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National Semiconductor

November 2000

# LM431
# Adjustable Precision Zener Shunt Regulator

## General Description

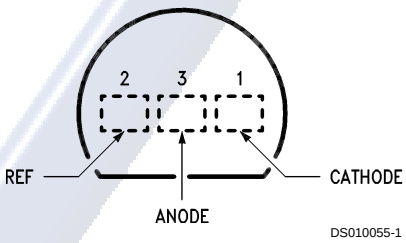
The LM431 is a 3-terminal adjustable shunt regulator with guaranteed temperature stability over the entire temperature range of operation. It is now available in a chip sized package (4-Bump micro SMD) using National's micro SMD package technology. The output voltage may be set at any level greater than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

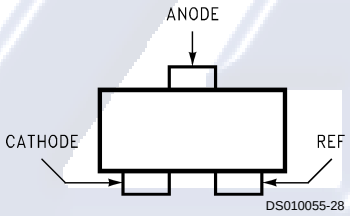
## Connection Diagrams

**TO-92: Plastic Package**



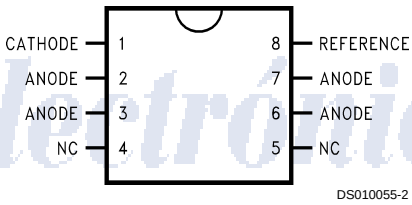

**Top View**

**SOT-23: 3-Lead Small Outline**



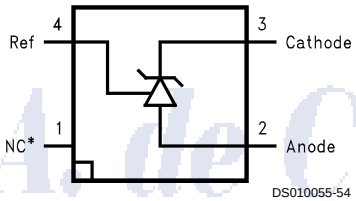

**Top View**

**SO-8: 8-Pin Surface Mount**




**Top view**

**4-Bump micro SMD**




**Top View**
**(bump side down)**

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

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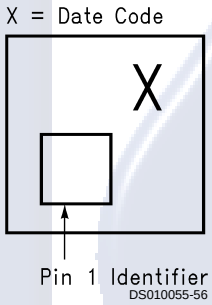
## Ordering Information

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

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

**micro SMD Top View Marking Example**









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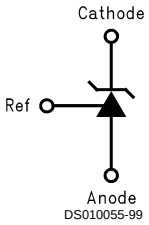
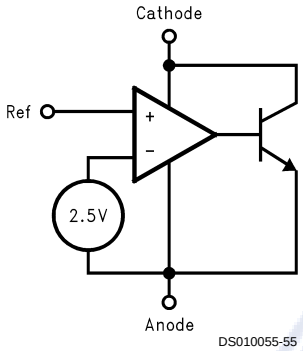
## Symbol and Functional Diagrams




## DC Test Circuits

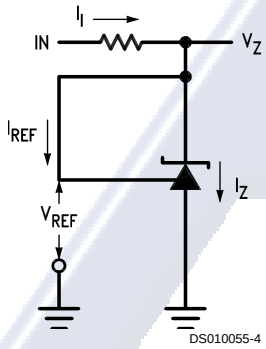
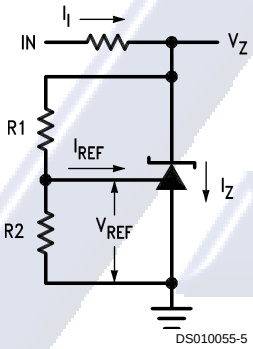



**FIGURE 1. Test Circuit for $V_Z = V_{REF}$**




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

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

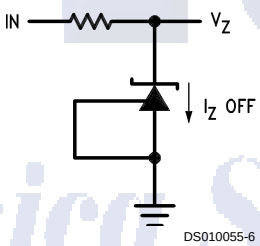



**FIGURE 3. Test Circuit for Off-State Current**



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## 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 (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˚C unless otherwise specified

