

# 1A Fixed and Adjustable Low Dropout Positive Voltage Regulators

## General Description

The RT9164A series of high performance positive voltage regulators is designed for applications requiring low dropout performance at fully rated current. Additionally, the RT9164A series provides excellent regulation over variations in line and load. Outstanding features include low dropout performance at rated current, fast transient response, internal current-limiting, and thermal-shutdown protection of the output device. The RT9164A series of three terminal regulators offers fixed and adjustable voltage options available in space-saving SOT-223, TO-252, and TO-263 packages.

## Ordering Information

RT9164A-□□□□	
	Package Type
	G : SOT-223
	L: TO-252
	LR : TO-252 (R-Type)
	M : TO-263
	Lead Plating System
	P : Pb Free
	G : Green (Halogen Free and Pb Free)
	Output Voltage
	Default : Adjustable
	15 : 1.5V
	18 : 1.8V
	25 : 2.5V
	28 : 2.85V
	30 : 3.0V
	33 : 3.3V
	35 : 3.5V

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.

## Features

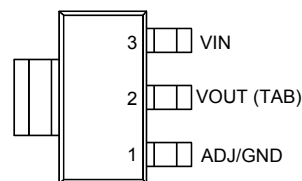
- Low Dropout Performance, 1.4V Max
- Full Current Rating Over Line and Temperature
- Fast Transient Response
- $\pm 2\%$  Output Voltage Accuracy
- 1.5V, 1.8V, 2.5V, 2.85V, 3.0V, 3.3V, and 3.5V Fixed Adjustable Output Voltage
- SOT-223, TO-252, and TO-263 Packages
- RoHS Compliant and 100% Lead (Pb)-Free

## Applications

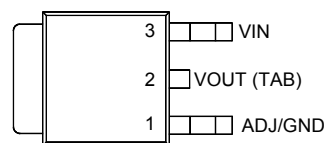
- Active SCSI Termination
- Low Voltage Microcontrollers
- Switching Power Supply Post-Regulator

## Pin ConFIGurations

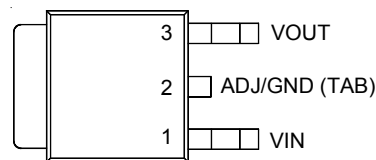
(TOP VIEW)



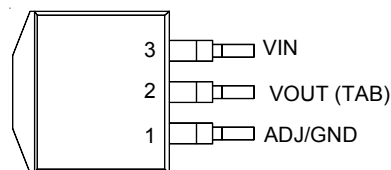
SOT-223



TO-252

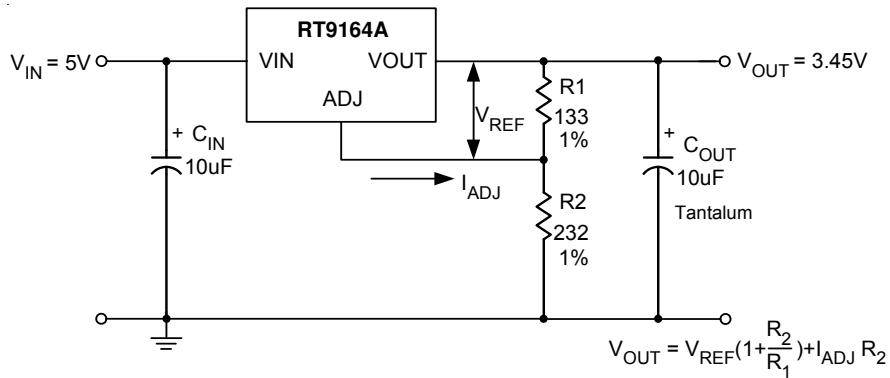


TO-252 (R-Type)



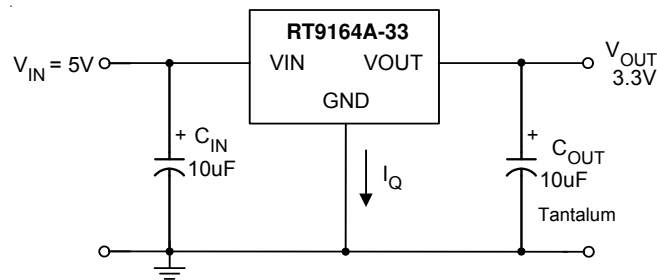
TO-263

## Typical Application Circuit



- (1)  $C_{IN}$  needed if device is far from filter capacitors.
- (2)  $C_{OUT}$  required for stability.

Figure 1. Adjustable Voltage Regulator



- (1)  $C_{IN}$  needed if device is far from filter capacitors.
- (2)  $C_{OUT}$  required for stability.

