

# LM431

## Adjustable Precision Zener Shunt Regulator

### General Description

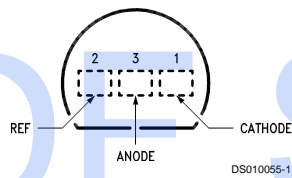
The LM431 is a 3-terminal adjustable shunt regulator with guaranteed temperature stability over the entire temperature range of operation. The output voltage may be set at any level greater than 2.5V ( $V_{REF}$ ) up to 36V merely by selecting two external resistors that act as a voltage divided network. 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

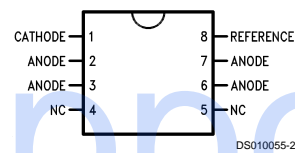
### Connection Diagrams

TO-92: Plastic Package



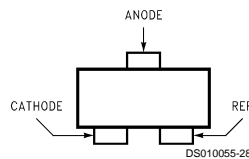
**Top View**  
Order Number LM431ACZ, LM431AIZ,  
LM431BCZ, LM431BIZ, LM431CCZ  
or LM431CIZ

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	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	$I_Z = 10\text{ mA}$ (Figure 2)				mV/V
		$V_Z$ from $V_{REF}$ to 10V		-1.4	-2.7	
		$V_Z$ 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	$\Omega$

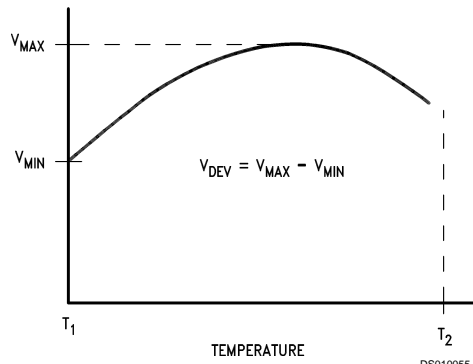
**Note 2:** Absolute Maximum Ratings indicate limits beyond which damage to the device may occur. Electrical specifications do not apply when operating the device beyond its rated operating conditions.

**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/ $^\circ\text{C}$ , the SO-8 at 6.5 mW/ $^\circ\text{C}$ , and the SOT-23 at 2.2 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:

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

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.

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

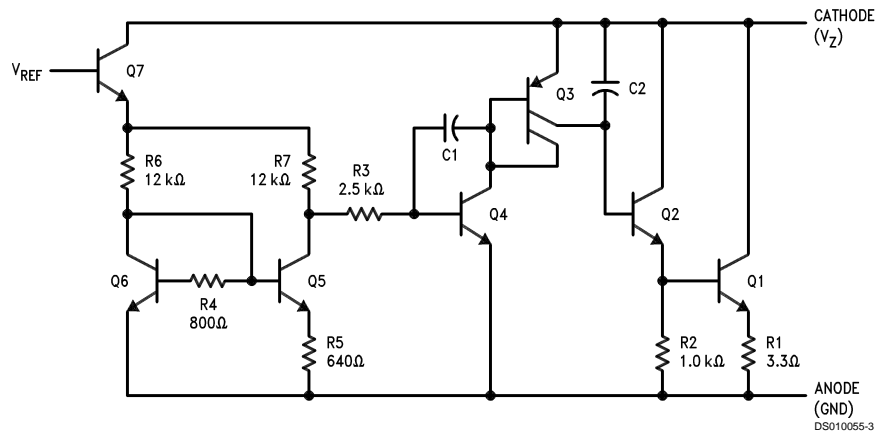
**Note 6:** The dynamic output impedance,  $r_z$ , is defined as:

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

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:

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

## Equivalent Circuit



## DC Test Circuits

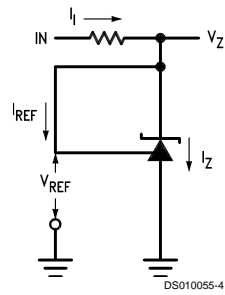
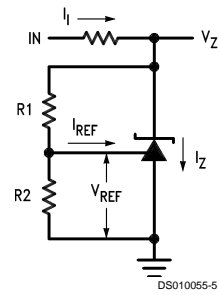


