

## LM431 Adjustable Precision Zener Shunt Regulator

### General Description

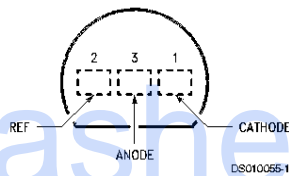
The LM431 is a 3-terminal adjustable shunt regulator with guaranteed temperature stability over the entire temperature range of operation. The output voltage may be set at any level greater than 2.5V ( $V_{REF}$ ) up to 36V merely by selecting two external resistors that act as a voltage divided network.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

### Features

- Average temperature coefficient 50 ppm/°C
- Temperature compensated for operation over the full temperature range
- Programmable output voltage
- Fast turn-on response
- Low output noise

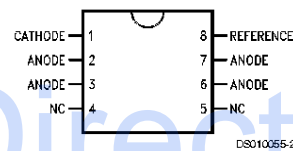
### Connection Diagrams

**TO-92: Plastic Package**



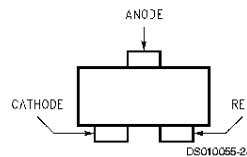
**Top View**  
Order Number LM431ACZ, LM431AIZ,  
LM431BCZ, LM431BIZ, LM431CCZ  
or LM431CIZ

**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 LM431CIZ	LM431BCZ LM431BIZ	LM431ACZ LM431AIZ	0°C to +70°C -40°C to +85°C
SO-8	LM431CCM LM431CIM	LM431BCM LM431BIM	LM431ACM LM431AIM	0°C to +70°C -40°C to +85°C
SOT-23	LM431CCM3 LM431CIM3	LM431BCM3 LM431BIM3	LM431ACM3 LM431AIM3	0°C to +70°C -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	$I_Z = 10\text{ mA}$ , $V_Z$ from $V_{REF}$ to 10V (Figure 2)		-1.4	-2.7	mV/V
		$V_Z$ from 10V to 36V		-1.0	-2.0	
$I_{REF}$	Reference Input Current	$R_1 = 10\text{ k}\Omega$ , $R_2 = \infty$ , $I_I = 10\text{ mA}$ (Figure 2)		2.0	4.0	$\mu\text{A}$
$\infty I_{REF}$	Deviation of Reference Input Current over Temperature	$R_1 = 10\text{ k}\Omega$ , $R_2 = \infty$ , $I_I = 10\text{ mA}$ , $T_A = \text{Full Range}$ (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)	$V_Z = V_{REF}$ , LM431A, Frequency = 0 Hz (Figure 1)			0.75	$\Omega$
		$V_Z = V_{REF}$ , LM431B, LM431C, Frequency = 0 Hz (Figure 1)			0.50	$\Omega$

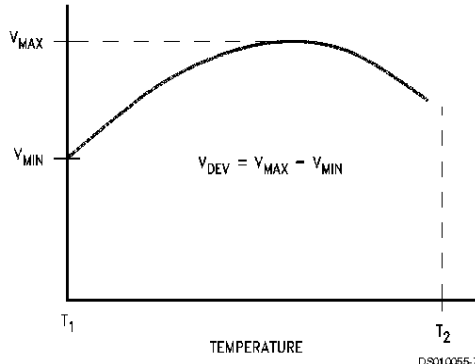
**Note 2:** Absolute Maximum Ratings indicate limits beyond which damage to the device may occur. Electrical specifications do not apply when operating the device beyond its rated operating conditions.

**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 mW/°C, the SO-8 at 6.5 mW/°C, and the SOT-23 at 2.2 mW/°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.