| Symbol | Parameter | Conditions | | Min | Typ | Max | Units |
|---|---|---|---|---|---|---|---|
| $V_{REF}$ | Reference Voltage | $V_Z = V_{REF}$, $I_I$ = 10 mA<br>LM431A *(Figure 1 )* | | 2.440 | 2.495 | 2.550 | V |
| | | $V_Z = V_{REF}$, $I_I$ = 10 mA<br>LM431B *(Figure 1 )* | | 2.470 | 2.495 | 2.520 | V |
| | | $V_Z = V_{REF}$, $I_I$ = 10 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 mA,<br>$T_A$ = 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 mA *(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 kΩ, $R_2$ = ∞,<br>$I_I$ = 10 mA *(Figure 2 )* | | | 2.0 | 4.0 | µA |
| $\propto I_{REF}$ | Deviation of Reference Input Current over Temperature | $R_1$ = 10 kΩ, $R_2$ = ∞,<br>$I_I$ = 10 mA,<br>$T_A$ = Full Range *(Figure 2 )* | | | 0.4 | 1.2 | µA |
| $I_{Z(MIN)}$ | Minimum Cathode Current for Regulation | $V_Z = V_{REF}$ *(Figure 1 )* | | | 0.4 | 1.0 | mA |
| $I_{Z(OFF)}$ | Off-State Current | $V_Z$ = 36V, $V_{REF}$ = 0V *(Figure 3 )* | | | 0.3 | 1.0 | µA |
| $r_Z$ | Dynamic Output Impedance (Note 6) | $V_Z = V_{REF}$, LM431A,<br>Frequency = 0 Hz *(Figure 1 )* | | | | 0.75 | Ω |
| | | $V_Z = V_{REF}$, LM431B, LM431C<br>Frequency = 0 Hz *(Figure 1 )* | | | | 0.50 | Ω |

**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.

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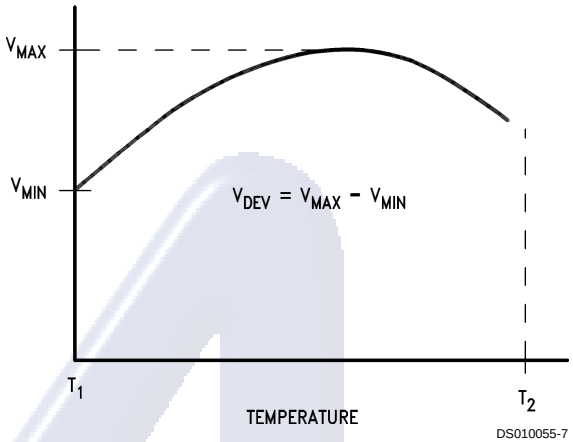
## LM431
## Electrical Characteristics (Continued)




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

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

Where:

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

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

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

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

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

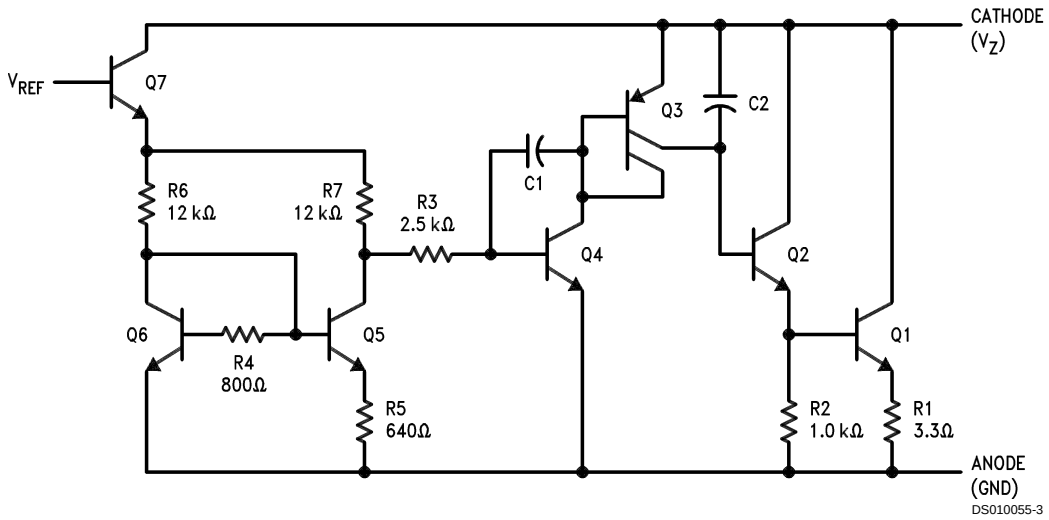
$$r_Z = \frac{\Delta V_Z}{\Delta I_Z}$$

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:

$$r_Z = \frac{\Delta V_Z}{\Delta I_Z} \cong \left[r_Z\left(1 + \frac{R1}{R2}\right)\right]$$



