

April 1998

**LM431****Adjustable Precision Zener Shunt Regulator****General Description**

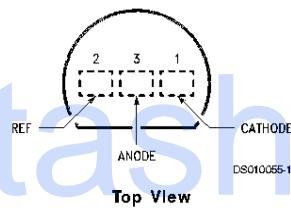
The LM431 is a 3-terminal adjustable shunt regulator with guaranteed temperature stability over the entire temperature range of operation. The output voltage may be set at any level greater than 2.5V ( $V_{REF}$ ) up to 36V merely by selecting two external resistors that act as a voltage divided network. Due to the sharp turn-on characteristics this device is an excellent replacement for many zener diode applications.

**Features**

- Average temperature coefficient 50 ppm/ $^{\circ}\text{C}$
- Temperature compensated for operation over the full temperature range
- Programmable output voltage
- Fast turn-on response
- Low output noise

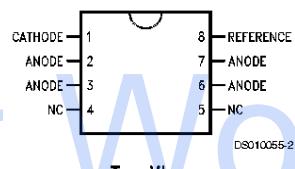
**Connection Diagrams**

TO-92: Plastic Package



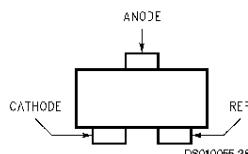
Top View  
Order Number LM431ACZ, LM431AIZ,  
LM431BCZ, LM431BIZ, LM431CCZ  
or LM431CIZ

SO-8: 8-Pin Surface Mount



Top View  
Order Number LM431ACM, LM431AIM,  
LM431BCM, LM431BIM, LM431CCM  
or LM431CIM

SOT-23: 3-Lead Small Outline



Top View  
Order Number LM431ACM3, LM431AIM3,  
LM431BCM3, LM431BIM3, LM431CCM3  
or LM431CIM3

**Ordering Information** (Note 1)

Package	Typical Accuracy			Temperature Range
	0.5%	1%	2%	
TO-92	LM431CCZ	LM431BCZ	LM431ACZ	0°C to +70°C
	LM431CIZ	LM431BIZ	LM431AIZ	-40°C to +85°C
SO-8	LM431CCM	LM431BCM	LM431ACM	0°C to +70°C
	LM431CIM	LM431BIM	LM431AIM	-40°C to +85°C
SOT-23	LM431CCM3	LM431BCM3	LM431ACM3	0°C to +70°C
	LM431CIM3	LM431BIM3	LM431AIM3	-40°C to +85°C

Note 1: See Table 1 for package marking for SOT-23.

### 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
Lead Temperature	
TO-92 Package/SO-8 Package/SOT-23 Package (Soldering, 10 sec.)	265°C
Internal Power Dissipation (Notes 3, 4)	
TO-92 Package	0.78W
SO-8 Package	0.81W
SOT-23 Package	0.28W

Cathode Voltage	37V
Continuous Cathode Current	-10 mA to +150 mA
Reference Voltage	-0.5V
Reference Input Current	10 mA

### 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	$V_Z = V_{REF}, I_i = 10 \text{ mA}$ LM431A (Figure 1)	2.440	2.495	2.550	V
		$V_Z = V_{REF}, I_i = 10 \text{ mA}$ LM431B (Figure 1)	2.470	2.495	2.520	V
		$V_Z = V_{REF}, I_i = 10 \text{ mA}$ LM431C (Figure 1)	2.485	2.500	2.510	V
$V_{DEV}$	Deviation of Reference Input Voltage Over Temperature (Note 5)	$V_Z = V_{REF}, I_i = 10 \text{ mA},$ $T_A = \text{Full Range}$ (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	$I_Z = 10 \text{ mA}$	-1.4	-2.7		mV/V
		$V_Z$ from $V_{REF}$ to 10V (Figure 2)	-1.0	-2.0		
$I_{REF}$	Reference Input Current	$R_1 = 10 \text{ k}\Omega, R_2 = \infty,$ $I_i = 10 \text{ mA}$ (Figure 2)		2.0	4.0	$\mu\text{A}$
$\% I_{REF}$	Deviation of Reference Input Current over Temperature	$R_1 = 10 \text{ k}\Omega, R_2 = \infty,$ $I_i = 10 \text{ mA},$ $T_A = \text{Full Range}$ (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 3)		0.3	1.0	$\mu\text{A}$
$r_Z$	Dynamic Output Impedance (Note 6)	$V_Z = V_{REF}, \text{LM431A},$ Frequency = 0 Hz (Figure 1)			0.75	$\Omega$
		$V_Z = V_{REF}, \text{LM431B, LM431C}$ Frequency = 0 Hz (Figure 1)			0.50	$\Omega$