Figure 2. Fixed Voltage Regulator

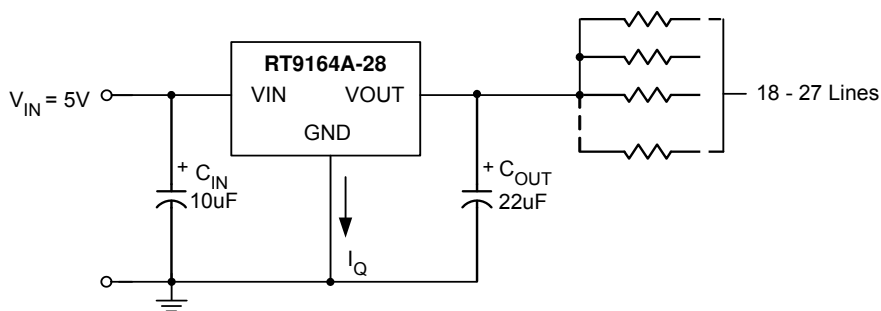
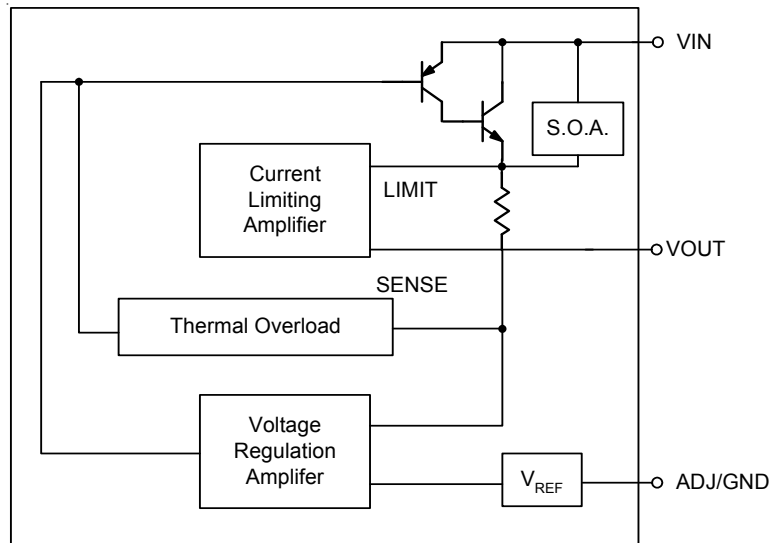


Figure 3. Active SCSI Bus Terminator

**Function Block Diagram**



**Functional Pin Description**

Pin Name	Pin Function
ADJ/GND	Adjust Output or Ground.
VOUT	Output Voltage.
VIN	Power Input.

## Absolute Maximum Ratings (Note 1)

- Supply Input Voltage ----- 15V
- Power Dissipation,  $P_D$  @  $T_A = 25^\circ\text{C}$ 
  - SOT-223 ----- 0.740W
  - TO-252 ----- 1.471W
  - TO-263 ----- 2.222W
- Package Thermal Resistance (Note 2)
  - SOT-223,  $\theta_{JA}$  -----  $135^\circ\text{C/W}$
  - SOT-223,  $\theta_{JC}$  -----  $19^\circ\text{C/W}$
  - TO-252,  $\theta_{JA}$  -----  $68^\circ\text{C/W}$
  - TO-252,  $\theta_{JC}$  -----  $7.5^\circ\text{C/W}$
  - TO-263,  $\theta_{JA}$  -----  $45^\circ\text{C/W}$
  - TO-263,  $\theta_{JC}$  -----  $7.8^\circ\text{C/W}$
- Lead Temperature (Soldering, 10 sec.) -----  $260^\circ\text{C}$
- Junction Temperature -----  $150^\circ\text{C}$
- Storage Temperature Range -----  $-65^\circ\text{C}$  to  $150^\circ\text{C}$
- ESD Susceptibility (Note 3)
  - HBM (Human Body Mode) ----- 8kV
  - MM (Machine Mode) ----- 750V

## Recommended Operating Conditions (Note 4)

- Supply Input Voltage ----- 3V to 14V
- Junction Temperature Range -----  $-40^\circ\text{C}$  to  $125^\circ\text{C}$

## Electrical Characteristics

( $T_A = 25^\circ\text{C}$ , unless otherwise specified)