## Equivalent Circuit





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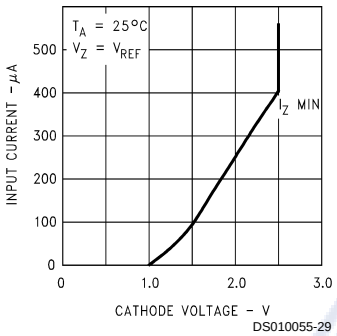
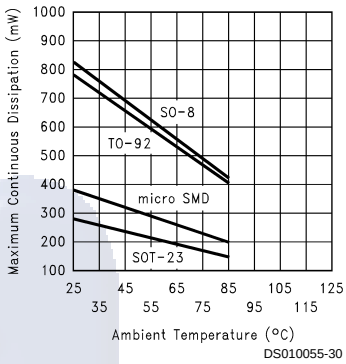
# Typical Performance Characteristics

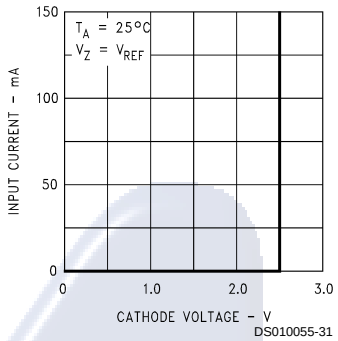
### Input Current vs $V_Z$



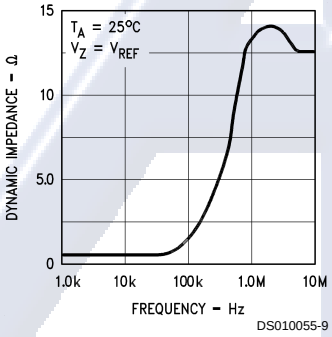

### Thermal Information

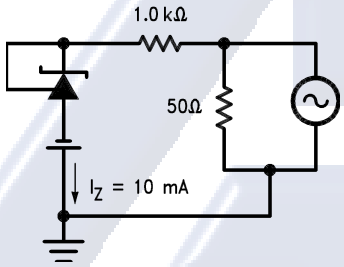



### Input Current vs $V_Z$

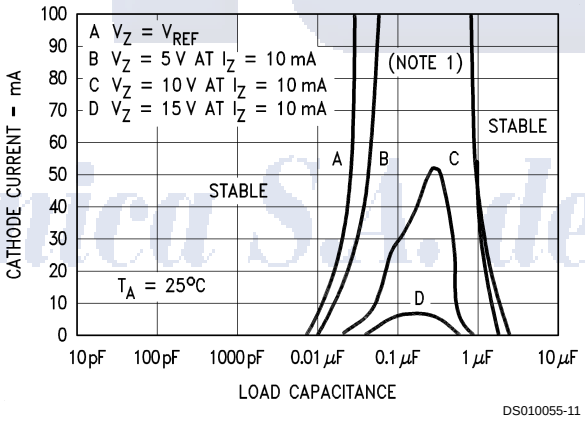



### Dynamic Impedance vs Frequency



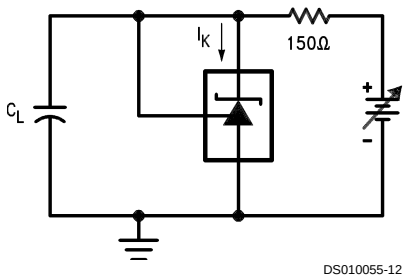




### Stability Boundary Conditions

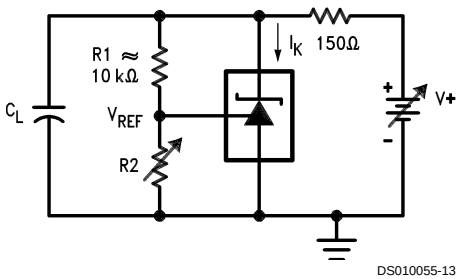



**Note:** The areas under the curves represent conditions that may cause the device to oscillate. For curves B, C, and D, R2 and $V^+$ were adjusted to establish the initial $V_Z$ and $I_Z$ conditions with $C_L$ = 0. $V^+$ and $C_L$ were then adjusted to determine the ranges of stability.