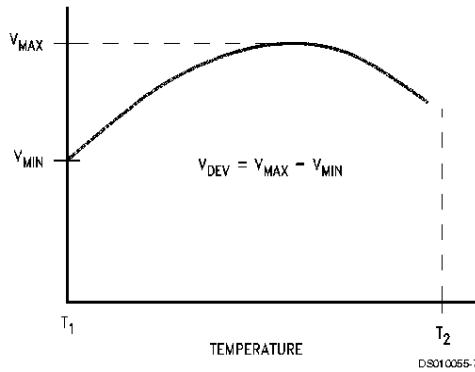
**Note 2:** Absolute Maximum Ratings indicate limits beyond which damage to the device may occur. Electrical specifications do not apply when operating the device beyond its rated operating conditions.

**Note 3:**  $T_J \text{ Max} = 150^\circ\text{C}$ .

**Note 4:** Ratings apply to ambient temperature at  $25^\circ\text{C}$ . Above this temperature, derate the TO-92 at  $6.2 \text{ mW}/^\circ\text{C}$ , the SO-8 at  $6.5 \text{ mW}/^\circ\text{C}$ , and the SOT-23 at  $2.2 \text{ mW}/^\circ\text{C}$ .

## LM431 Electrical Characteristics (Continued)

**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,  $\alpha V_{REF}$ , is defined as:

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

Where:

$T_2 - T_1$  = full temperature change

$\alpha V_{REF}$  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.

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

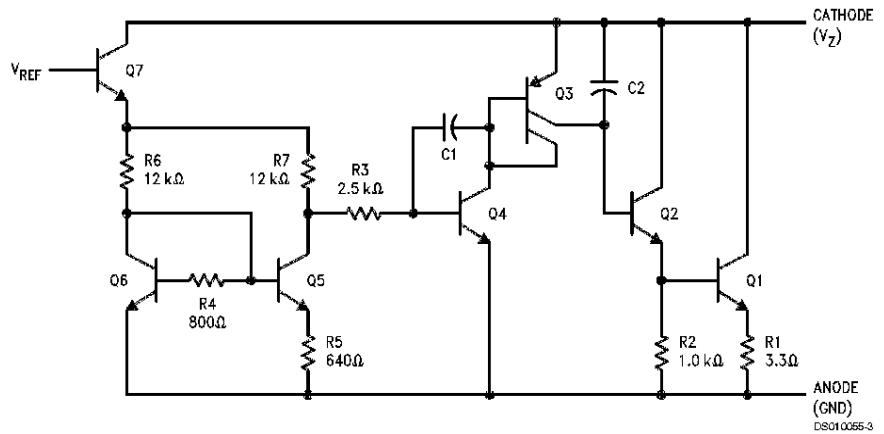
**Note 6:** The dynamic output impedance,  $r_Z$ , is defined as:

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

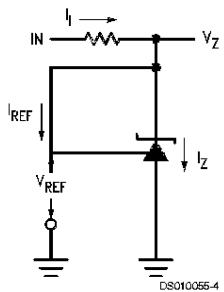
When the device is programmed with two external resistors,  $R1$  and  $R2$ , (see *Figure 2*), the dynamic output impedance of the overall circuit,  $r_Z$ , is defined as:

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

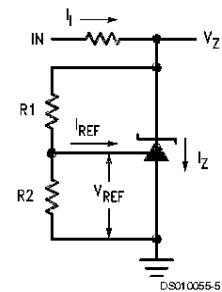
### Equivalent Circuit



### DC Test Circuits

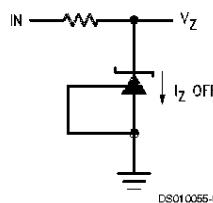


**FIGURE 1. Test Circuit for  $V_Z = V_{REF}$**



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

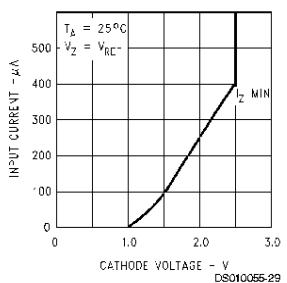
**FIGURE 2. Test Circuit for  $V_Z > V_{REF}$**



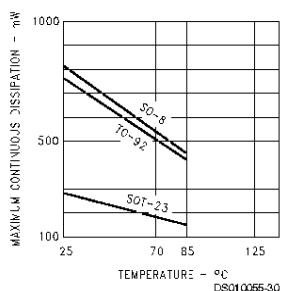
**FIGURE 3. Test Circuit for Off-State Current**

## Typical Performance Characteristics

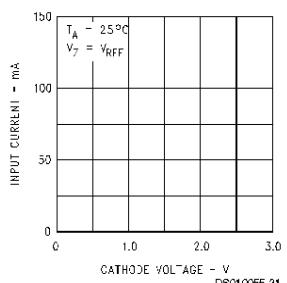
**Input Current vs  $V_z$**



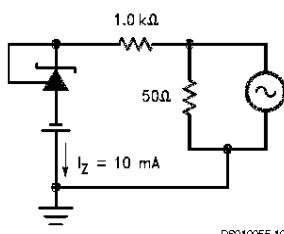
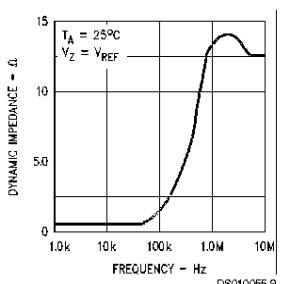
**Thermal Information**



**Input Current vs  $V_z$**

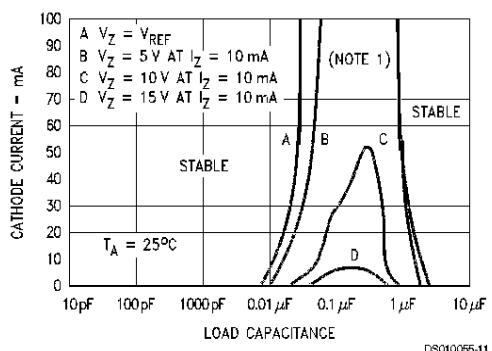


**Dynamic Impedance vs Frequency**



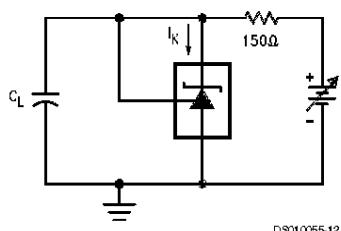
DS010055-10

**Stability Boundary Conditions**



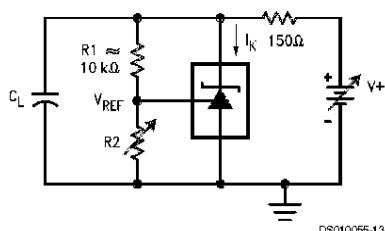
**Note:** The areas under the curves represent conditions that may cause the device to oscillate. For curves B, C, and D, R2 and  $V^+$  were adjusted to establish the initial  $V_z$  and  $I_z$  conditions with  $C_L = 0$ .  $V^+$  and  $C_L$  were then adjusted to determine the ranges of stability.