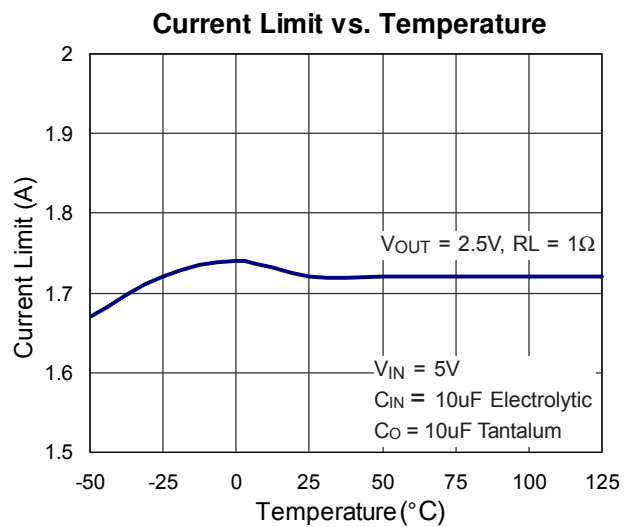
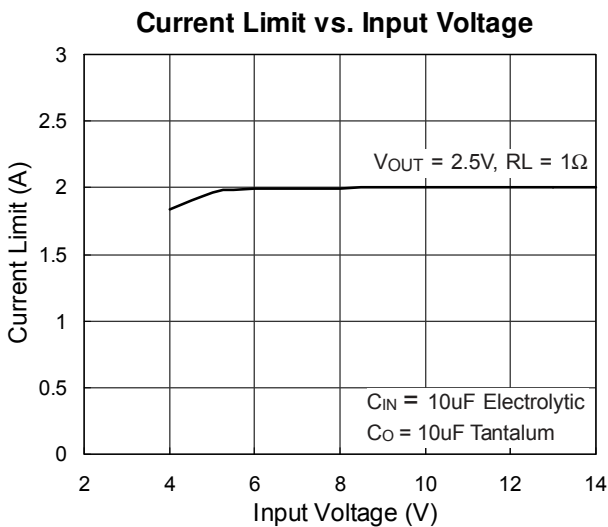
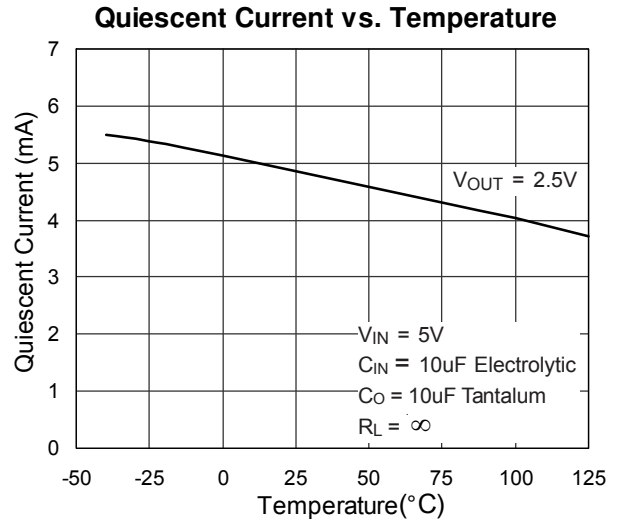
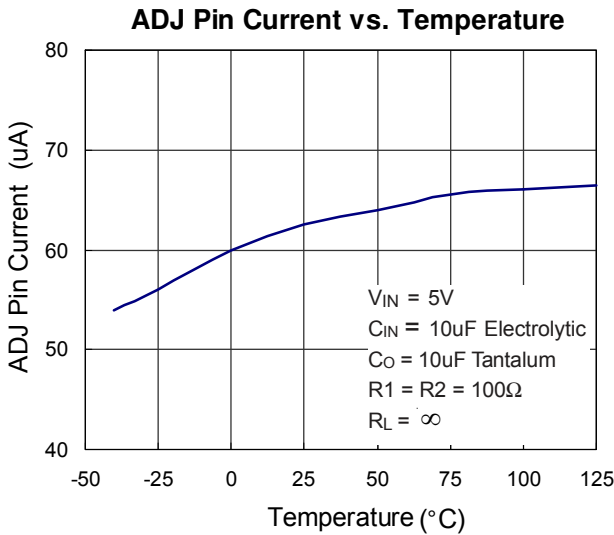
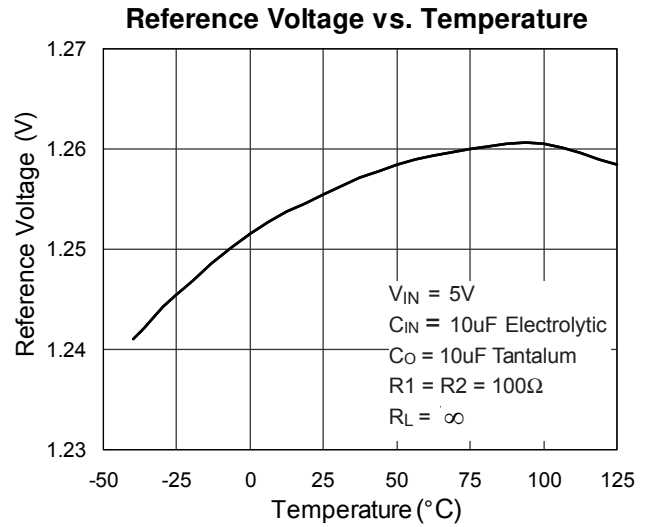
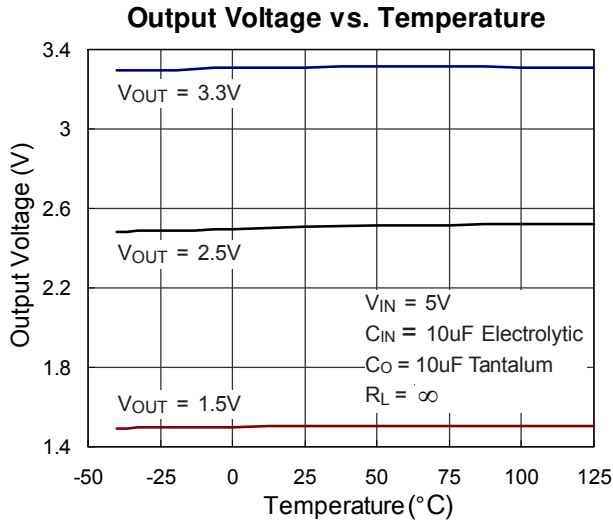
Parameter	Symbol	Test Conditions	Min	Typ	Max	Unit	
Reference Voltage (Note 5)	RT9164A	$V_{REF}$	$I_{OUT} = 10\text{mA}$ , $(V_{IN} - V_{OUT}) = 2\text{V}$ , $T_A = 25^\circ\text{C}$	1.243	1.256	1.281	V
			$10\text{mA} < I_{OUT} < 1.0\text{A}$ , $1.5\text{V} < V_{IN} - V_{OUT} < 10\text{V}$	1.231	1.256	1.294	V
Output Voltage (Note 5)	RT9164A -15	$V_{OUT}$	$I_{OUT} = 10\text{mA}$ , $V_{IN} = 3.3\text{V}$ , $T_J = 25^\circ\text{C}$	1.485	1.5	1.53	V
			$10\text{mA} < I_{OUT} < 1.0\text{A}$ , $3.3\text{V} < V_{IN} < 10\text{V}$	1.470	1.5	1.55	
	RT9164A -18	$V_{OUT}$	$I_{OUT} = 10\text{mA}$ , $V_{IN} = 3.3\text{V}$ , $T_J = 25^\circ\text{C}$	1.797	1.815	1.85	
			$10\text{mA} < I_{OUT} < 1.0\text{A}$ , $3.3\text{V} < V_{IN} < 10\text{V}$	1.779	1.815	1.87	
	RT9164A -25	$V_{OUT}$	$I_{OUT} = 10\text{mA}$ , $V_{IN} = 4.0\text{V}$ , $T_J = 25^\circ\text{C}$	2.475	2.500	2.550	
			$10\text{mA} < I_{OUT} < 1.0\text{A}$ , $4.0\text{V} < V_{IN} < 10\text{V}$	2.450	2.500	2.575	
	RT9164A -28	$V_{OUT}$	$I_{OUT} = 10\text{mA}$ , $V_{IN} = 4.25\text{V}$ , $T_J = 25^\circ\text{C}$	2.822	2.850	2.910	
			$10\text{mA} < I_{OUT} < 1.0\text{A}$ , $4.25\text{V} < V_{IN} < 10\text{V}$	2.793	2.850	2.936	
	RT9164A -30	$V_{OUT}$	$I_{OUT} = 10\text{mA}$ , $V_{IN} = 4.5\text{V}$ , $T_J = 25^\circ\text{C}$	2.970	3.000	3.060	
			$10\text{mA} < I_{OUT} < 1.0\text{A}$ , $4.5\text{V} < V_{IN} < 10\text{V}$	2.940	3.000	3.090	

