LM431
Adjustable Precision Zener Shunt Regulator

General Description
The LM431 is a 3-terminal adjustable shunt regulator with guaranteed temperature stability over the entire temperature range of operation. It is now available in a chip sized package (4-Bump micro SMD) using National’s micro SMD package technology. The output voltage may be set at any level greater than 2.5V (V_{REF}) up to 36V merely by selecting two external resistors that act as a voltage divided network. Due to the sharp turn-on characteristics this device is an excellent replacement for many zener diode applications.

Features
- Average temperature coefficient 50 ppm/°C
- Temperature compensated for operation over the full temperature range
- Programmable output voltage
- Fast turn-on response
- Low output noise
- LM431 in micro SMD package
- See AN-1112 for micro SMD considerations

Connection Diagrams

TO-92: Plastic Package

SOT-23: 3-Lead Small Outline

SO-8: 8-Pin Surface Mount

4-Bump micro SMD

Note: *NC = Not internally connected. Must be electrically isolated from the rest of the circuit for the microSMD package.
## Ordering Information

<table>
<thead>
<tr>
<th>Package</th>
<th>Typical Accuracy</th>
<th>Order Number/Package Marking</th>
<th>Temperature Range</th>
<th>Transport Media</th>
<th>NSC Drawing</th>
</tr>
</thead>
<tbody>
<tr>
<td>TO-92</td>
<td>0.5%</td>
<td>LM431CZ/ LM431CCZ</td>
<td>0˚C to +70˚C</td>
<td>Rails</td>
<td>Z03A</td>
</tr>
<tr>
<td></td>
<td>1%</td>
<td>LM431BCZ/ LM431BCZ</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2%</td>
<td>LM431ACZ/ LM431ACZ</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>LM431CIZ/ LM431CIZ</td>
<td>−40˚C to +85˚C</td>
<td>Rails</td>
<td>Z03A</td>
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<tr>
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<td>LM431BIZ/ LM431BIZ</td>
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<td></td>
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<td></td>
<td>LM431AIZ/ LM431AIZ</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SO-8</td>
<td>0%</td>
<td>LM431CCM/ 431CCM</td>
<td>0˚C to +70˚C</td>
<td>Rails and Tape &amp; Reel</td>
<td>M08A</td>
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<td>LM431BCM/ 431BCM</td>
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<tr>
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<td>LM431ACM/ LM431ACM</td>
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<td>LM431CIM/ 431CIM</td>
<td>−40˚C to +85˚C</td>
<td>Rails and Tape &amp; Reel</td>
<td>MF03A</td>
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<td>LM431BIM/ 431BIM</td>
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<td>LM431AIM/ LM431AIM</td>
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<tr>
<td>SOT-23</td>
<td>0%</td>
<td>LM431CCM3/ N1B</td>
<td>0˚C to +70˚C</td>
<td>Rails and Tape &amp; Reel</td>
<td>MF03A</td>
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<td>LM431BCM3/ N1D</td>
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<td>LM431ACM3/ N1F</td>
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<td></td>
<td>LM431CIM3/ N1A</td>
<td>−40˚C to +85˚C</td>
<td>Rails and Tape &amp; Reel</td>
<td>MF03A</td>
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<td>LM431BIM3/ N1C</td>
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<td>LM431AIM3/ N1E</td>
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<tr>
<td>micro SMD</td>
<td>0%</td>
<td>–</td>
<td>−40˚C to +85˚C</td>
<td>250 Units Tape and Reel</td>
<td>BPA04AFB</td>
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<td></td>
<td></td>
<td>–</td>
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<td>3k Units Tape and Reel</td>
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</table>

**Note 1:** The micro SMD package marking is a 1 digit manufacturing Date Code only

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### micro SMD Top View Marking Example

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X = Date Code

Pin A1 Identifier
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[Image: micro SMD Top View Marking Example]
Symbol and Functional Diagrams

DC Test Circuits

FIGURE 1. Test Circuit for $V_Z = V_{REF}$

Note: $V_Z = V_{REF} \frac{1 + R1}{R2} + I_{REF} \cdot R1$

FIGURE 2. Test Circuit for $V_Z > V_{REF}$

FIGURE 3. Test Circuit for Off-State Current
Absolute Maximum Ratings (Note 2)
If Military/Aerospace specified devices are required, please contact the National Semiconductor Sales Office/Distributors for availability and specifications.

| Storage Temperature Range | −65˚C to +150˚C |
| Operating Temperature Range | Industrial (LM431xI) −40˚C to +85˚C |
| | Commercial (LM431xC) 0˚C to +70˚C |

Soldering Information
- Infrared or Convection (20 sec.) 235˚C
- Wave Soldering (10 sec.) 260˚C (lead temp.)

