

# LM431

## Adjustable Precision Zener Shunt Regulator

### General Description

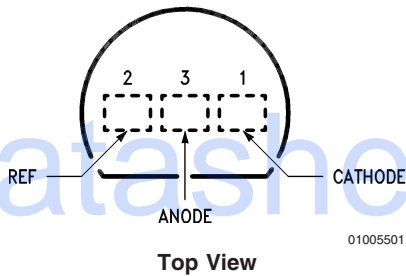
The LM431 is a 3-terminal adjustable shunt regulator with guaranteed temperature stability over the entire temperature range of operation. It is now available in a chip sized package (4-Bump micro SMD) using National's micro SMD package technology. The output voltage may be set at any level greater than 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

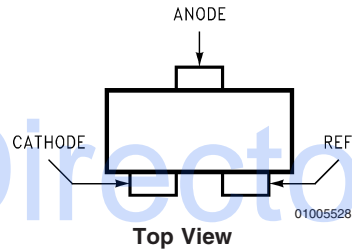
- Average temperature coefficient 50 ppm/°C
- Temperature compensated for operation over the full temperature range
- Programmable output voltage
- Fast turn-on response
- Low output noise
- LM431 in micro SMD package
- See AN-1112 for micro SMD considerations

### Connection Diagrams

TO-92: Plastic Package



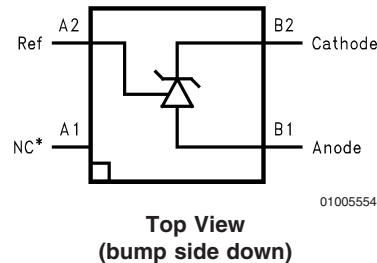
SOT-23: 3-Lead Small Outline



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.

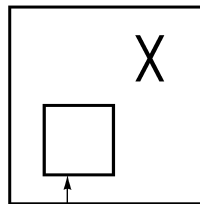
## Ordering Information

| Package   | Typical Accuracy Order Number/Package Marking |                       |                                     | Temperature Range | Transport Media   | NSC Drawing |
|-----------|---|-----------------------|-------------------------------------|-------------------|---|-------------|
|           | 0.5%  | 1%                    | 2%                                  |                   |   |             |
| TO-92     | LM431CCZ/<br>LM431CCZ                         | LM431BCZ/<br>LM431BCZ | LM431ACZ/<br>LM431ACZ               | 0°C to +70°C      | Rails   | Z03A        |
|           | LM431CIZ/<br>LM431CIZ                         | LM431BIZ/<br>LM431BIZ | LM431AIZ/<br>LM431AIZ               | -40°C to +85°C    |   |             |
| SO-8      | LM431CCM/<br>431CCM                           | LM431BCM/<br>431BCM   | LM431ACM/<br>LM431ACM               | 0°C to +70°C      | Rails   | M08A        |
|           | LM431CCMX/<br>431CCM                          | LM431BCM/<br>431BCM   | LM431ACMX/<br>LM431ACM              |                   | Tape & Reel   |             |
|           | LM431CIM/<br>431CIM                           | LM431BIM/<br>431BIM   | LM431AIM/<br>LM431AIM               | -40°C to +85°C    | Rails   |             |
|           | LM431CIMX/<br>431CIM                          | LM431BIMX/<br>431BIM  | LM431AIMX/<br>LM431AIM              |                   | Tape & Reel   |             |
| SOT-23    | LM431CCM3/<br>N1B                             | LM431BCM3/<br>N1D     | LM431ACM3/<br>N1F                   | 0°C to +70°C      | Rails   | MF03A       |
|           | LM431CCM3X/<br>N1B                            | LM431BCM3X/<br>N1D    | LM431ACM3X/<br>N1F                  |                   | Tape & Reel   |             |
|           | LM431CIM3<br>N1A                              | LM431BIM3<br>N1C      | LM431AIM3<br>N1E                    | -40°C to +85°C    | Rails   |             |
|           | LM431CIM3X<br>N1A                             | LM431BIM3X<br>N1C     | LM431AIM3X<br>N1E                   |                   | Tape & Reel   |             |
| micro SMD | -   | -                     | LM431AIBP<br>LM431AIBPX<br>(Note 1) | -40°C to +85°C    | 250 Units Tape and<br>Reel<br>3k Units Tape and<br>Reel | BPA04AFB    |