FIGURE 1. Test Circuit for  $V_Z = V_{REF}$



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

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

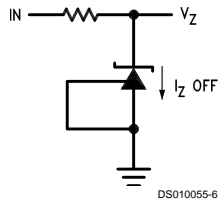
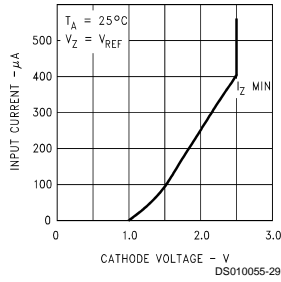


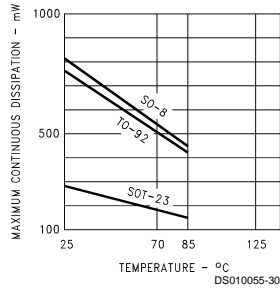
FIGURE 3. Test Circuit for Off-State Current

# Typical Performance Characteristics

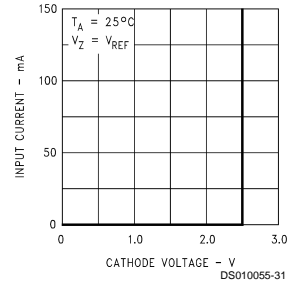
**Input Current vs  $V_Z$**



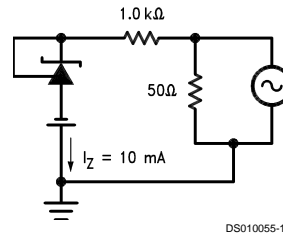
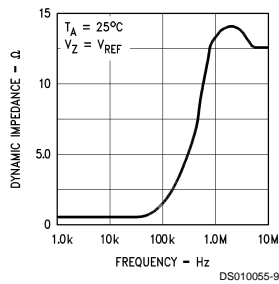
**Thermal Information**



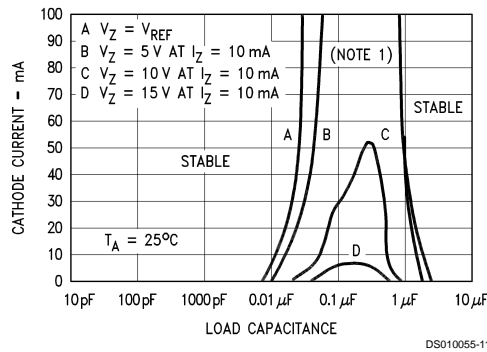
**Input Current vs  $V_Z$**



**Dynamic Impedance vs Frequency**

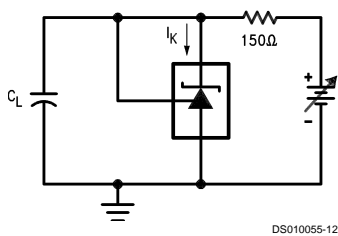


**Stability Boundary Conditions**

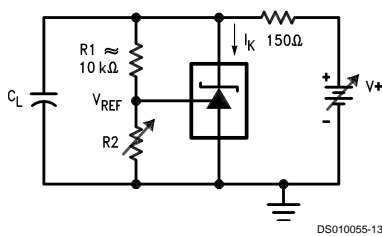


**Note:** The areas under the curves represent conditions that may cause the device to oscillate. For curves B, C, and D,  $R_2$  and  $V^+$  were adjusted to establish the initial  $V_Z$  and  $I_Z$  conditions with  $C_L = 0$ .  $V^+$  and  $C_L$  were then adjusted to determine the ranges of stability.