**Test Circuit for Curve A Above**



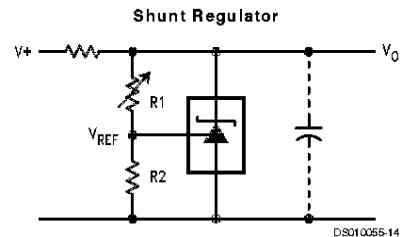
DS010055-12

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



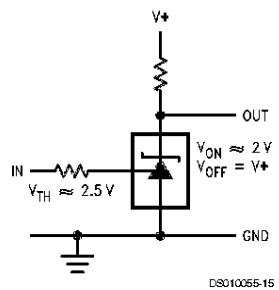
DS010055-13

## Typical Applications



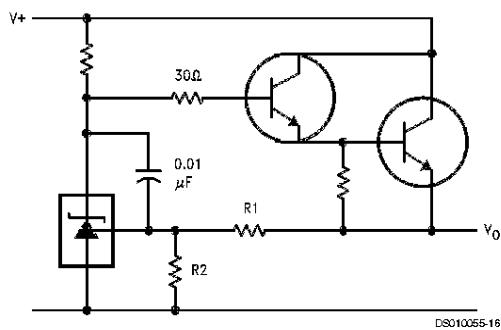
$$V_O \approx \left(1 + \frac{R_1}{R_2}\right) V_{REF}$$