### Test Circuit for Curve A Above




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







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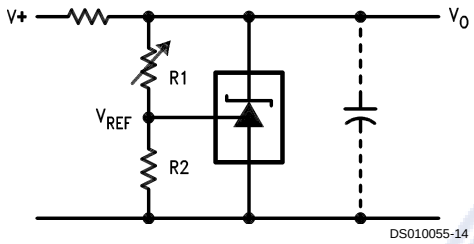
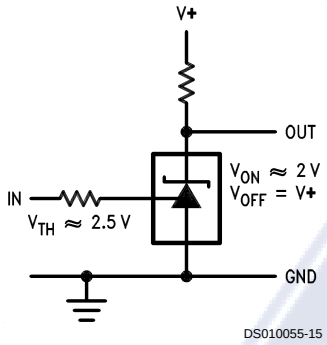
## Typical Applications

### Shunt Regulator

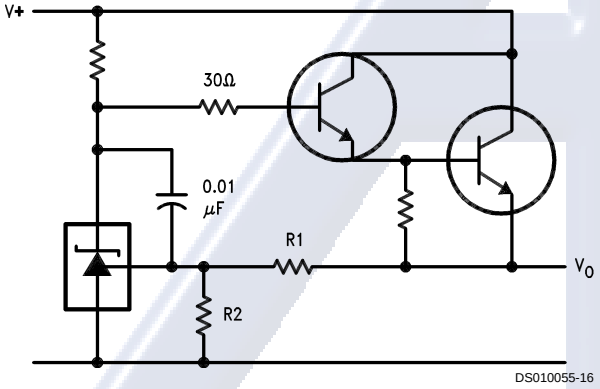



$$V_O \approx \left(1 + \frac{R1}{R2}\right) V_{REF}$$

### Single Supply Comparator with Temperature Compensated Threshold

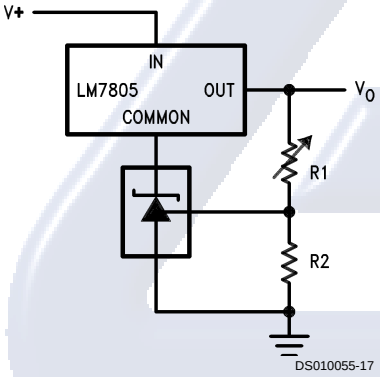



### Series Regulator




$$V_O \approx \left(1 + \frac{R1}{R2}\right) V_{REF}$$

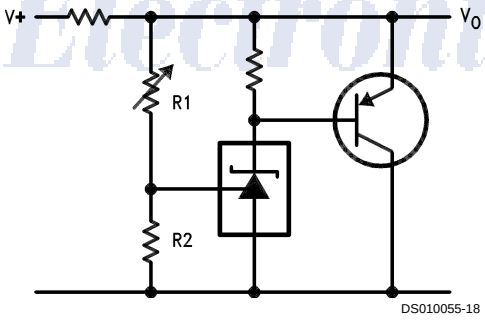
### Output Control of a Three Terminal Fixed Regulator




