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-

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

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
- ±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
1 ADJ/GND
2 VOUT (TAB)
3 VIN

TO-252
1 ADJ/GND
2 VOUT (TAB)
3 VIN

TO-252 (R-Type)
1 VOUT
2 ADJ/GND (TAB)
3 VIN

TO-263
1 ADJ/GND
2 VOUT (TAB)
3 VIN
Typical Application Circuit

**Figure 1. Adjustable Voltage Regulator**

![Typical Application Circuit Diagram](image)

Vin = 5V  Vout = 3.45V

R1 = 133Ω  1%
R2 = 232Ω  1%
Cin = 10µF  Tantalum
Cout = 10µF  Tantalum
Iadj

(1) Cin needed if device is far from filter capacitors.
(2) Cout required for stability.

**Figure 2. Fixed Voltage Regulator**

![Typical Application Circuit Diagram](image)

Vin = 5V  Vout = 3.3V

Cin = 10µF  Tantalum
Cout = 10µF  Tantalum
Iq

(1) Cin needed if device is far from filter capacitors.
(2) Cout required for stability.

**Figure 3. Active SCSI Bus Terminator**

![Typical Application Circuit Diagram](image)

Vin = 5V  Vout = 3.3V  18 - 27 Lines

Iq

Vin = 5V  Gnd

Cin = 10µF
Cout = 22µF

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Function Block Diagram

![Diagram Image]

### Functional Pin Description

<table>
<thead>
<tr>
<th>Pin Name</th>
<th>Pin Function</th>
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<tbody>
<tr>
<td>ADJ/GND</td>
<td>Adjust Output or Ground.</td>
</tr>
<tr>
<td>VOUT</td>
<td>Output Voltage.</td>
</tr>
<tr>
<td>VIN</td>
<td>Power Input.</td>
</tr>
<tr>
<td>VREF</td>
<td></td>
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</tbody>
</table>
Absolute Maximum Ratings  (Note 1)

- Supply Input Voltage
- Power Dissipation, \( P_D \) @ \( T_A = 25\,^\circ C \)
  - SOT-223
  - TO-252
  - TO-263

- Package Thermal Resistance (Note 2)
  - SOT-223, \( \theta_{JA} \)
  - SOT-223, \( \theta_{JC} \)
  - TO-252, \( \theta_{JA} \)
  - TO-252, \( \theta_{JC} \)
  - TO-263, \( \theta_{JA} \)
  - TO-263, \( \theta_{JC} \)

- Lead Temperature (Soldering, 10 sec.)
- Junction Temperature

- Storage Temperature Range

ESD Susceptibility (Note 3)
- HBM (Human Body Mode)
- MM (Machine Mode)

Recommended Operating Conditions  (Note 4)