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

### micro SMD Top View Marking Example

X = Date Code



Pin A1 Identifier

01005556

# Symbol and Functional Diagrams



## DC Test Circuits



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



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

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



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 (LM431xl)        | -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 (Notes 3, 4) |       |
| TO-92 Package                           | 0.78W |
| SO-8 Package                            | 0.81W |
| SOT-23 Package                          | 0.28W |
| micro SMD Package                       | 0.30W |

**Operating Conditions**

|                 | Min       | Max    |
|-----------------|-----------|--------|
| Cathode Voltage | $V_{REF}$ | 37V    |
| Cathode Current | 1.0 mA    | 100 mA |

## LM431

### Electrical Characteristics

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

| Symbol                              | Parameter   | Conditions   | Min                         | Typ   | Max   | Units         |
|-------------------------------------|---|--|-----------------------------|-------|-------|---------------|
| $V_{REF}$                           | Reference Voltage   | $V_Z = V_{REF}$ , $I_I = 10\text{ mA}$<br>LM431A (Figure 1)  | 2.440                       | 2.495 | 2.550 | V             |
|                                     |   | $V_Z = V_{REF}$ , $I_I = 10\text{ mA}$<br>LM431B (Figure 1)  | 2.470                       | 2.495 | 2.520 | V             |
|                                     |   | $V_Z = V_{REF}$ , $I_I = 10\text{ mA}$<br>LM431C (Figure 1)  | 2.485                       | 2.500 | 2.510 | V             |
| $V_{DEV}$                           | Deviation of Reference Input Voltage Over Temperature (Note 5)            | $V_Z = V_{REF}$ , $I_I = 10\text{ mA}$ ,<br>$T_A = \text{Full Range}$ (Figure 1)                               |                             | 8.0   | 17    | mV            |
| $\frac{\Delta V_{REF}}{\Delta V_Z}$ | Ratio of the Change in Reference Voltage to the Change in Cathode Voltage | $I_Z = 10\text{ mA}$<br>(Figure 2)   | $V_Z$ from $V_{REF}$ to 10V | -1.4  | -2.7  | mV/V          |
|                                     |   |  | $V_Z$ from 10V to 36V       | -1.0  | -2.0  |               |
| $I_{REF}$                           | Reference Input Current   | $R_1 = 10\text{ k}\Omega$ , $R_2 = \infty$ ,<br>$I_I = 10\text{ mA}$ (Figure 2)                                |                             | 2.0   | 4.0   | $\mu\text{A}$ |
| $\infty I_{REF}$                    | Deviation of Reference Input Current over Temperature                     | $R_1 = 10\text{ k}\Omega$ , $R_2 = \infty$ ,<br>$I_I = 10\text{ mA}$ ,<br>$T_A = \text{Full Range}$ (Figure 2) |                             | 0.4   | 1.2   | $\mu\text{A}$ |
| $I_{Z(MIN)}$                        | Minimum Cathode Current for Regulation                                    | $V_Z = V_{REF}$ (Figure 1)   |                             | 0.4   | 1.0   | mA            |
| $I_{Z(OFF)}$                        | Off-State Current   | $V_Z = 36\text{V}$ , $V_{REF} = 0\text{V}$ (Figure *NO TARGET FOR fi*)   |                             | 0.3   | 1.0   | $\mu\text{A}$ |
| $r_Z$                               | Dynamic Output Impedance (Note 6)   | $V_Z = V_{REF}$ , LM431A,<br>Frequency = 0 Hz (Figure 1)   |                             |       | 0.75  | $\Omega$      |
|                                     |   | $V_Z = V_{REF}$ , LM431B, LM431C<br>Frequency = 0 Hz (Figure 1)  |                             |       | 0.50  | $\Omega$      |

**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:**  $T_{J\text{ Max}} = 150^\circ\text{C}$ .

**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.

## LM431 Electrical Characteristics (Continued)



01005507

The average temperature coefficient of the reference input voltage,  $\alpha V_{REF}$ , is defined as:

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

Where:

$T_2 - T_1$  = full temperature change (0-70°C).