$$V_O = \left(1 + \frac{R1}{R2}\right) V_{REF}$$

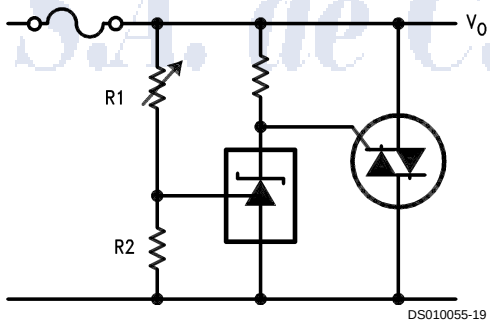
$$V_{O\ MIN} = V_{REF} + 5V$$

### Higher Current Shunt Regulator




$$V_O \approx \left(1 + \frac{R1}{R2}\right) V_{REF}$$

### Crow Bar




$$V_{LIMIT} \approx \left(1 + \frac{R1}{R2}\right) V_{REF}$$



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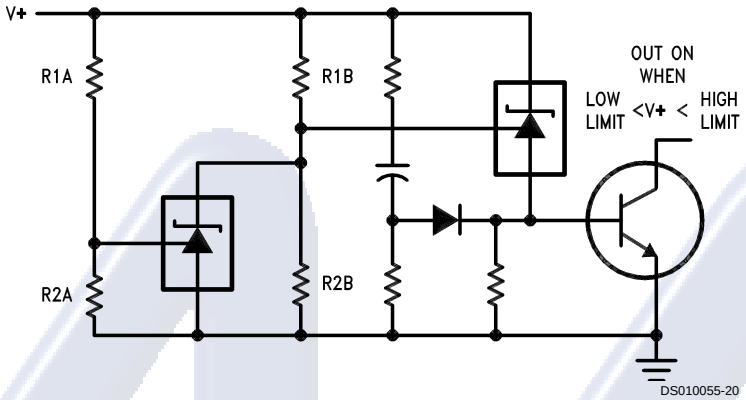
## Typical Applications (Continued)

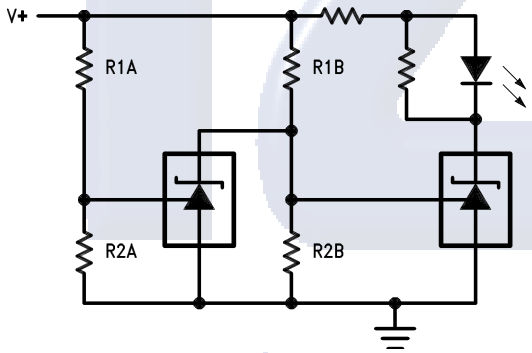
**Over Voltage/Under Voltage Protection Circuit**




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

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

**Voltage Monitor**




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

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

LED ON WHEN
LOW LIMIT < $V^+$ < HIGH LIMIT



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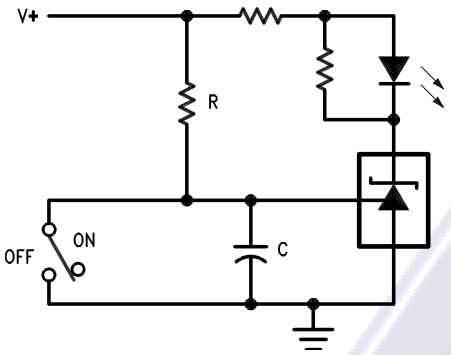
## Typical Applications (Continued)

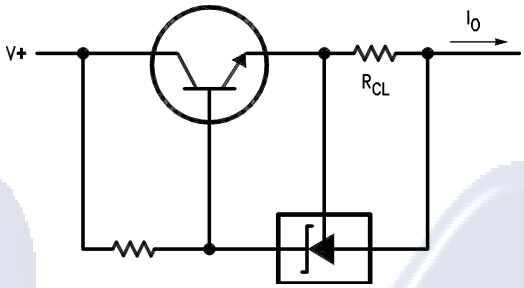
**Delay Timer**




DS010055-22

$$\text{DELAY} = R \bullet C \bullet \ell n \frac{V+}{(V^+) - V_{REF}}$$

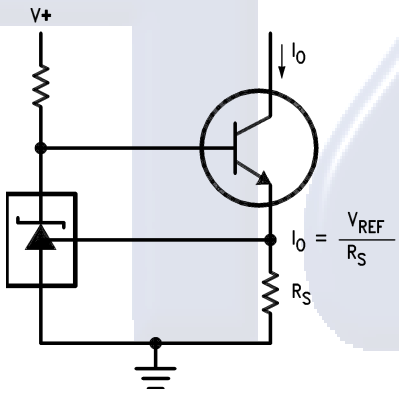
**Current Limiter or Current Source**




DS010055-23

$$I_O = \frac{V_{REF}}{R_{CL}}$$

**Constant Current Sink**

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## 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 1 (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.