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

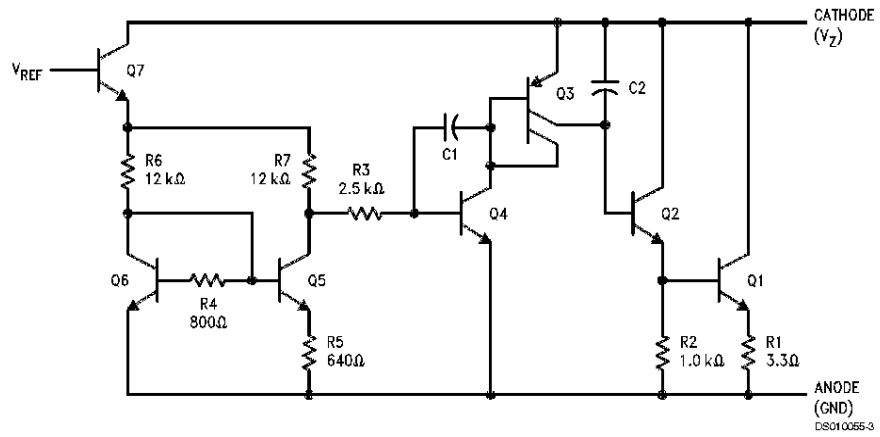
**Note 6:** The dynamic output impedance,  $r_z$ , is defined as:

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

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

$$r_z = \frac{\Delta V_Z}{\Delta I_Z} \sim \left[ r_z \left( 1 + \frac{R_1}{R_2} \right) \right]$$

## Equivalent Circuit



## DC Test Circuits

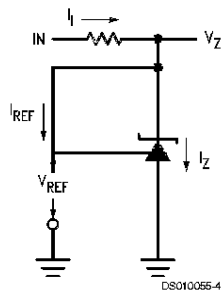
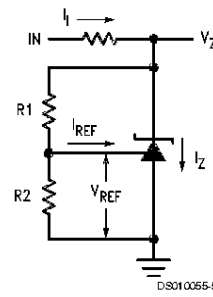


FIGURE 1. Test Circuit for  $V_Z = V_{REF}$



Note:  $V_Z = V_{REF} (1 + R1/R2) + I_{REF} \cdot R1$   
 FIGURE 2. Test Circuit for  $V_Z > V_{REF}$

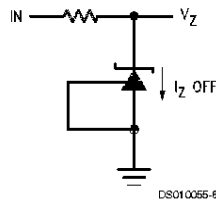
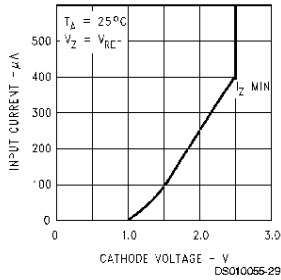


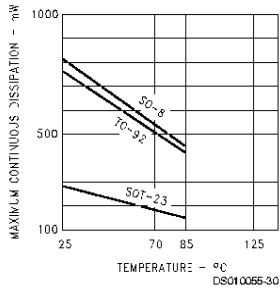
FIGURE 3. Test Circuit for Off-State Current

## Typical Performance Characteristics

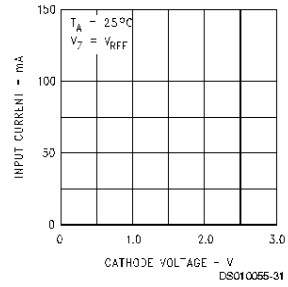
Input Current vs  $V_Z$



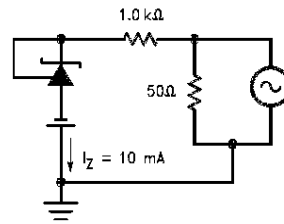
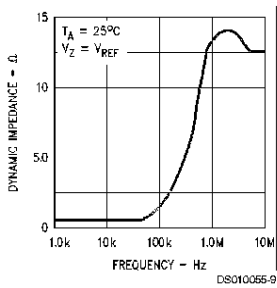
Thermal Information