$\alpha V_{REF}$  can be positive or negative depending on whether the slope is positive or negative.

Example:  $V_{DEV} = 8.0 \text{ mV}$ ,  $V_{REF} = 2495 \text{ mV}$ ,  $T_2 - T_1 = 70^{\circ}\text{C}$ , slope is positive.

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

**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, R1 and R2, (see Figure 2), the dynamic output impedance of the overall circuit,  $r_z$ , is defined as:

$$r_z = \frac{\Delta V_z}{\Delta I_z} \cong \left[ r_z \left( 1 + \frac{R_1}{R_2} \right) \right]$$

## Equivalent Circuit



01005503

## Typical Performance Characteristics

Input Current vs  $V_Z$



01005529

Thermal Information



01005530

Input Current vs  $V_Z$



01005531

Dynamic Impedance vs Frequency



01005509

# Typical Performance Characteristics (Continued)

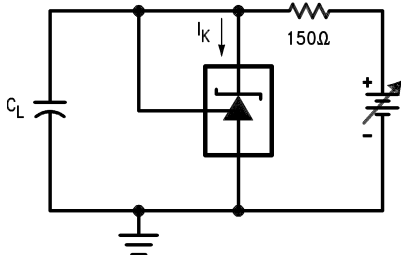
## Stability Boundary Conditions



01005510

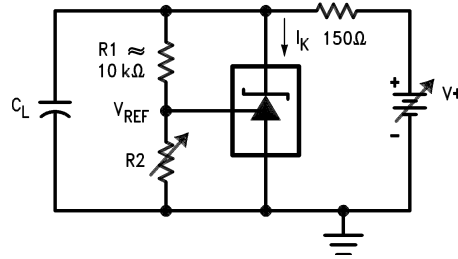
**Note:** The areas under the curves represent conditions that may cause the device to oscillate. For curves B, C, and D, R2 and V+ were adjusted to establish the initial Vz and Iz conditions with CL = 0. V+ and CL were then adjusted to determine the ranges of stability.

### Test Circuit for Curve A Above



01005512

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



01005513

## Typical Applications

### Shunt Regulator



01005514

$$V_O \approx \left(1 + \frac{R_1}{R_2}\right) V_{REF}$$

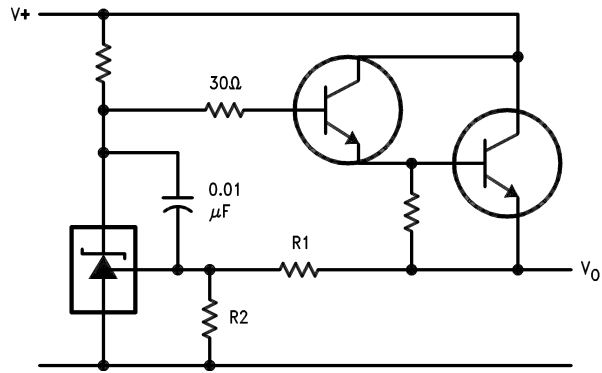
### Single Supply Comparator with Temperature Compensated Threshold



01005515

Typical Applications (Continued)

Series Regulator



01005516

$$V_O \approx \left(1 + \frac{R_1}{R_2}\right) V_{REF}$$

Output Control of a Three Terminal Fixed Regulator



01005517

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

$$V_{O\ MIN} = V_{REF} + 5V$$

Higher Current Shunt Regulator



01005518

$$V_O \approx \left(1 + \frac{R_1}{R_2}\right) V_{REF}$$

Crow Bar



01005519

$$V_{LIMIT} \approx \left(1 + \frac{R_1}{R_2}\right) V_{REF}$$



Typical Applications (Continued)