To be continued

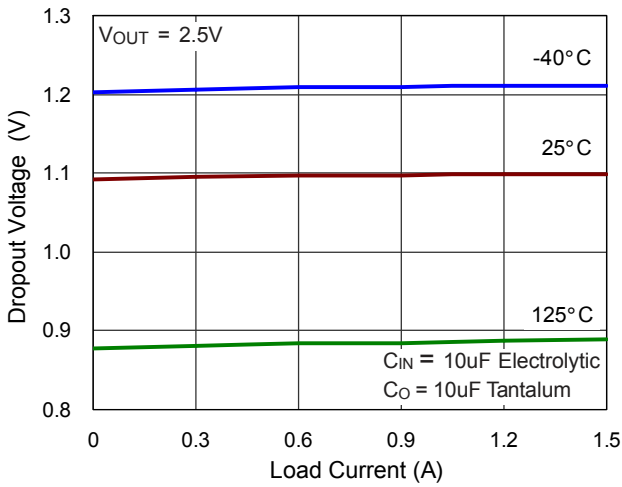
Parameter		Symbol	Test Conditions	Min	Typ	Max	Unit
Output Voltage (Note 5)	RT9164A-33	$V_{OUT}$	$I_{OUT} = 10mA, V_{IN} = 4.75V, T_J = 25^{\circ}C$	3.267	3.300	3.365	V
			$10mA < I_{OUT} < 1.0A, 4.75V < V_{IN} < 10V$	3.234	3.300	3.400	
	RT9164A-35		$I_{OUT} = 10mA, V_{IN} = 5V, T_J = 25^{\circ}C$	3.465	3.500	3.570	
			$10mA < I_{OUT} < 1.0A, 5.0V < V_{IN} < 10V$	3.430	3.500	3.605	
Line Regulation (Note 5)	RT9164A	$\Delta V_{LINE}$	$I_{OUT} = 10mA, 1.5V \leq V_{IN} - V_{OUT} \leq 10V$	--	0.1	0.3	%
	RT9164A-15		$I_{OUT} = 10mA, 3.3V \leq V_{IN} \leq 15V$	--	1	6	mV
	RT9164A-18		$I_{OUT} = 10mA, 3.3V \leq V_{IN} \leq 15V$	--	1	6	
	RT9164A-25		$I_{OUT} = 10mA, 4.0V \leq V_{IN} \leq 15V$	--	1	6	
	RT9164A-28		$I_{OUT} = 10mA, 4.25V \leq V_{IN} \leq 15V$	--	1	6	
	RT9164A-30		$I_{OUT} = 10mA, 4.5V \leq V_{IN} \leq 15V$	--	1	6	
	RT9164A-33		$I_{OUT} = 10mA, 4.75V \leq V_{IN} \leq 15V$	--	1	6	
	RT9164A-35		$I_{OUT} = 10mA, 5.0V \leq V_{IN} \leq 15V$	--	1	6	
Load Regulation (Note 5)	RT9164A	$\Delta V_{LOAD}$	$(V_{IN} - V_{OUT}) = 3V, 10mA \leq I_{OUT} \leq 1.0A$	--	0.2	0.4	%
	RT9164A-15		$V_{IN} = 3.3V, 10mA \leq I_{OUT} \leq 1.0A$	--	1	10	mV
	RT9164A-18		$V_{IN} = 3.3V, 10mA \leq I_{OUT} \leq 1.0A$	--	1	10	
	RT9164A-25		$V_{IN} = 4.0V, 10mA \leq I_{OUT} \leq 1.0A$	--	1	10	
	RT9164A-28		$V_{IN} = 4.25V, 10mA \leq I_{OUT} \leq 1.0A$	--	1	10	
	RT9164A-30		$V_{IN} = 4.5V, 10mA \leq I_{OUT} \leq 1.0A$	--	1	12	
	RT9164A-33		$V_{IN} = 4.75V, 10mA \leq I_{OUT} \leq 1.0A$	--	1	12	
	RT9164A-35		$V_{IN} = 5.0V, 10mA \leq I_{OUT} \leq 1.0A$	--	1	15	
Dropout Voltage (Note 6)		$V_{DROP}$	$I_{OUT} = 500mA$	--	1.15	1.25	V
			$I_{OUT} = 1.0A$	--	1.3	1.4	
Current Limit		$I_{LIM}$	$V_{IN} = 5V$	1.0	1.8	--	A
Minimum Load Current	RT9164A		$(V_{IN} - V_{OUT}) = 2V$	--	5	10	mA
Quiescent Current	RT9164A-XX	$I_Q$	$V_{IN} = 5V$	--	5	10	
Ripple Rejection		PSRR	$f_{RIPPLE} = 120Hz, (V_{IN} - V_{OUT}) = 2V, V_{RIPPLE} = 1V_{P-P}$	--	72	--	dB
Adjust Pin Current		$I_{ADJ}$		--	65	120	$\mu A$
Adjust Pin Current Change		$\Delta I_{ADJ}$	$10mA \leq I_{OUT} \leq 1.0A, V_{IN} = 5V$	--	0.2	5	$\mu A$

- 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 test board of JEDEC 51-3 thermal measurement standard. The case point of  $\theta_{JC}$  is on the center of the exposed pad. The pad size is  $6\text{mm}^2$  on SOT-223 packages,  $100\text{mm}^2$  on TO-252 packages,  $125\text{mm}^2$  on TO-263 packages.
- Note 3.** Devices are ESD sensitive. Handling precaution recommended.
- Note 4.** The device is not guaranteed to function outside its operating conditions.
- Note 5.** Low duty cycle pulse testing with Kelvin connections.
- Note 6.** The dropout voltage is defined as  $V_{IN} - V_{OUT}$ , which is measured when  $V_{OUT}$  is  $V_{OUT(NORMAL)} - 100\text{mV}$ .