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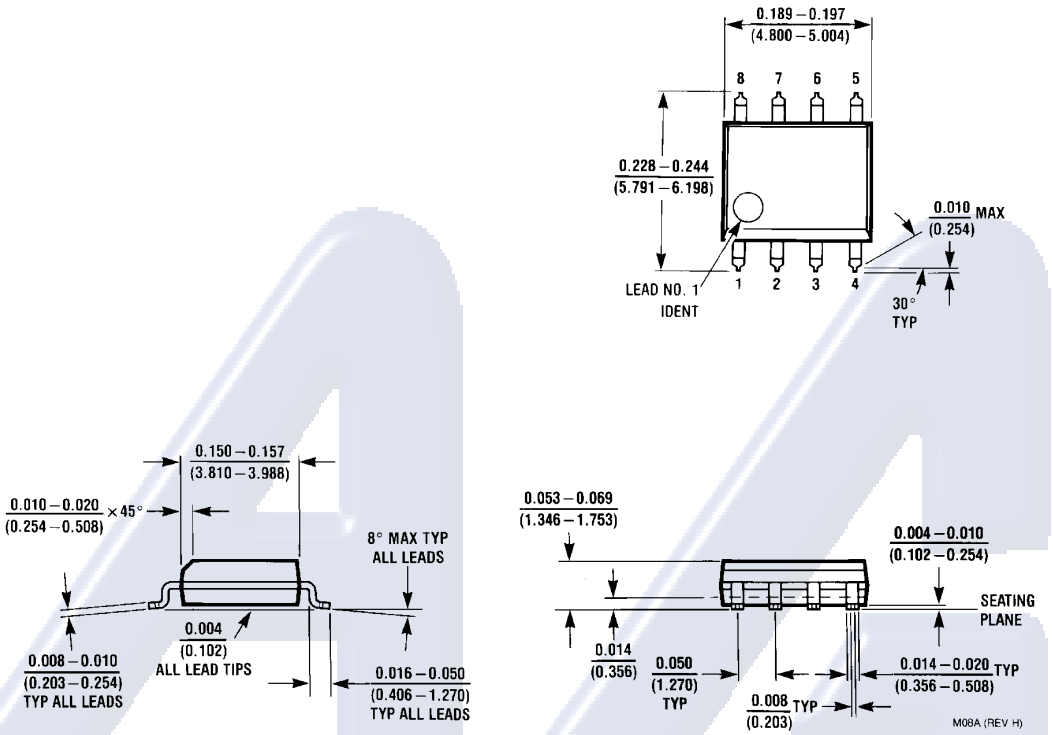
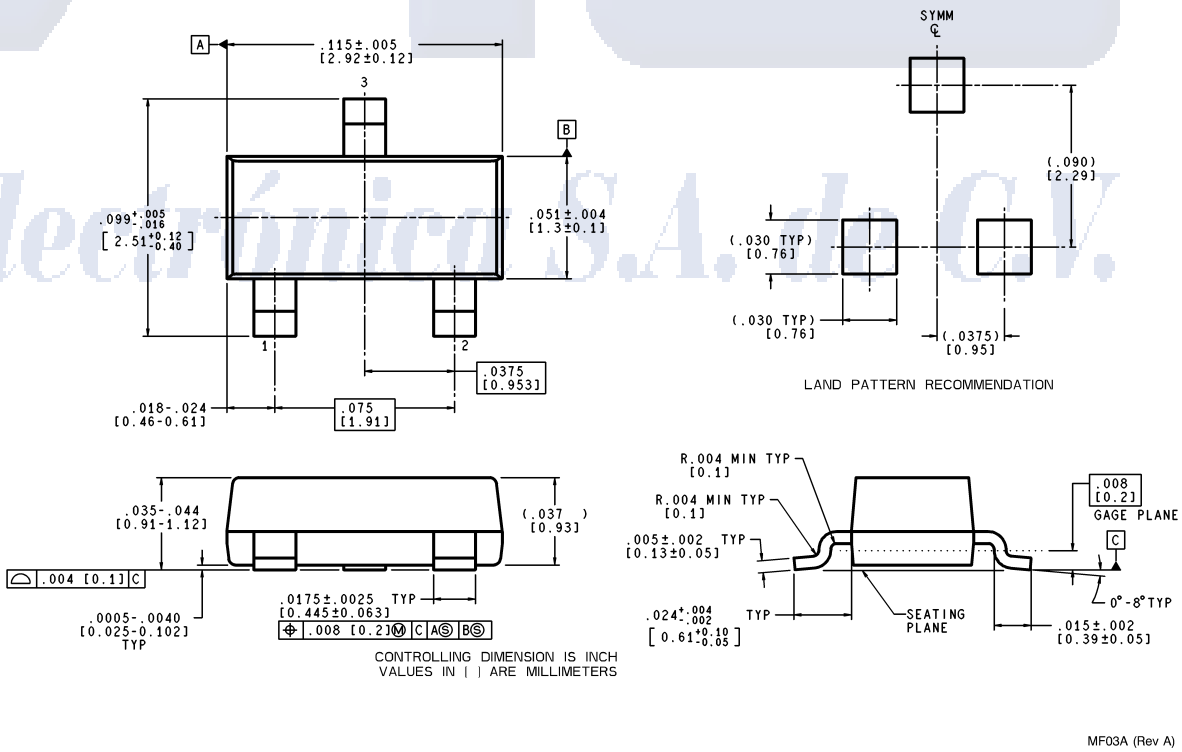
## Physical Dimensions inches (millimeters) unless otherwise noted