- Cathode Voltage 37V
- Continuous Cathode Current −10 mA to +150 mA

Reference Voltage −0.5V
Reference Input Current 10 mA
Internal Power Dissipation
- TO-92 Package 0.78W
- SO-8 Package 0.81W
- SOT-23 Package 0.28W
- micro SMD Package 0.30W

Operating Conditions

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Parameter</th>
<th>Conditions</th>
<th>Min</th>
<th>Typ</th>
<th>Max</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>V REF</td>
<td>Reference Voltage</td>
<td>V Z = V REF, I I = 10 mA, T A = Full Range (Figure 1 )</td>
<td>2.440</td>
<td>2.495</td>
<td>2.550</td>
<td>V</td>
</tr>
<tr>
<td></td>
<td></td>
<td>LM431A (Figure 1 )</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>V Z = V REF, I I = 10 mA, T A = Full Range (Figure 1 )</td>
<td>2.470</td>
<td>2.495</td>
<td>2.520</td>
<td>V</td>
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<tr>
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<td></td>
<td>LM431B (Figure 1 )</td>
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<td></td>
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<tr>
<td></td>
<td></td>
<td>V Z = V REF, I I = 10 mA, T A = Full Range (Figure 1 )</td>
<td>2.485</td>
<td>2.500</td>
<td>2.510</td>
<td>V</td>
</tr>
<tr>
<td>V DEV</td>
<td>Deviation of Reference Input Voltage Over Temperature (Note 5)</td>
<td>V Z = V REF, I I = 10 mA, T A = Full Range (Figure 1 )</td>
<td>8.0</td>
<td>17</td>
<td>mV</td>
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<tr>
<td>ΔV REF</td>
<td>ΔV Z Ratio of the Change in Reference Voltage to the Change in Cathode Voltage</td>
<td>I Z = 10 mA</td>
<td>V Z from V REF to 10V</td>
<td>−1.4</td>
<td>−2.7</td>
<td>mV/V</td>
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<td></td>
<td></td>
<td>LM431A (Figure 1 )</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>I Z = 10 mA</td>
<td>V Z from 10V to 36V</td>
<td>−1.0</td>
<td>−2.0</td>
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<tr>
<td>I REF</td>
<td>Reference Input Current</td>
<td>R 1 = 10 kΩ, R 2 = ∞, I I = 10 mA (Figure 2 )</td>
<td>2.0</td>
<td>4.0</td>
<td>μA</td>
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<tr>
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<td>LM431A, LM431B, LM431C, Frequency = 0 Hz (Figure 1 )</td>
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<tr>
<td>∞I REF</td>
<td>Deviation of Reference Input Current over Temperature</td>
<td>R 1 = 10 kΩ, R 2 = ∞, I I = 10 mA, T A = Full Range (Figure 2 )</td>
<td>0.4</td>
<td>1.2</td>
<td>μA</td>
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<tr>
<td>I Z(MIN)</td>
<td>Minimum Cathode Current for Regulation</td>
<td>V Z = V REF (Figure 1 )</td>
<td>0.4</td>
<td>1.0</td>
<td>mA</td>
<td></td>
</tr>
<tr>
<td>I Z(OFF)</td>
<td>Off-State Current</td>
<td>V Z = 36V, V REF = 0V (Figure 3 )</td>
<td>0.3</td>
<td>1.0</td>
<td>μA</td>
<td></td>
</tr>
<tr>
<td>r Z Dynamic Output Impedance (Note 6)</td>
<td>V Z = V REF, LM431A, Frequency = 0 Hz (Figure 1 )</td>
<td>0.75</td>
<td>Ω</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>LM431B, LM431C, Frequency = 0 Hz (Figure 1 )</td>
<td>0.50</td>
<td>Ω</td>
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<td></td>
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</tbody>
</table>

Note 2: Absolute Maximum Ratings indicate limits beyond which damage to the device may occur. Electrical specifications do not apply when operating the device beyond its rated operating conditions.

Note 3: T J Max = 150˚C.

Note 4: Ratings apply to ambient temperature at 25˚C. Above this temperature, derate the TO-92 at 6.2 mW/˚C, the SO-8 at 6.5 mW/˚C, the SOT-23 at 2.2 mW/˚C and the micro SMD at 3mW/˚C.

Note 5: Deviation of reference input voltage, V DEV, is defined as the maximum variation of the reference input voltage over the full temperature range.
The average temperature coefficient of the reference input voltage, $\propto V_{\text{REF}}$, is defined as:

$$\propto V_{\text{REF}} \text{ ppm} / ^\circ C = \pm \left( \frac{V_{\text{Max}} - V_{\text{Min}}}{V_{\text{REF (at 25)}\circ C}} \right) \frac{10^6}{T_2 - T_1} = \pm \left( \frac{V_{\text{DEV}}}{V_{\text{REF (at 25)}\circ C}} \right) \frac{10^6}{T_2 - T_1}$$

Where:

- $T_2 - T_1$ = full temperature change (0-70°C).
- $\propto V_{\text{REF}}$ can be positive or negative depending on whether the slope is positive or negative.
- Example: $V_{\text{DEV}} = 8.0$ mV, $V_{\text{REF}} = 2495$ mV, $T_2 - T_1 = 70^\circ C$, slope is positive.