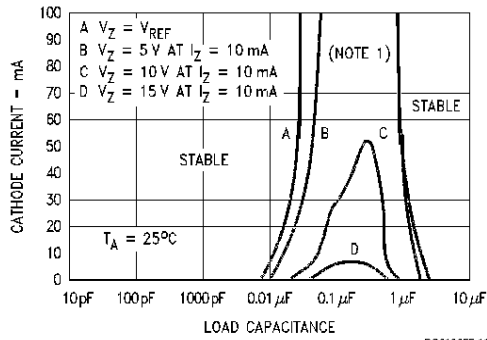
Input Current vs  $V_Z$



Dynamic Impedance vs Frequency

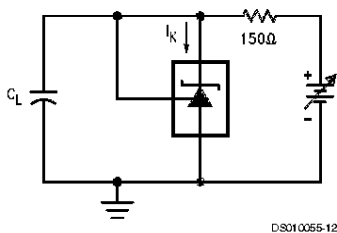


Stability Boundary Conditions

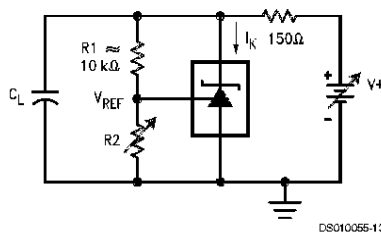


**Note:** The areas under the curves represent conditions that may cause the device to oscillate. For curves B, C, and D,  $R_2$  and  $V^+$  were adjusted to establish the initial  $V_Z$  and  $I_Z$  conditions with  $C_L = 0$ .  $V^+$  and  $C_L$  were then adjusted to determine the ranges of stability.

Test Circuit for Curve A Above

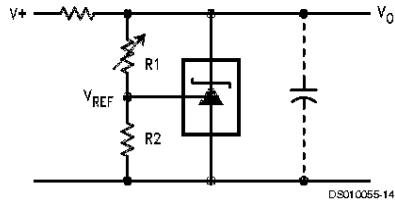


Test Circuit for Curves B, C and D Above



## Typical Applications

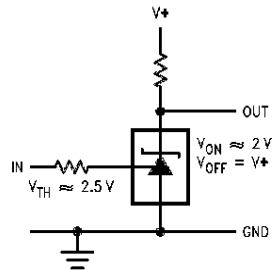
**Shunt Regulator**



DS010055-14

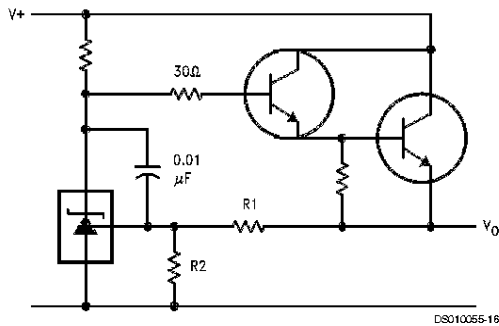
$$V_O \approx \left(1 + \frac{R_1}{R_2}\right) V_{REF}$$