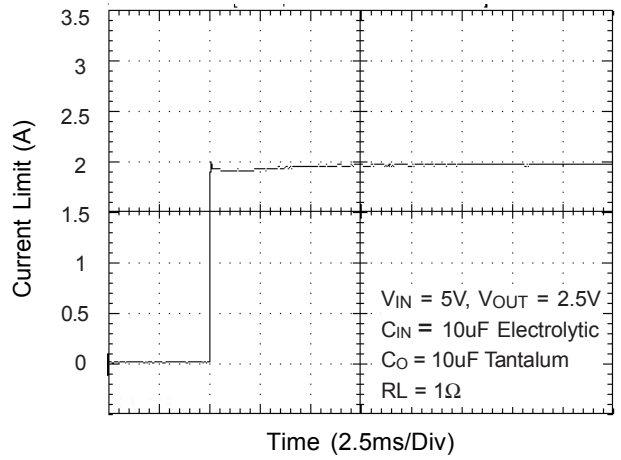
**Typical Operating Characteristics**



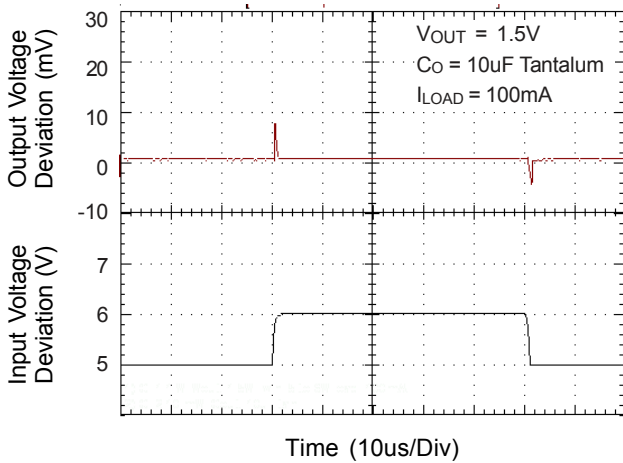
Dropout Voltage vs.  $I_o$



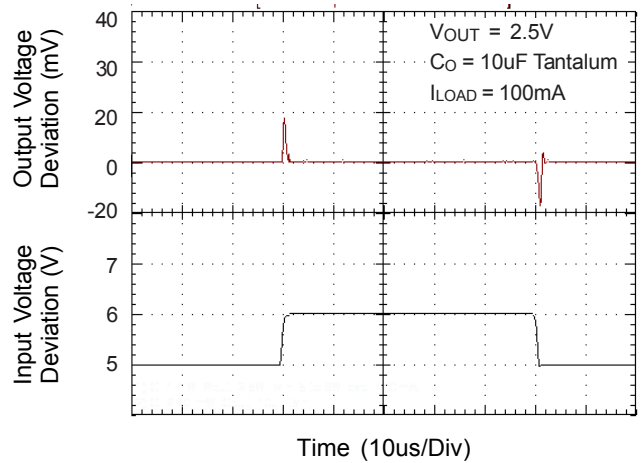
Current Limit



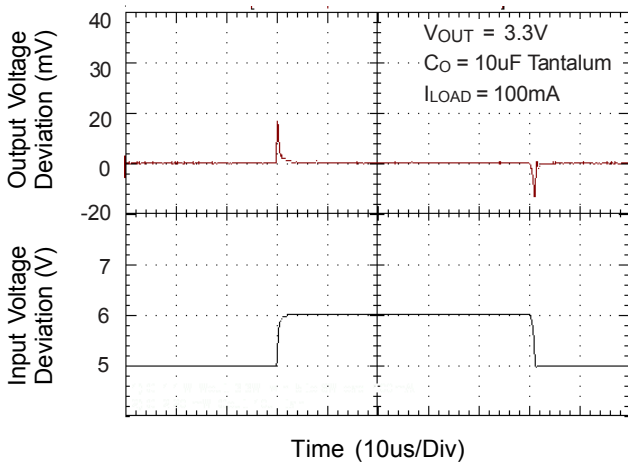
Line Transient Response



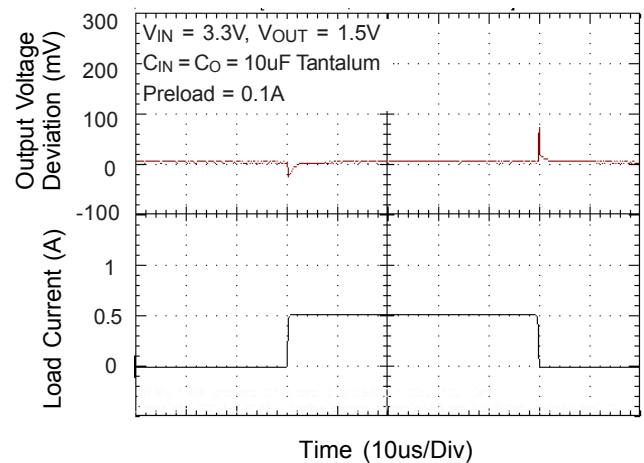
Line Transient Response



Line Transient Response

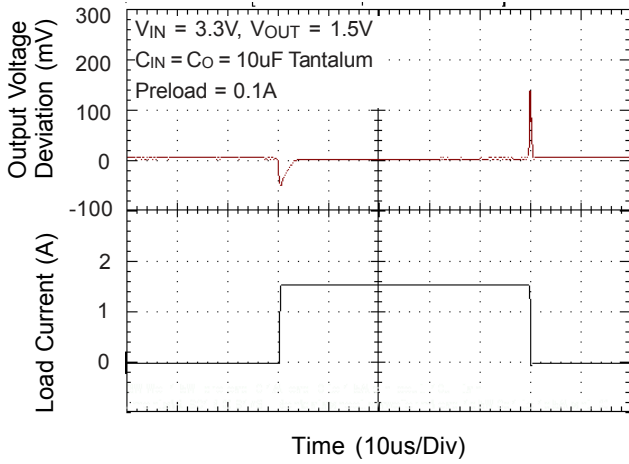


Load Transient Response

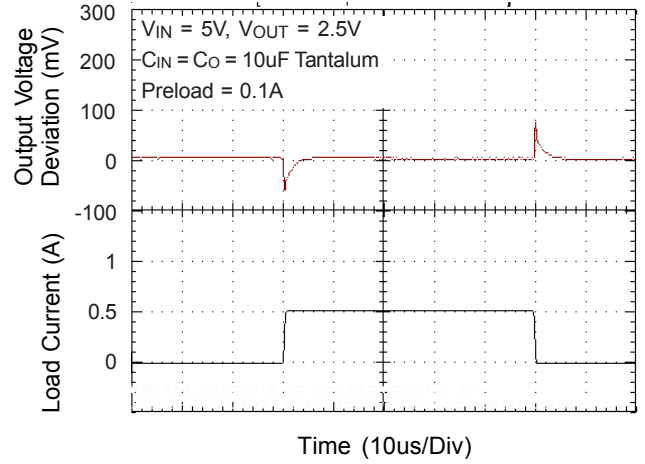




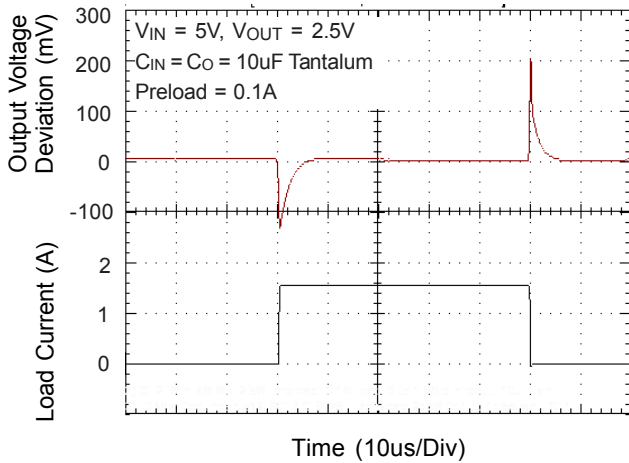
**Load Transient Response**



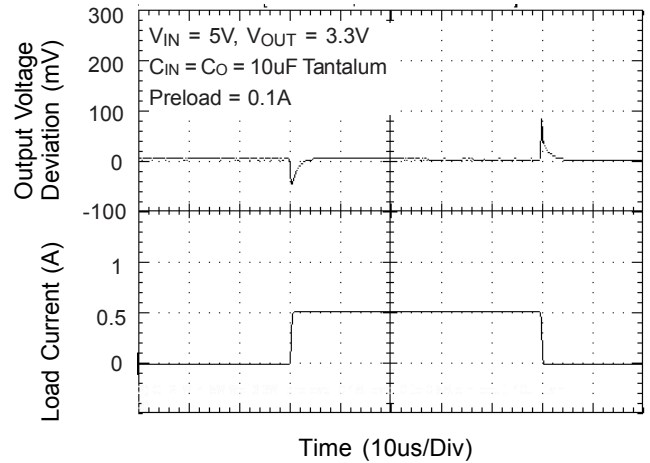
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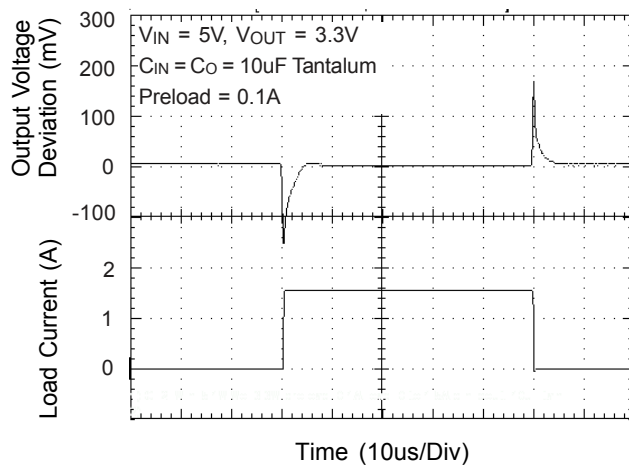
**Load Transient Response**



**Load Transient Response**



**Load Transient Response**



## Application Information

### Output voltage adjustment

Like most regulators, the RT9164A regulates the output by comparing the output voltage to an internally generated reference voltage. On the adjustable version as shown in Figure 4, the  $V_{REF}$  is available externally as 1.25V between  $V_{OUT}$  and ADJ. The voltage ratio formed by R1 and R2 should be set to conduct 10mA (minimum output load). The output voltage is given by the following equation :

$$V_{OUT} = V_{REF} \left( 1 + \frac{R_2}{R_1} \right) + I_{ADJ} R_2$$

On fixed versions of RT9164A, the voltage divider is provided internally.

