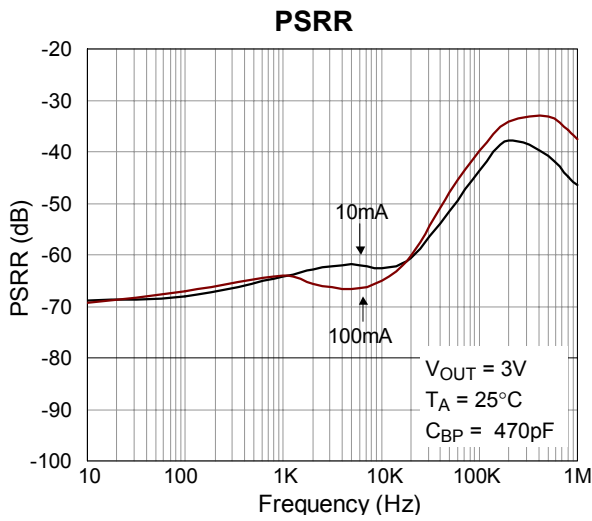


**Output Voltage Variation vs. Temperature**

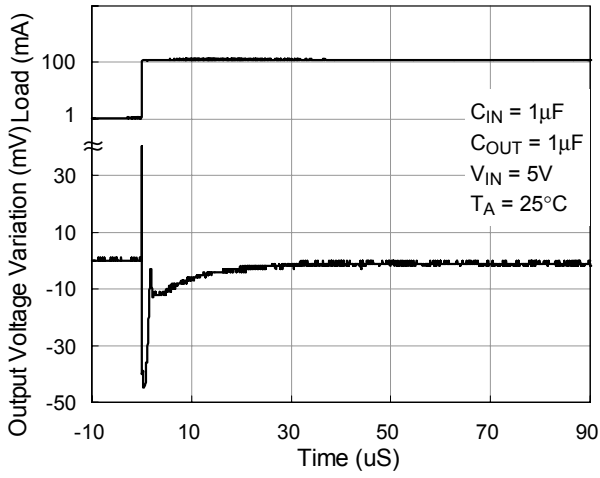


**GND Current vs. Temperature**

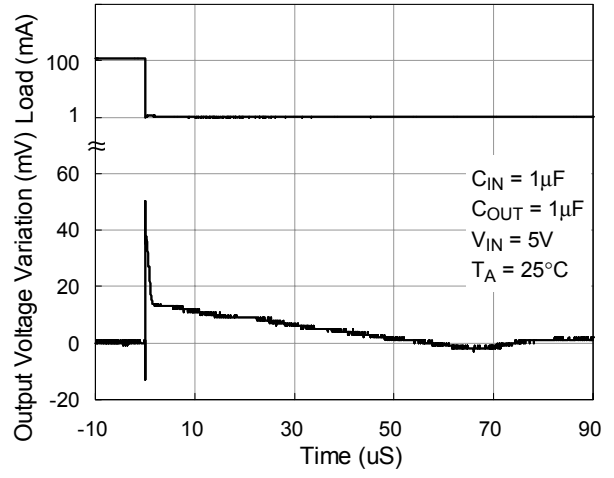




Load Transient Response  
from 1mA to 100mA



Load Transient Response  
from 100mA to 1mA



**Application Guides**

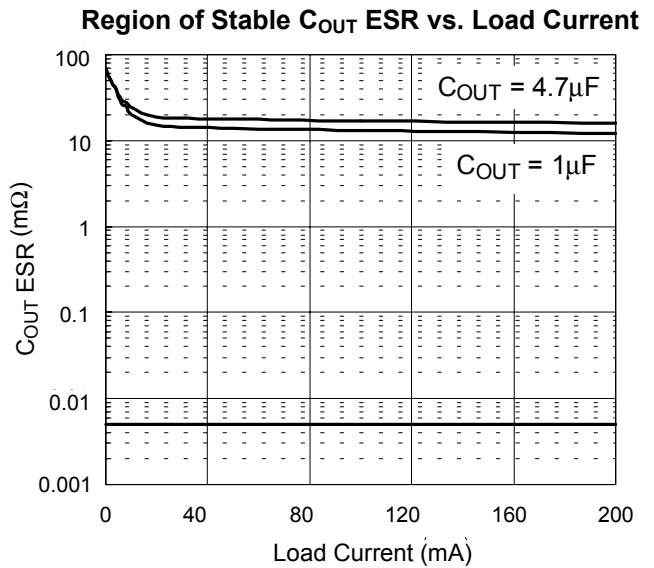
**Capacitor Selection and Regulator Stability**

Like any low-dropout regulator, the external capacitors used with the RT9177 must be carefully selected for regulator stability and performance.