**Test Circuit for Curve A Above**

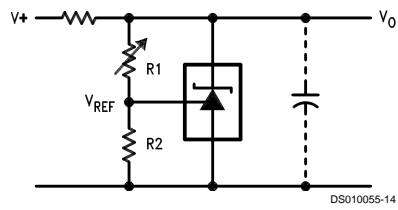


**Test Circuit for Curves B, C and D Above**



## Typical Applications

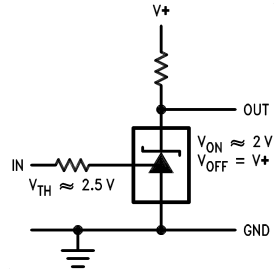
**Shunt Regulator**



DS010055-14

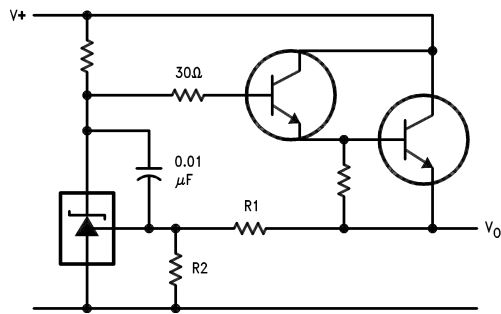
$$V_O \approx \left(1 + \frac{R_1}{R_2}\right) V_{REF}$$

**Single Supply Comparator with Temperature Compensated Threshold**



DS010055-15

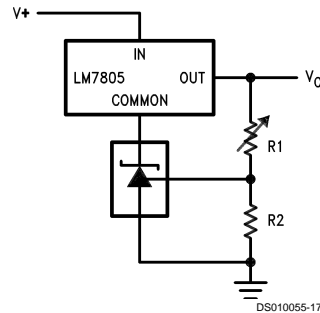
**Series Regulator**



DS010055-16

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

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

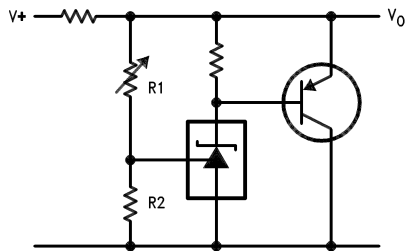


DS010055-17

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

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

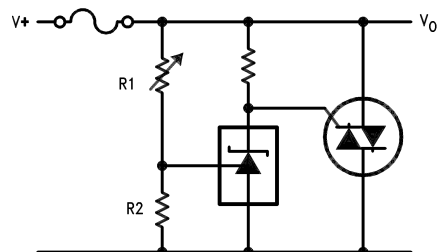
**Higher Current Shunt Regulator**



DS010055-18

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

**Crow Bar**

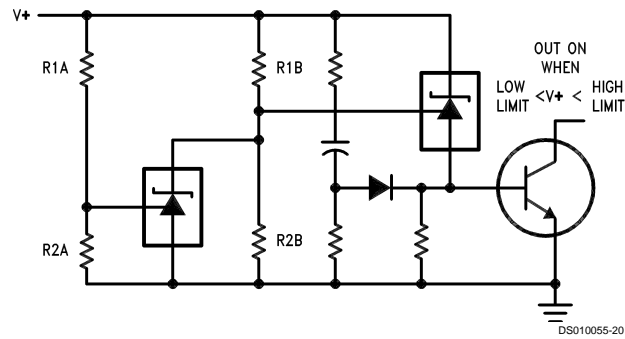


DS010055-19

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

## Typical Applications (Continued)

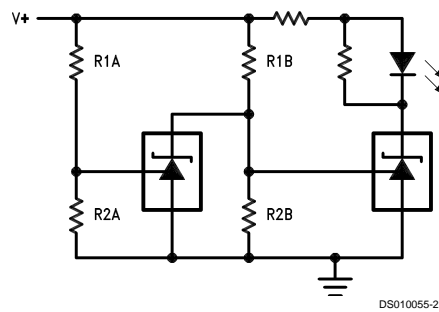
### Over Voltage/Under Voltage Protection Circuit