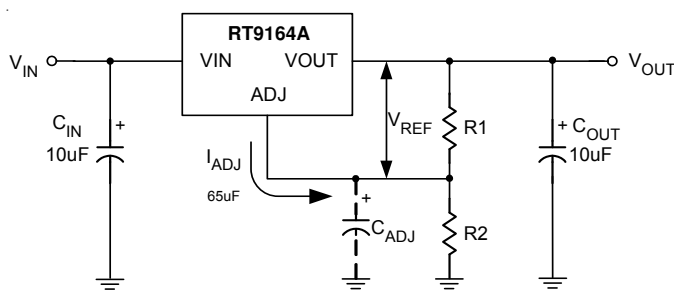


Figure 4. Basic Adjustable Regulator

### Input Bypass Capacitor

An input capacitor is recommended. A 10µF tantalum on the input is a suitable input bypassing for almost all applications.

### Adjust Terminal Bypass Capacitor

The adjust terminal can be bypassed to ground with a bypass capacitor ( $C_{ADJ}$ ) to improve ripple rejection. This bypass capacitor prevents ripple from being amplified as the output voltage is increased. At any ripple frequency, the impedance of the  $C_{ADJ}$  should be less than R1 to prevent the ripple from being amplified :

$$(2\pi \times f_{RIPPLE} \times C_{ADJ}) < R_1$$

The R1 is the resistor between the output and the adjust pin. Its value is normally in the range of 100-200Ω. For example, with  $R_1 = 124\Omega$  and  $f_{RIPPLE} = 120\text{Hz}$ , the  $C_{ADJ}$  should be  $> 11\mu\text{F}$ .

### Output Capacitor

RT9164A requires a capacitor from  $V_{OUT}$  to GND to provide compensation feedback to the internal gain stage. This is to ensure stability at the output terminal. Typically, 10µF tantalum or 50µF aluminum electrolytic with 30mΩ to 2Ω range capacitor is sufficient.

The output capacitor does not have a theoretical upper limit and increasing its value will increase stability.  $C_{OUT} = 100\mu\text{F}$  or more is typical for high current regulator design.

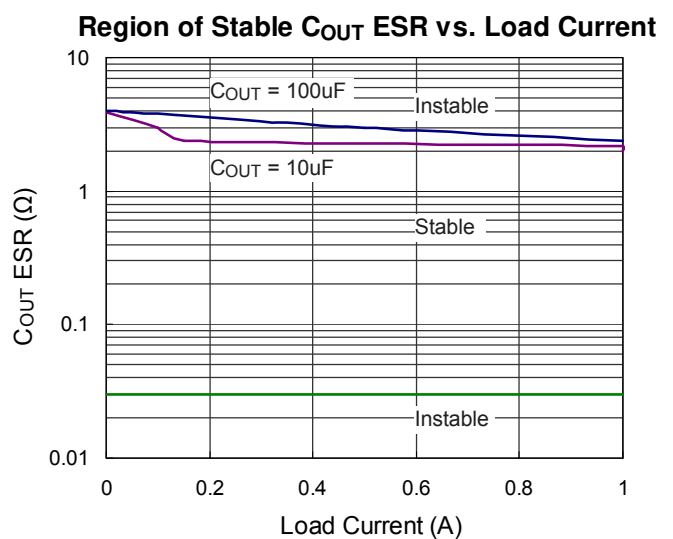


Figure 5

### Load Regulation

When the adjustable regulator is used (Figure 6), the best load regulation is accomplished when the top of the resistor divider (R1) is connected directly to the output pin of the RT9164A. When so connected,  $R_P$  is not multiplied by the divider ratio. For Fixed output version, the top of R1 is internally connected to the output and ground pins can be connected to low side of the load.

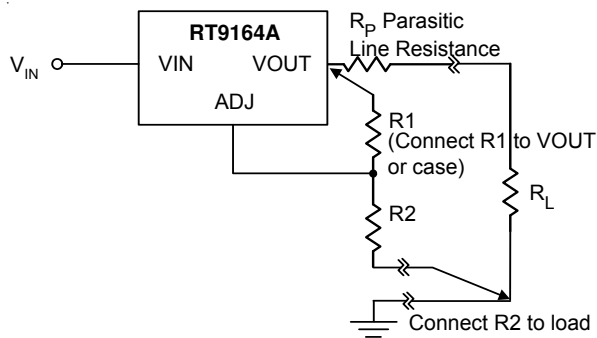


Figure 6. Best Load Regulation Using Adjustable Output Regulator

**Thermal Protection**

RT9164A has thermal protection which limits junction temperature to 150°C. However, device functionality is only guaranteed to a maximum junction temperature of 125°C. The power dissipation and junction temperature for RT9164A are given by

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

$$T_{JUNCTION} = T_{AMBIENT} + (P_D \times \theta_{JA})$$

**Note: T<sub>JUNCTION</sub> must not exceed 125°C**

**Current Limit Protection**

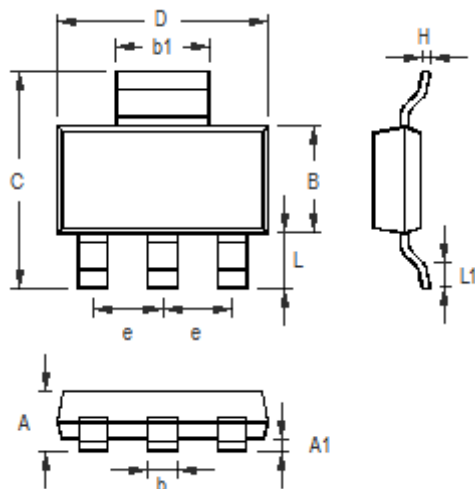
RT9164A is protected against overload conditions. Current protection is triggered at typically 1.8A.

**Thermal Consideration**

The RT9164A series contain thermal limiting circuitry designed to protect itself from over-temperature conditions. Even for normal load conditions, maximum junction temperature ratings must not be exceeded. As mention in thermal protection section, we need to consider all sources of thermal resistance between junction and ambient. It includes junction-to-case, case-to-heat-sink interface, and heat sink thermal resistance itself.