Using a capacitor whose value is  $\geq 1\mu\text{F}$  on the RT9177 input and the amount of capacitance can be increased without limit. The input capacitor must be located at a distance of no 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 RT9177 is designed specifically for working with low ESR ceramic output capacitor in space-saving and performance considerations. Using a ceramic capacitor whose value is at least  $1\mu\text{F}$  with ESR is  $> 5\text{m}\Omega$  on the RT9177 output ensures stability. The RT9177 works well even with a 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. An 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 RT9177 and return 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 maybe suffer failure due to surge currents 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.

Use a  $10\text{nF}$  bypass capacitor at BP for low output voltage noise. The capacitor, in conjunction with an internal  $200\text{K}\Omega$  resistor, which connects bypass pin and the band-gap reference, creates an  $80\text{Hz}$  low-pass filter for noise reduction. Increasing the capacitance will slightly decrease the output noise, but increase the start-up time. The capacitor connected to the bypass pin for noise reduction must have very low leakage. This capacitor leakage current causes the output voltage to decline by a proportional amount to the current due to the voltage drop on the internal  $200\text{K}\Omega$  resistor. Fig. 2 shows the power on response.

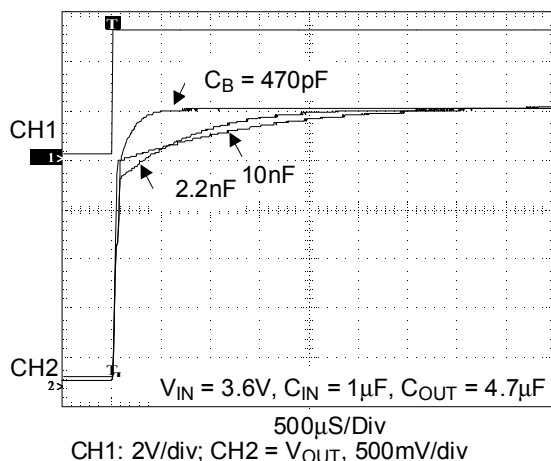


Fig. 2

### Load-Transient Considerations

The RT9177 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 1mA to 100mA 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 RT9177 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  $V_{IN}$  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 RT9177 input voltage or another logic supply. The high-level voltage may exceed the RT9177 input voltage, but must remain within the absolute maximum ratings for the SHDN pin.

### Internal P-Channel Pass Transistor

The RT9177 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 RT9177 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 RT9177 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 RT9177 has an inherent diode connected between the regulator input and output (see Fig.3). 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.4). 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 and  $< 100\text{mA}$  to prevent mis-operation to damage the part.



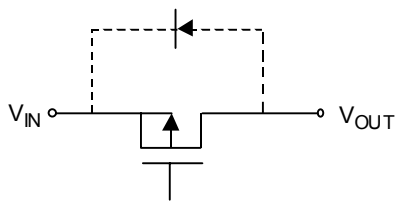


Fig.3

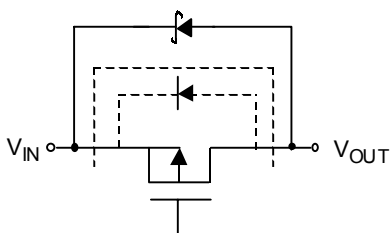


Fig.4

**Current Limit and Thermal Protection**

The RT9177 is included a current limit circuit used to monitor and control the pass transistor's gate voltage to limit the output current to 300mA in typical and thermal-overload protection circuit used to limit total power dissipation. When the junction temperature exceeds  $T_J = 150^{\circ}\text{C}$ , the thermal sensor signals the shutdown logic to turn off the pass transistor and allow the IC to cool down. The thermal sensor will turn on the pass transistor again after the IC's junction temperature cool down to  $120^{\circ}\text{C}$ . This will cause a pulsing output during continuous thermal-overload conditions. Thermal-overloaded protection is designed to protect the RT9177 in the event of fault conditions. Do not exceed the absolute maximum junction-temperature rating of  $T_J = 125^{\circ}\text{C}$  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.

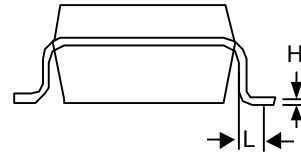
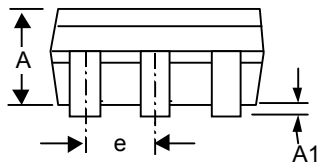
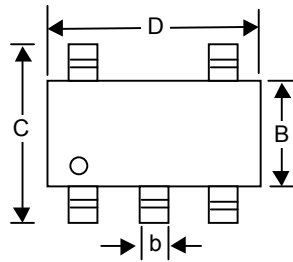
**Operating Region and Power Dissipation**

The maximum power dissipation of RT9177 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 RT9177 die junction and the surrounding environment,  $\theta_{JA}$  is the thermal resistance from the junction to the surrounding environment. The GND pin of the RT9177 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



Symbols	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



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