- Supply Input Voltage
- Junction Temperature Range

Electrical Characteristics

(\( T_A = 25\,^\circ C \), unless otherwise specified)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Test Conditions</th>
<th>Min</th>
<th>Typ</th>
<th>Max</th>
<th>Unit</th>
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<tbody>
<tr>
<td>Reference Voltage</td>
<td>RT9164A</td>
<td>( V_{REF} ) ( I_{OUT} = 10,mA, (V_{IN} - V_{OUT}) = 2V, T_A = 25,^\circ C )</td>
<td>1.243</td>
<td>1.256</td>
<td>1.281</td>
<td>V</td>
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<td></td>
<td>10,mA &lt; ( I_{OUT} &lt; 1.0A, ) 1.5,V &lt; ( V_{IN} - V_{OUT} &lt; 10,V )</td>
<td>1.231</td>
<td>1.256</td>
<td>1.294</td>
<td>V</td>
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<tr>
<td>Output Voltage</td>
<td>RT9164A-15</td>
<td>( V_{OUT} ) ( I_{OUT} = 10,mA, V_{IN} = 3.3,V, T_J = 25,^\circ C )</td>
<td>1.485</td>
<td>1.5</td>
<td>1.53</td>
<td>V</td>
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<td>10,mA &lt; ( I_{OUT} &lt; 1.0A, 3.3,V &lt; ( V_{IN} &lt; 10,V )</td>
<td>1.470</td>
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<td>1.55</td>
<td>V</td>
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<td></td>
<td>RT9164A-18</td>
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<td>1.797</td>
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<td>10,mA &lt; ( I_{OUT} &lt; 1.0A, 3.3,V &lt; ( V_{IN} &lt; 10,V )</td>
<td>1.779</td>
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<td>RT9164A-25</td>
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<td>2.475</td>
<td>2.500</td>
<td>2.550</td>
<td>V</td>
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<td>10,mA &lt; ( I_{OUT} &lt; 1.0A, 4.0,V &lt; ( V_{IN} &lt; 10,V )</td>
<td>2.450</td>
<td>2.500</td>
<td>2.575</td>
<td>V</td>
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<td></td>
<td>RT9164A-28</td>
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<td>2.822</td>
<td>2.850</td>
<td>2.910</td>
<td>V</td>
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<td>10,mA &lt; ( I_{OUT} &lt; 1.0A, 4.25,V &lt; ( V_{IN} &lt; 10,V )</td>
<td>2.793</td>
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<td>RT9164A-30</td>
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<td>2.970</td>
<td>3.000</td>
<td>3.060</td>
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<td>10,mA &lt; ( I_{OUT} &lt; 1.0A, 4.5,V &lt; ( V_{IN} &lt; 10,V )</td>
<td>2.940</td>
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<td>3.090</td>
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To be continued
<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Test Conditions</th>
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<th>Max</th>
<th>Unit</th>
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<tbody>
<tr>
<td>Output Voltage (Note 5)</td>
<td>VOUT</td>
<td>I_{OUT} = 10mA, V_{IN} = 4.75V, T_{J} = 25°C</td>
<td>3.267</td>
<td>3.300</td>
<td>3.365</td>
<td>V</td>
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<td></td>
<td>10mA &lt; I_{OUT} &lt; 1.0A, 4.75V &lt; V_{IN} &lt; 10V</td>
<td>3.234</td>
<td>3.300</td>
<td>3.400</td>
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<td>I_{OUT} = 10mA, V_{IN} = 5V, T_{J} = 25°C</td>
<td>3.465</td>