**Single Supply Comparator with Temperature Compensated Threshold**



DS010055-15

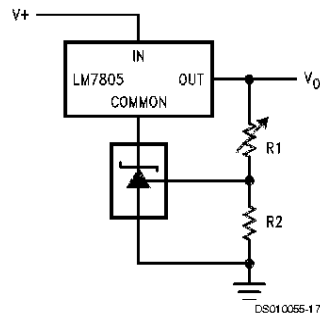
**Series Regulator**



DS010055-16

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

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

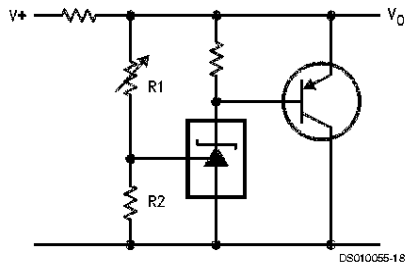


DS010055-17

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

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

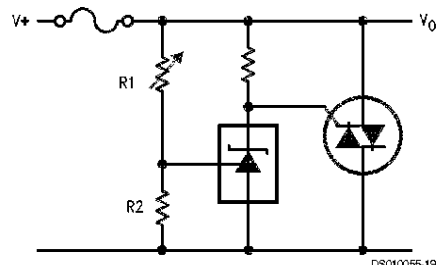
**Higher Current Shunt Regulator**



DS010055-18

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

**Crow Bar**

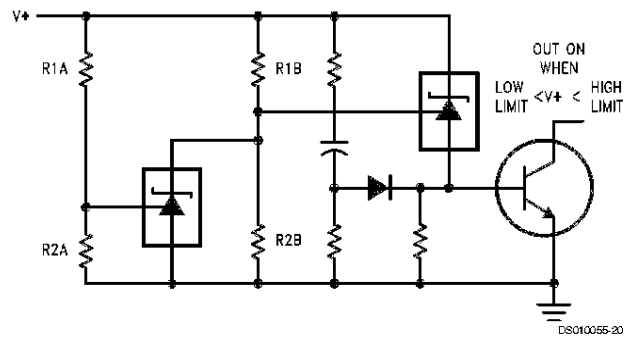


DS010055-19

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

## Typical Applications (Continued)

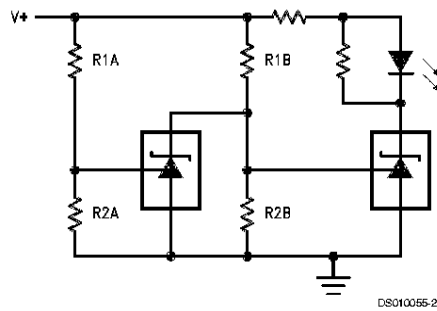
Over Voltage/Under Voltage Protection Circuit



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

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

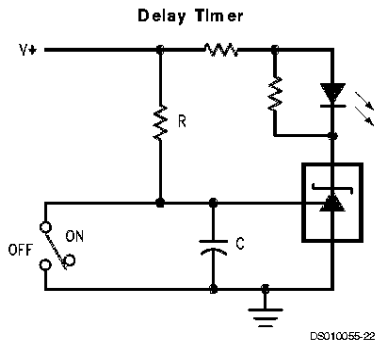
Voltage Monitor



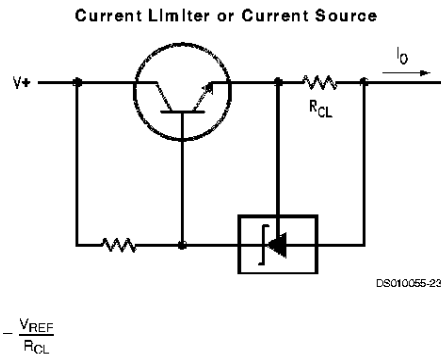
$$\text{LOW LIMIT} \approx V_{\text{REF}} \left( 1 + \frac{R1B}{R2B} \right) \quad \text{LED ON WHEN } \text{LOW LIMIT} < V^+ < \text{HIGH LIMIT}$$

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

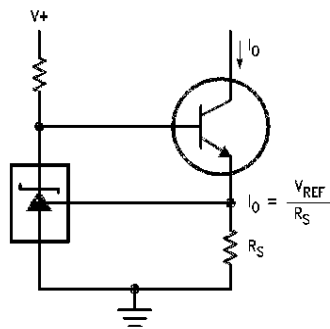
## Typical Applications (Continued)



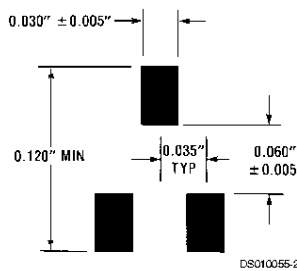
$$\text{DELAY} = R \cdot C \cdot \ln \frac{V_i}{(V_i) - V_{\text{REF}}}$$



### Constant Current Sink



## Recommended Solder Pads for SOT-23 Package

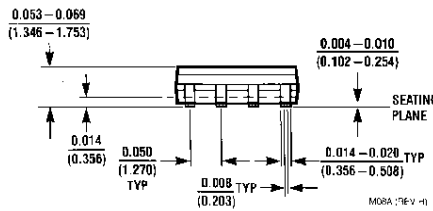
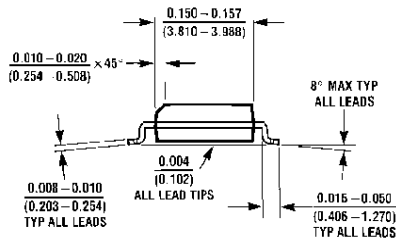
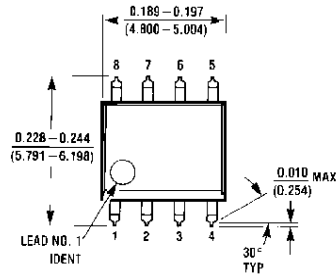