**NS Package Number M08A**




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

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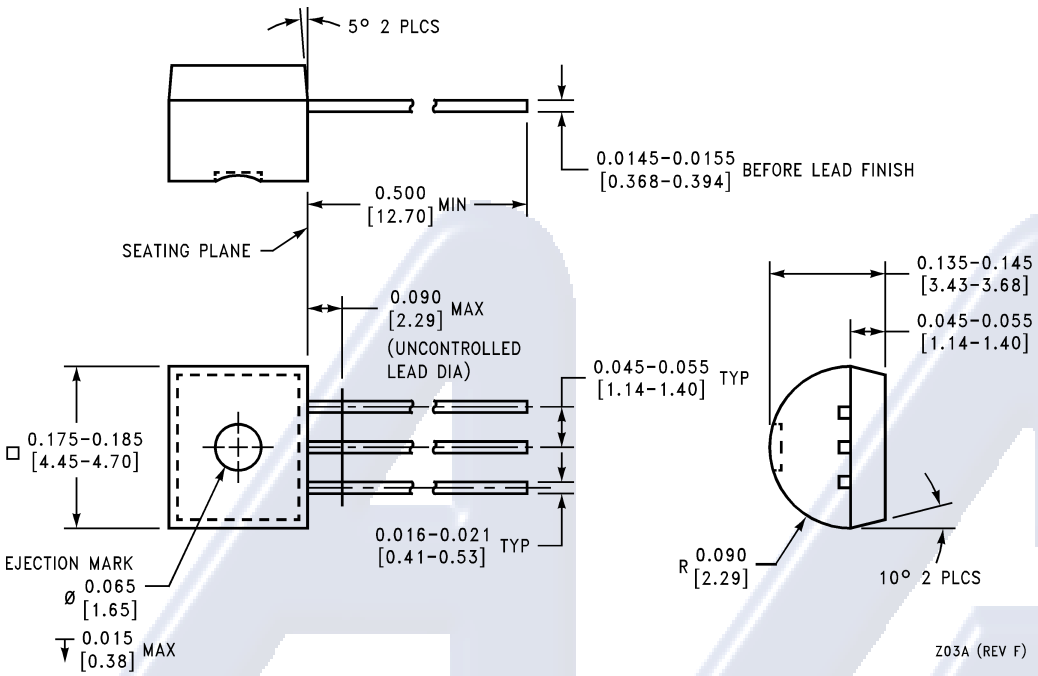
## Physical Dimensions inches (millimeters) unless otherwise noted (Continued)