<td>3.500</td>
<td>3.570</td>
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<td>10mA &lt; I_{OUT} &lt; 1.0A, 5.0V &lt; V_{IN} &lt; 10V</td>
<td>3.430</td>
<td>3.500</td>
<td>3.605</td>
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<td>Line Regulation (Note 5)</td>
<td>AVLINE</td>
<td>I_{OUT} = 10mA, 1.5V ≤ V_{IN} - V_{OUT} ≤ 10V</td>
<td>--</td>
<td>0.1</td>
<td>0.3</td>
<td>%</td>
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<td></td>
<td></td>
<td>I_{OUT} = 10mA, 3.3V ≤ V_{IN} ≤ 15V</td>
<td>--</td>
<td>1</td>
<td>6</td>
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<tr>
<td></td>
<td></td>
<td>I_{OUT} = 10mA, 4.0V ≤ V_{IN} ≤ 15V</td>
<td>--</td>
<td>1</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>I_{OUT} = 10mA, 4.25V ≤ V_{IN} ≤ 15V</td>
<td>--</td>
<td>1</td>
<td>6</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>I_{OUT} = 10mA, 4.5V ≤ V_{IN} ≤ 15V</td>
<td>--</td>
<td>1</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>I_{OUT} = 10mA, 5.0V ≤ V_{IN} ≤ 15V</td>
<td>--</td>
<td>1</td>
<td>6</td>
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<tr>
<td>Load Regulation (Note 5)</td>
<td>AVLLOAD</td>
<td>(V_{IN} - V_{OUT}) = 3V, 10mA ≤ I_{OUT} ≤ 1.0A</td>
<td>--</td>
<td>0.2</td>
<td>0.4</td>
<td>%</td>
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<tr>
<td></td>
<td></td>
<td>V_{IN} = 3.3V, 10mA ≤ I_{OUT} ≤ 1.0A</td>
<td>--</td>
<td>1</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>V_{IN} = 4.0V, 10mA ≤ I_{OUT} ≤ 1.0A</td>
<td>--</td>
<td>1</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>V_{IN} = 4.25V, 10mA ≤ I_{OUT} ≤ 1.0A</td>
<td>--</td>
<td>1</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>V_{IN} = 4.5V, 10mA ≤ I_{OUT} ≤ 1.0A</td>
<td>--</td>
<td>1</td>
<td>12</td>
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<tr>
<td></td>
<td></td>
<td>V_{IN} = 5.0V, 10mA ≤ I_{OUT} ≤ 1.0A</td>
<td>--</td>
<td>1</td>
<td>15</td>
<td></td>
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<tr>
<td>Dropout Voltage (Note 6)</td>
<td>VDROP</td>
<td>I_{OUT} = 500mA</td>
<td>--</td>
<td>1.15</td>
<td>1.25</td>
<td>V</td>
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<tr>
<td></td>
<td></td>
<td>I_{OUT} = 1.0A</td>
<td>--</td>
<td>1.3</td>
<td>1.4</td>
<td></td>
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<tr>
<td>Current Limit</td>
<td>I_{LIM}</td>
<td>V_{IN} = 5V</td>
<td>1.0</td>
<td>1.8</td>
<td>--</td>
<td>A</td>
</tr>
<tr>
<td>Minimum Load Current</td>
<td></td>
<td>(V_{IN} - V_{OUT}) = 2V</td>
<td>--</td>
<td>5</td>
<td>10</td>
<td>mA</td>
</tr>
<tr>
<td>Quiescent Current</td>
<td>I_{Q}</td>
<td>V_{IN} = 5V</td>
<td>--</td>
<td>5</td>
<td>10</td>
<td>mA</td>
</tr>
<tr>
<td>Ripple Rejection</td>
<td>PSRR</td>
<td>f_{RIPPLE} = 120Hz, (V_{IN} - V_{OUT}) = 2V, V_{RIPPLE} = 1V_{P-P}</td>
<td>--</td>
<td>72</td>
<td>--</td>
<td>dB</td>
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<tr>
<td>Adjust Pin Current</td>
<td>I_{ADJ}</td>
<td></td>
<td>--</td>
<td>65</td>
<td>120</td>
<td>μA</td>
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<tr>
<td>Adjust Pin Current Change</td>
<td>ΔI_{ADJ}</td>
<td>10mA ≤ I_{OUT} ≤ 1.0A, V_{IN} = 5V</td>
<td>--</td>
<td>0.2</td>
<td>5</td>
<td>μA</td>
</tr>
</tbody>
</table>