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

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

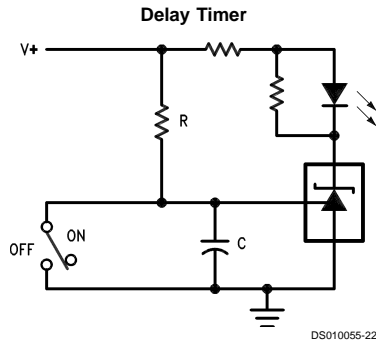
### Voltage Monitor



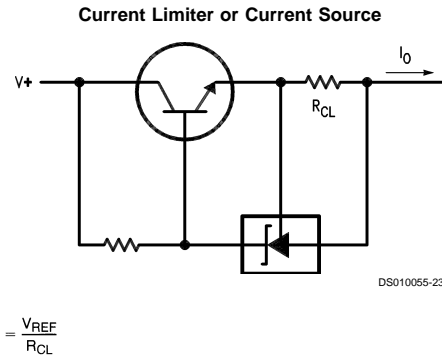
$$\text{LOW LIMIT} \approx V_{\text{REF}} \left( 1 + \frac{R1B}{R2B} \right) \quad \text{LED ON WHEN LOW LIMIT} < V^+ < \text{HIGH LIMIT}$$

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

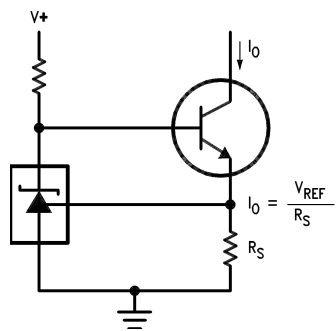
## Typical Applications (Continued)



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



### Constant Current Sink



## Recommended Solder Pads for SOT-23 Package

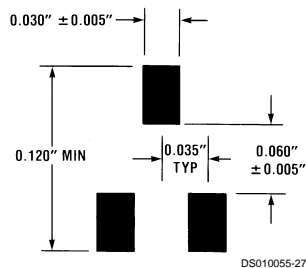
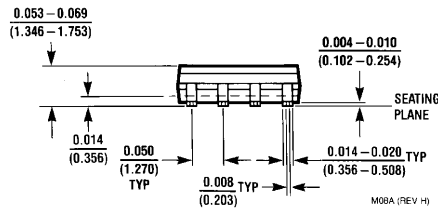
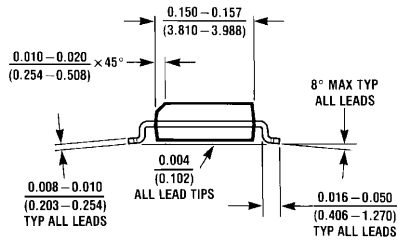
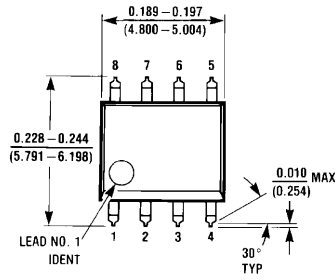