**NS Package Number Z03A**



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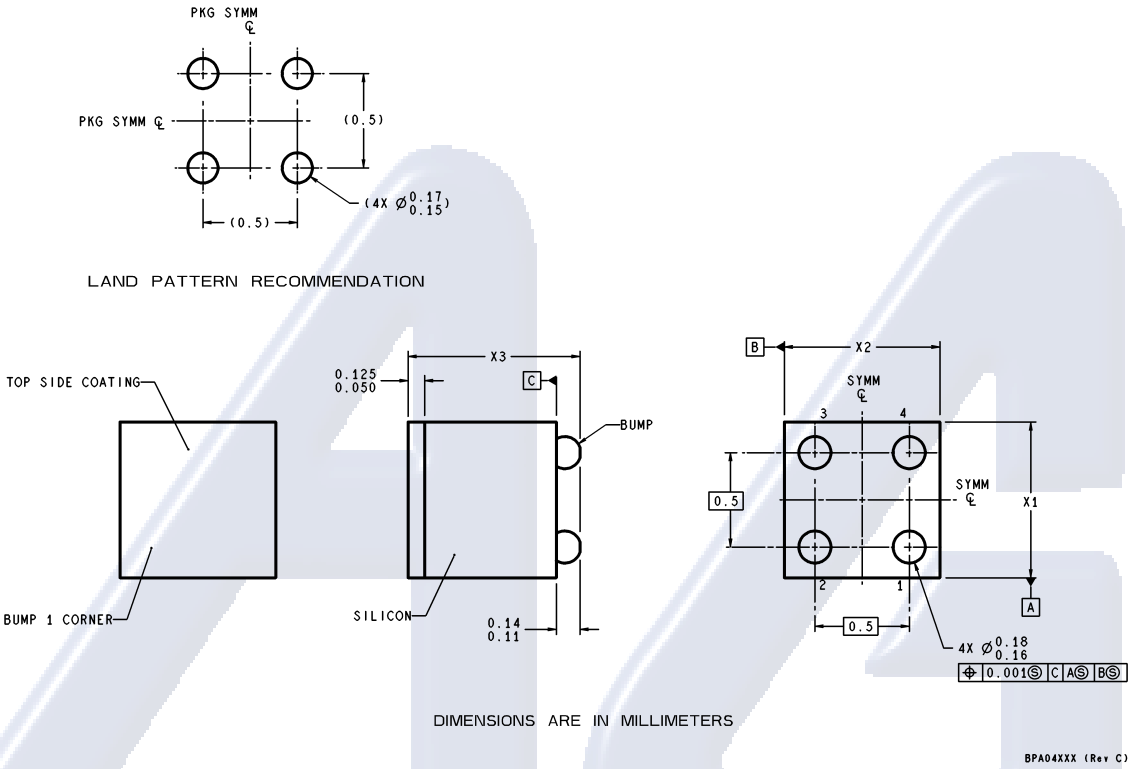
## Physical Dimensions inches (millimeters) unless otherwise noted (Continued)




NOTES: UNLESS OTHERWISE SPECIFIED

1. EPOXY COATING
2. 63Sn/37Pb EUTECTIC BUMP
3. RECOMMEND NON-SOLDER MASK DEFINED LANDING PAD.
4. PIN 1 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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## Notes



**LIFE SUPPORT POLICY**

NATIONAL'S PRODUCTS ARE NOT AUTHORIZED FOR USE AS CRITICAL COMPONENTS IN LIFE SUPPORT DEVICES OR SYSTEMS WITHOUT THE EXPRESS WRITTEN APPROVAL OF THE PRESIDENT AND GENERAL COUNSEL OF NATIONAL SEMICONDUCTOR CORPORATION. As used herein:

1. Life support devices or systems are devices or systems which, (a) are intended for surgical implant into the body, or (b) support or sustain life, and whose failure to perform when properly used in accordance with instructions for use provided in the labeling, can be reasonably expected to result in a significant injury to the user.
2. A critical component is any component of a life support device or system whose failure to perform can be reasonably expected to cause the failure of the life support device or system, or to affect its safety or effectiveness.

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