### Single Supply Comparator with Temperature Compensated Threshold



DS010055-15

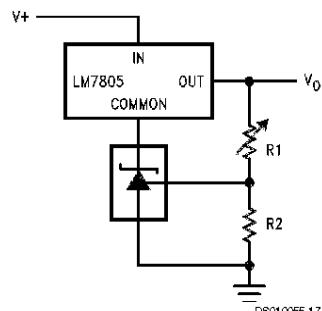
### Series Regulator



DS010055-16

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

### Output Control of a Three Terminal Fixed Regulator

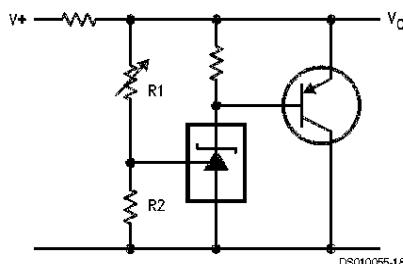


DS010055-17

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

$$V_O \text{ MIN} = V_{REF} + 5V$$

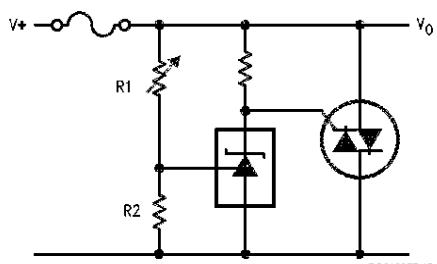
### Higher Current Shunt Regulator



DS010055-18

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

### Crow Bar

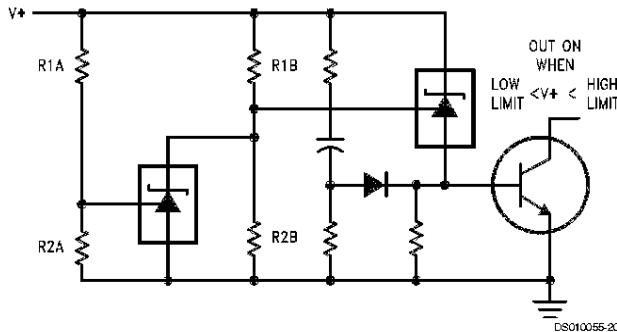


DS010055-19

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

## Typical Applications (Continued)

Over Voltage/Under Voltage Protection Circuit

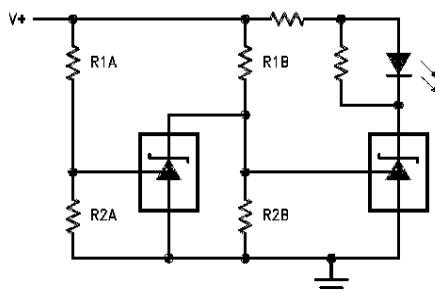


DS010055-20

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

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

Voltage Monitor



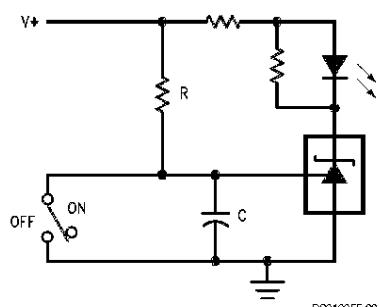
DS010055-21

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

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

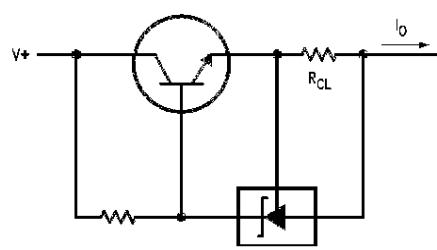
### Typical Applications (Continued)

**Delay Timer**



DS010055-22

**Current Limiter or Current Source**

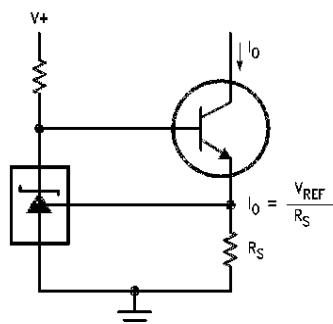


DS010055-23

$$I_0 = \frac{V_{REF}}{R_{CL}}$$

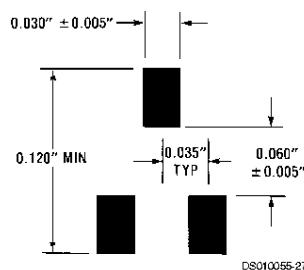
$$\text{DELAY} = R \cdot C \cdot \ln \frac{V_i}{(V_i) - V_{REF}}$$

**Constant Current Sink**



DS010055-24

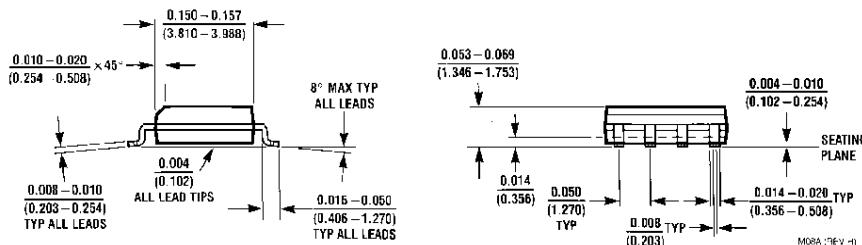
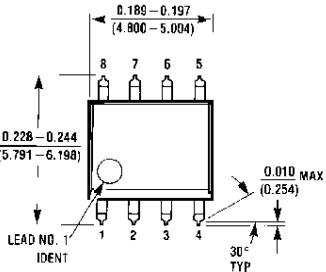
### Recommended Solder Pads for SOT-23 Package