Over Voltage/Under Voltage Protection Circuit

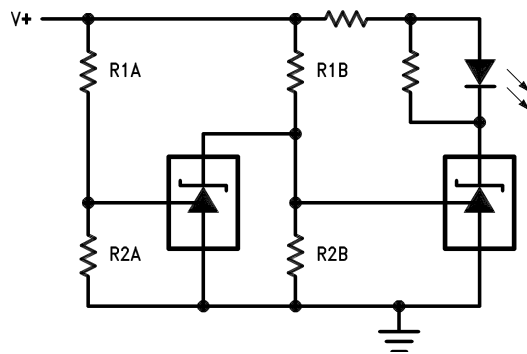


01005520

$$\text{LOW LIMIT} \approx V_{\text{REF}} \left( 1 + \frac{R1B}{R2B} \right) + V_{\text{BE}}$$

$$\text{HIGH LIMIT} \approx V_{\text{REF}} \left( 1 + \frac{R1A}{R2A} \right)$$

Voltage Monitor



01005521

$$\text{LOW LIMIT} \approx V_{\text{REF}} \left( 1 + \frac{R1B}{R2B} \right)$$

$$\text{HIGH LIMIT} \approx V_{\text{REF}} \left( 1 + \frac{R1A}{R2A} \right)$$

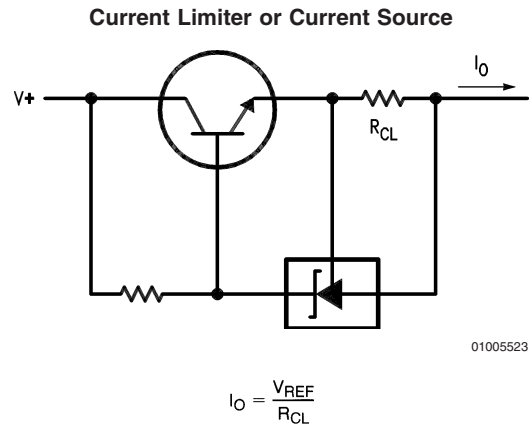
LED ON WHEN  
LOW LIMIT < V+ < HIGH LIMIT

## Typical Applications (Continued)



01005522

$$\text{DELAY} = R \cdot C \cdot \ln \frac{V^+}{(V^+) - V_{\text{REF}}}$$



01005523

$$I_o = \frac{V_{\text{REF}}}{R_{\text{CL}}}$$

### Constant Current Sink



01005524

## Application Info

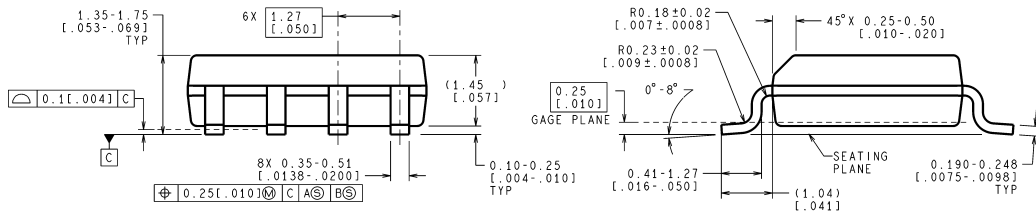
### 1.0 Mounting

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.

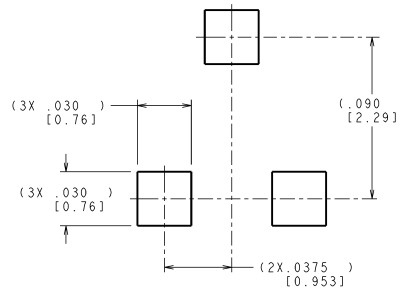
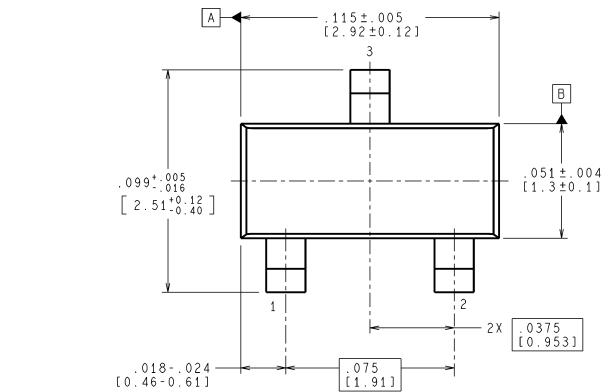
**Physical Dimensions** inches (millimeters) unless otherwise noted