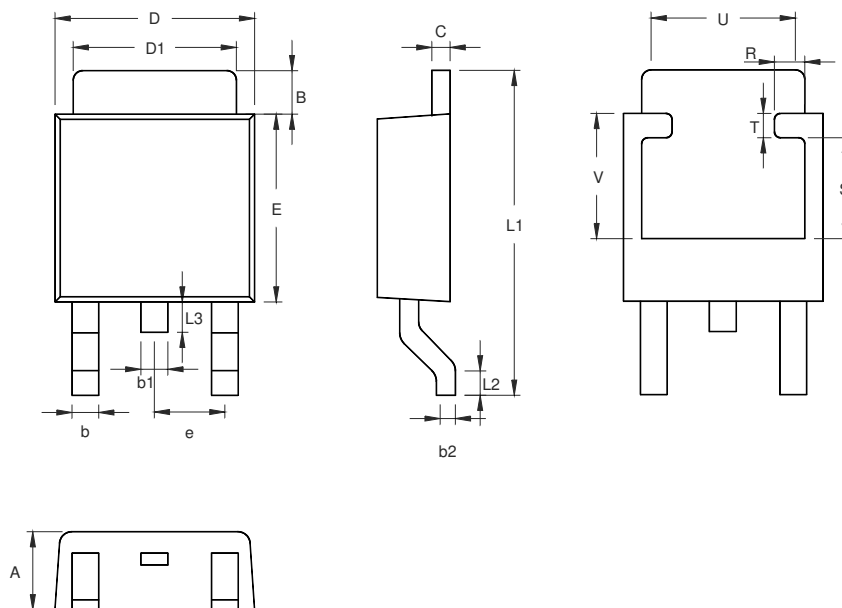
Junction-to-case thermal resistance is specified from the IC junction to the bottom of the case directly below the die. Proper mounting is required to ensure the best possible thermal flow from this area of the package to the heat sink. The case of all devices in this series is electrically connected to the output. Therefore, if the case of the device must be electrically isolated, a thermally conductive spacer is recommended.

## Outline Dimension



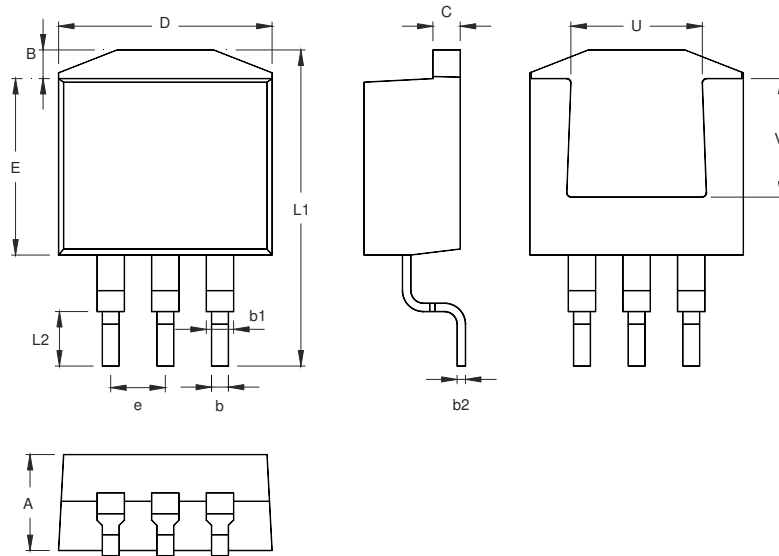
Symbol	Dimensions In Millimeters		Dimensions In Inches	
	Min	Max	Min	Max
A	1.400	1.800	0.055	0.071
A1	0.020	0.100	0.001	0.004
b	0.600	0.840	0.024	0.033
B	3.300	3.700	0.130	0.146
C	6.700	7.300	0.264	0.287
D	6.300	6.700	0.248	0.264
b1	2.900	3.100	0.114	0.122
e	2.300		0.091	
H	0.230	0.350	0.009	0.014
L	1.500	2.000	0.059	0.079
L1	0.800	1.100	0.031	0.043

**3-Lead SOT-223 Surface Mount Package**



Symbol	Dimensions In Millimeters		Dimensions In Inches	
	Min	Max	Min	Max
A	2.184	2.388	0.086	0.094
B	0.889	2.032	0.035	0.080
b	0.508	0.889	0.020	0.035
b1	1.016 Ref.		0.040 Ref.	
b2	0.457	0.584	0.018	0.023
C	0.457	0.584	0.018	0.023
D	6.350	6.731	0.250	0.265
D1	5.207	5.461	0.205	0.215
E	5.334	6.223	0.210	0.245
e	2.108	2.438	0.083	0.096
L1	9.398	10.414	0.370	0.410
L2	0.508 Ref.		0.020 Ref.	
L3	0.635	1.016	0.025	0.040
U	3.810 Ref.		0.150 Ref.	
V	3.048 Ref.		0.120 Ref.	
R	0.200	0.850	0.008	0.033
S	2.500	3.400	0.098	0.134
T	0.500	0.850	0.020	0.033

**3-Lead TO-252 Surface Mount Package**



Symbol	Dimensions In Millimeters		Dimensions In Inches	
	Min	Max	Min	Max
A	4.064	4.826	0.160	0.190
B	1.143	1.676	0.045	0.066
b	0.660	0.914	0.026	0.036
b1	1.143	1.397	0.045	0.055
b2	0.305	0.584	0.012	0.023
C	1.143	1.397	0.045	0.055
D	9.652	10.668	0.380	0.420
E	8.128	9.652	0.320	0.380
e	2.286	2.794	0.090	0.110
L1	14.605	15.875	0.575	0.625
L2	2.286	2.794	0.090	0.110
U	6.223 Ref.		0.245 Ref.	
V	7.620 Ref.		0.300 Ref.	

**3-Lead TO- 263 Surface Mount Package**

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