$$\propto V_{\text{REF}} = \left( \frac{8.0 \text{ mV}}{2495 \text{ mV}} \right) \frac{10^6}{70^\circ C} = +46 \text{ ppm} / ^\circ C$$

**Note 6**: The dynamic output impedance, $r_Z$, is defined as:

$$r_Z = \frac{\Delta V_Z}{\Delta I_Z}$$

When the device is programmed with two external resistors, $R_1$ and $R_2$, (see Figure 2), the dynamic output impedance of the overall circuit, $r_Z$, is defined as:

$$\frac{\Delta V_Z}{\Delta I_Z} = R_Z \left( 1 + \frac{R_1}{R_2} \right)$$

**Equivalent Circuit**

![Equivalent Circuit Diagram]
Typical Performance Characteristics

**Input Current vs VZ**

![Graph](DS010055-29)

**Thermal Information**

![Graph](DS010055-30)

**Input Current vs VZ**

![Graph](DS010055-31)

**Dynamic Impedance vs Frequency**

![Graph](DS010055-9)

**Stability Boundary Conditions**

![Graph](DS010055-11)

**Note:** The areas under the curves represent conditions that may cause the device to oscillate. For curves B, C, and D, R2 and V+ were adjusted to establish the initial VZ and IZ conditions with CL = 0. V+ and CL were then adjusted to determine the ranges of stability.

**Test Circuit for Curve A Above**

![Circuit Diagram](DS010055-12)

**Test Circuit for Curves B, C and D Above**

![Circuit Diagram](DS010055-13)

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**Typical Applications**

**Shunt Regulator**

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

**Single Supply Comparator with Temperature Compensated Threshold**

\[ V_{ON} \approx 2 \text{ V} \]
\[ V_{TM} \approx 2.5 \text{ V} \]
\[ V_{OFF} = V_O \]

**Series Regulator**

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

**Output Control of a Three Terminal Fixed Regulator**

\[ V_O = \left( 1 + \frac{R_1}{R_2} \right) V_{REF} \]
\[ V_{O\text{MIN}} = V_{REF} + 5 \text{ V} \]

**Higher Current Shunt Regulator**

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

**Crow Bar**

\[ V_{LIMIT} = \left( 1 + \frac{R_1}{R_2} \right) V_{REF} \]
Typical Applications (Continued)

Over Voltage/Under Voltage Protection Circuit

LOW LIMIT = \( V_{\text{REF}} \left( 1 + \frac{R_{1B}}{R_{2B}} \right) + V_{\text{BE}} \)

HIGH LIMIT = \( V_{\text{REF}} \left( 1 + \frac{R_{1A}}{R_{2A}} \right) \)

Voltage Monitor

LOW LIMIT = \( V_{\text{REF}} \left( 1 + \frac{R_{1B}}{R_{2B}} \right) \) LED ON WHEN LOW LIMIT < \( V^+ \) < HIGH LIMIT

HIGH LIMIT = \( V_{\text{REF}} \left( 1 + \frac{R_{1A}}{R_{2A}} \right) \)
Typical Applications (Continued)

1.0 Mounting
To ensure that the geometry of the micro SMD package maintains good physical contact with the printed circuit board, pin A1 (NC) must be soldered to the pcb. Please see AN-1112 for more detailed information regarding board mounting techniques for the micro SMD package.

2.0 LM431 micro SMD Light Sensitivity
When the LM431 micro SMD package is exposed to bright sunlight, normal office fluorescent light, and other LED’s and lasers, it operates within the guaranteed limits specified in the electrical characteristics table.
Physical Dimensions inches (millimeters) unless otherwise noted

SOT-23 Molded Small Outline Transistor Package (M3)
NS Package Number MF03A
Physical Dimensions  inches (millimeters) unless otherwise noted (Continued)

NS Package Number Z03A
**Physical Dimensions** inches (millimeters) unless otherwise noted (Continued)

**NOTES:** UNLESS OTHERWISE SPECIFIED
1. EPOXY COATING
2. 63Sn/37Pb EUTECTIC BUMP
3. RECOMMEND NON-SOLDER MASK DEFINED LANDING PAD.
4. PIN A1 IS ESTABLISHED BY LOWER LEFT CORNER WITH RESPECT TO TEXT ORIENTATION. REMAINING PINS ARE NUMBERED.
5. XXX IN DRAWING NUMBER REPRESENTS PACKAGE SIZE VARIATION WHERE X1 IS PACKAGE WIDTH, X2 IS PACKAGE LENGTH AND X3 IS PACKAGE HEIGHT.
6. REFERENCE JEDEC REGISTRATION MO-211, VARIATION BA.

**4-Bump micro SMD**

\[
\begin{align*}
X_1 &= 0.777 \\
X_2 &= 0.904 \\
X_3 &= 0.850
\end{align*}
\]

NS Package Number BPA04AFB

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