**TABLE 1. Package Marking for SOT-23**

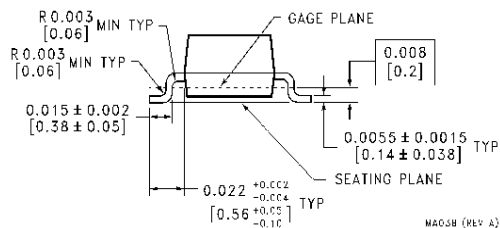
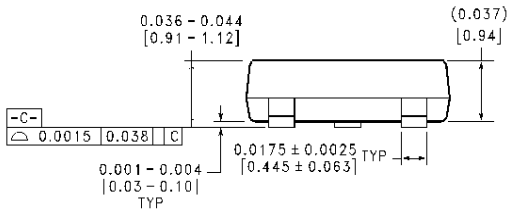
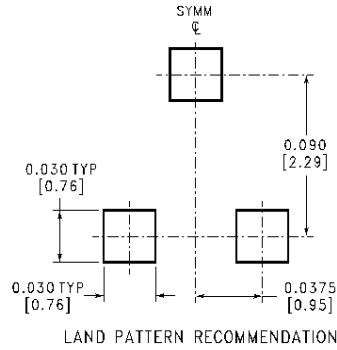
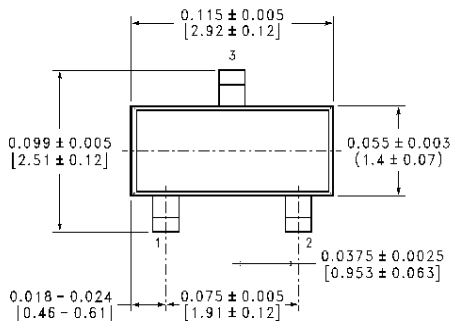
Order Number	Top Mark
LM431ACM3	N1F
LM431AIM3	N1E
LM431BCM3	N1D
LM431BIM3	N1C
LM431CCM3	N1B
LM431CIM3	N1A



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

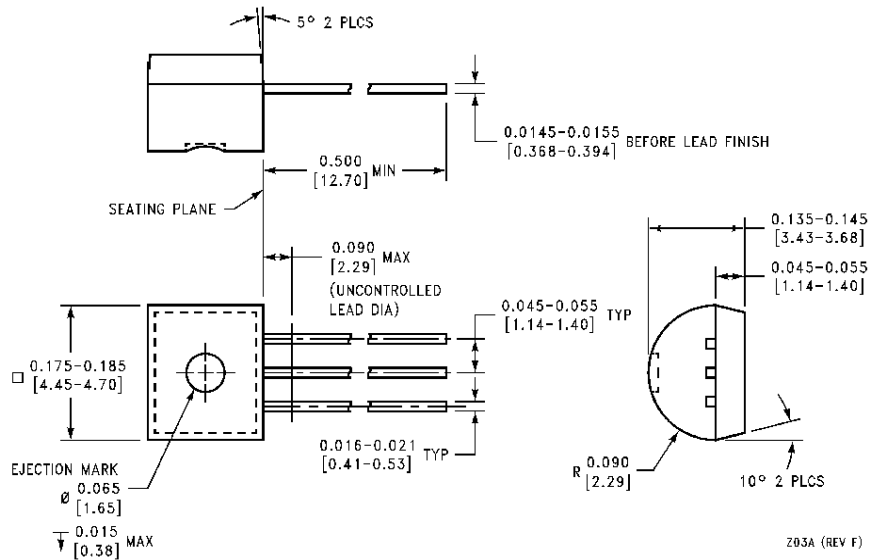


Order Number LM431ACM, LM431AIM,  
LM431BCM, LM431BIM, LM431CCM, or LM431CIM  
NS Package Number M08A



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

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



Order Number **LM431ACZ, LM431AIZ, LM431BCZ, LM431BIZ, LM431CCZ, or LM431CIZ**  
 NS Package Number **Z30A**

Z30A (REV F)

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