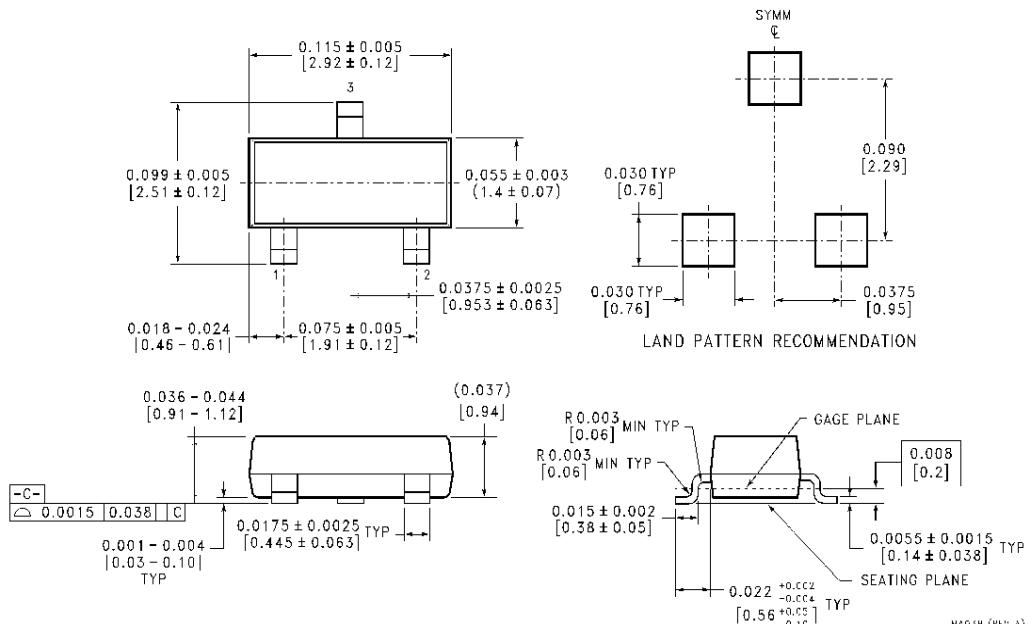
**TABLE 1. Package Marking for SOT-23**

Order Number	Top Mark
LM431ACM3	N1F
LM431AIM3	N1E
LM431BCM3	N1D
LM431BIM3	N1C
LM431CCM3	N1B
LM431CIM3	N1A

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



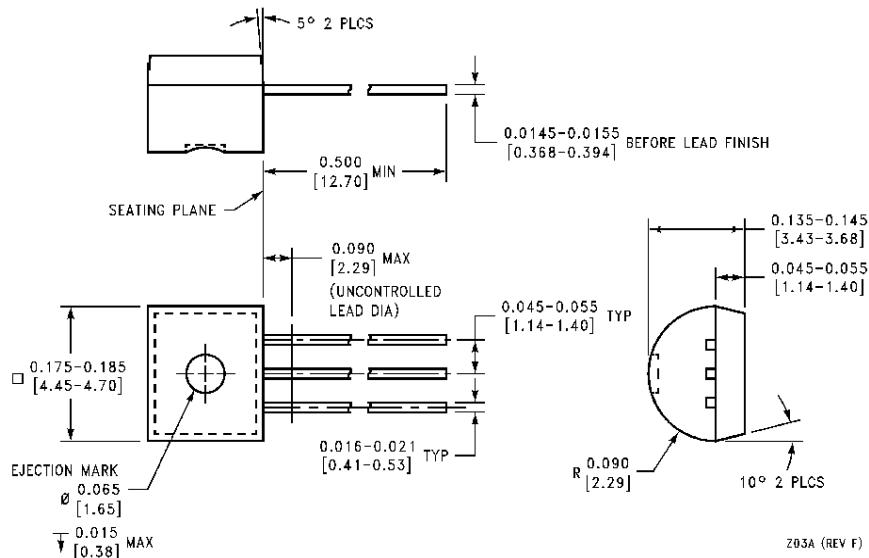
Order Number LM431ACM, LM431AIM,  
LM431BCM, LM431BIM, LM431CCM, or LM431CIM  
NS Package Number M08A



SOT-23 Molded Small Outline Transistor Package (M3)  
Order Number LM431ACM3, LM431AIM3,  
LM431BCM3, LM431BIM3, LM431CCM3, or LM431CIM3  
NS Package Number MA03B

## LM431 Adjustable Precision Zener Shunt Regulator

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



**Order Number LM431ACZ, LM431AIZ,  
 LM431BCZ, LM431BIZ, LM431CCZ, or LM431CIZ  
 NS Package Number Z03A**

Z03A (REV F)

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