TABLE 1. Package Marking for SOT-23

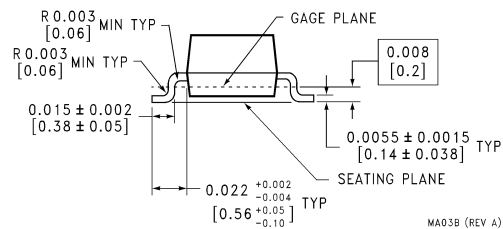
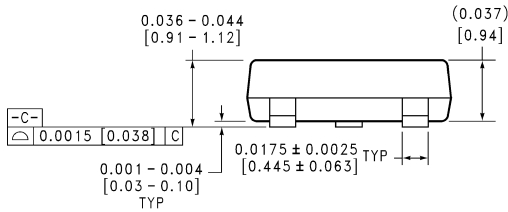
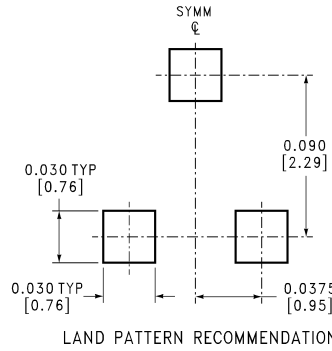
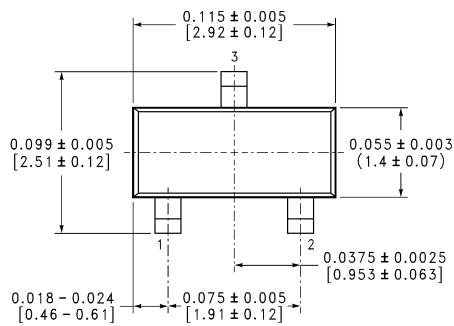
Order Number	Top Mark
LM431ACM3	N1F
LM431AIM3	N1E
LM431BCM3	N1D
LM431BIM3	N1C
LM431CCM3	N1B
LM431CIM3	N1A



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

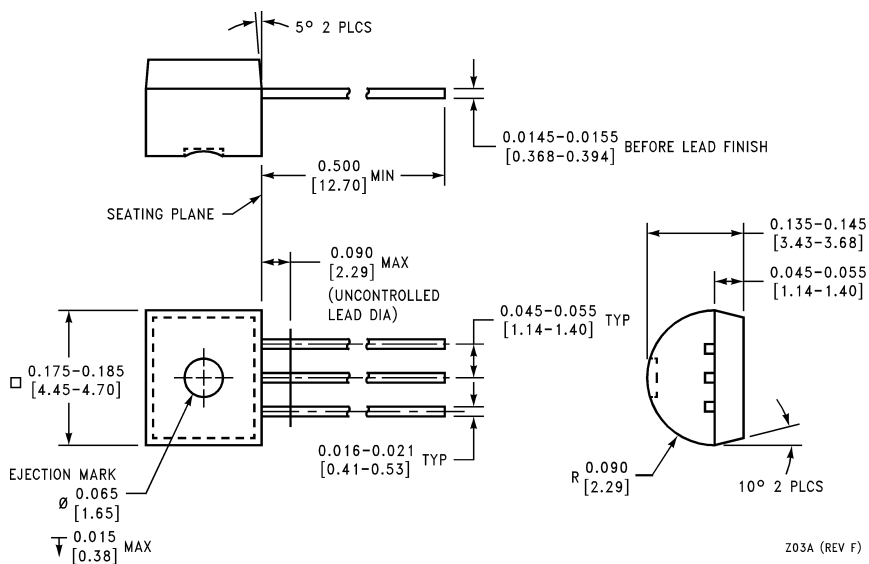


Order Number LM431ACM, LM431AIM,  
LM431BCM, LM431BIM, LM431CCM, or LM431CIM  
NS Package Number M08A



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)



Z03A (REV F)

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

**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 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 in 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.



**National Semiconductor Corporation**  
Americas  
Tel: 1-800-272-9959  
Fax: 1-800-737-7018  
Email: support@nsc.com

**National Semiconductor Europe**  
Fax: +49 (0) 1 80-530 85 86  
Email: europe.support@nsc.com  
Deutsch Tel: +49 (0) 1 80-530 85 85  
English Tel: +49 (0) 1 80-532 78 32  
Français Tel: +49 (0) 1 80-532 93 58  
Italiano Tel: +49 (0) 1 80-534 16 80

**National Semiconductor Asia Pacific Customer Response Group**  
Tel: 65-2544466  
Fax: 65-2504466  
Email: sea.support@nsc.com

**National Semiconductor Japan Ltd.**  
Tel: 81-3-5620-6175  
Fax: 81-3-5620-6179

www.national.com