**Notes:**
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 $T_A = 25^\circ C$ 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 6mm$^2$ on SOT-223 packages, 100mm$^2$ on TO-252 packages, 125mm$^2$ 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 $V_{OUT(NORMAL)} - 100mV$. 
Typical Operating Characteristics

**Output Voltage vs. Temperature**
- $V_{OUT} = 3.3V$
- $V_{IN} = 5V$
- $C_{IN} = 10uF$ Electrolytic
- $C_{O} = 10uF$ Tantalum
- $R_{L} = \infty$

**Reference Voltage vs. Temperature**
- $V_{IN} = 5V$
- $C_{IN} = 10uF$ Electrolytic
- $C_{O} = 10uF$ Tantalum
- $R_{1} = R_{2} = 100\Omega$
- $R_{L} = \infty$

**ADJ Pin Current vs. Temperature**
- $V_{IN} = 5V$
- $C_{IN} = 10uF$ Electrolytic
- $C_{O} = 10uF$ Tantalum
- $R_{1} = R_{2} = 100\Omega$
- $R_{L} = \infty$

**Quiescent Current vs. Temperature**

**Current Limit vs. Input Voltage**
- $V_{OUT} = 2.5V$, $RL = 1\Omega$

**Current Limit vs. Temperature**
- $V_{OUT} = 2.5V$, $RL = 1\Omega$

- $V_{IN} = 5V$
- $C_{IN} = 10uF$ Electrolytic
- $C_{O} = 10uF$ Tantalum
### Dropout Voltage vs. Io

- **VOUT = 2.5V**
- **CIN = 10µF Electrolytic**
- **CO = 10µF Tantalum**

#### Temperature
- **-40°C**
- **25°C**
- **125°C**

#### Load Current (A)
- 0
- 0.3
- 0.6
- 0.9
- 1.2
- 1.5

#### Dropout Voltage (V)
- 0.8
- 0.9
- 1.0
- 1.1
- 1.2
- 1.3

### Current Limit

- **VIN = 5V, VOUT = 2.5V**
- **CIN = 10µF Electrolytic**
- **CO = 10µF Tantalum**
- **R_L = 1Ω**

#### Time (2.5ms/Div)

### Line Transient Response

- **VOUT = 1.5V**
- **CO = 10µF Tantalum**
- **ILOAD = 100mA**

#### Time (10us/Div)

#### Output Voltage Deviation (mV)
- 0
- 10
- 20
- 30

#### Input Voltage Deviation (V)
- 5
- 6
- 7

### Line Transient Response

- **VOUT = 2.5V**
- **CO = 10µF Tantalum**
- **ILOAD = 100mA**

#### Time (10us/Div)

#### Output Voltage Deviation (mV)
- 0
- 10
- 20
- 30

#### Input Voltage Deviation (V)
- 5
- 6
- 7

### Line Transient Response

- **VOUT = 3.3V**
- **CO = 10µF Tantalum**
- **ILOAD = 100mA**

#### Time (10us/Div)

#### Output Voltage Deviation (mV)
- 0
- 10
- 20
- 30

#### Input Voltage Deviation (V)
- 5
- 6

### Load Transient Response

- **VIN = 3.3V, VOUT = 1.5V**
- **CIN = CO = 10µF Tantalum**
- **Preload = 0.1A**

#### Time (10us/Div)

#### Output Voltage Deviation (mV)
- 0
- 100
- 200
- 300

#### Load Current (A)
- 0
- 0.5
- 1

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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 VREF is available externally as 1.25V between VOUT 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:

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

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

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:

\[ (2\pi \times f_{RIPPLE} \times C_{ADJ}) < R1 \]

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 R1 = 124Ω and f_{RIPPLE} = 120Hz, the C_{ADJ} should be > 11μF.

Output Capacitor
RT9164A requires a capacitor from VOUT 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} = 100μF or more is typical for high current regulator design.

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

![Region of Stable C_{OUT} ESR vs. Load Current](image)

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.
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

\[
\begin{align*}
P_D &= (V_{IN} - V_{OUT}) \times I_{OUT} \\
T_{JUNCTION} &= T_{AMBIENT} + (P_D \times \theta_{JA})
\end{align*}
\]

Note: \(T_{JUNCTION}\) 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

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Dimensions In Millimeters</th>
<th>Dimensions In Inches</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Min</td>
<td>Max</td>
</tr>
<tr>
<td>A</td>
<td>1.400</td>
<td>1.800</td>
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<td>A1</td>
<td>0.020</td>
<td>0.100</td>
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<td>b</td>
<td>0.600</td>
<td>0.840</td>
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<td>B</td>
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<td>C</td>
<td>6.700</td>
<td>7.300</td>
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<tr>
<td>D</td>
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*3-Lead SOT-223 Surface Mount Package*
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3-Lead TO-252 Surface Mount Package
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3-Lead TO-263 Surface Mount Package