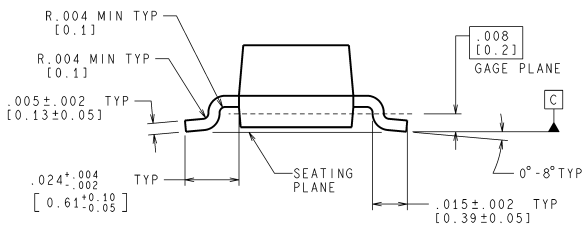
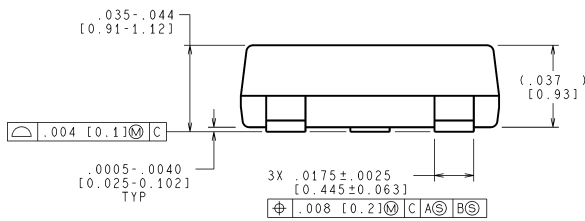
CONTROLLING DIMENSION IS MILLIMETER  
VALUES IN [ ] ARE INCHES  
DIMENSIONS IN ( ) FOR REFERENCE ONLY

M08A (Rev K)

**8-Pin SOIC**  
**NS Package Number M08A**



RECOMENDED LAND PATTERN



CONTROLLING DIMENSION IS INCH  
VALUES IN [ ] ARE MILLIMETERS

MF03A (Rev B)

**SOT-23 Molded Small Outline Transistor Package (M3)**  
**NS Package Number MF03A**

**Physical Dimensions** inches (millimeters) unless otherwise noted (Continued)

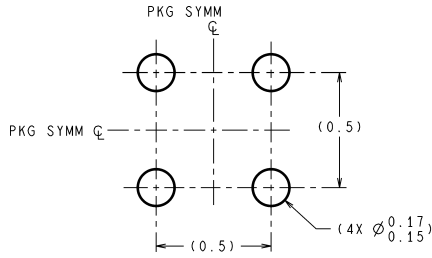


DIMENSIONS ARE IN MILLIMETERS

Z03A (Rev G)

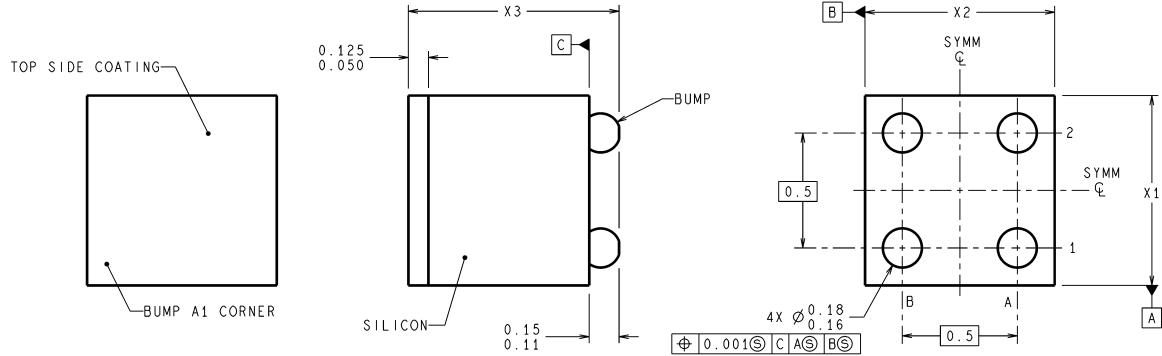
**NS Package Number Z03A**

**Physical Dimensions** inches (millimeters) unless otherwise noted (Continued)



DIMENSIONS ARE IN MILLIMETERS  
DIMENSIONS IN ( ) FOR REFERENCE ONLY

**LAND PATTERN RECOMMENDATION**



BPA04XXX (Rev E)

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**  
**X1 = 0.777 X2 = 0.904 X3 = 0.850**  
**NS Package Number BPA04AFB**

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