

LM431 Adjustable Precision Zener Shunt Regulator

General Description

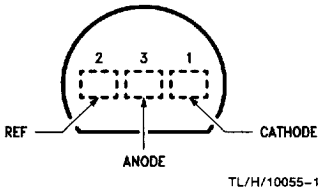
The LM431 is a 3-terminal adjustable shunt regulator with guaranteed temperature stability over the entire temperature range of operation. The output voltage may be set at any level greater than 2.5V (V_{REF}) up to 36V merely by selecting two external resistors that act as a voltage divided network.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

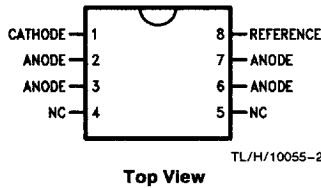
TO-92: Plastic Package



Top View

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

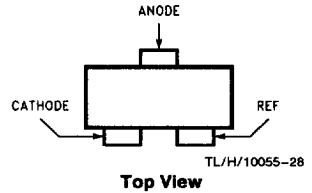
SO-8: 8-Pin Surface Mount



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*

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

*See Table 1 for package marking for SOT-23.

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Absolute Maximum Ratings

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 1, 2)	
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

Note 1: T_J Max = 150°C.

Note 2: 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, and the SOT-23 at 2.2 mW/°C.

LM431

Electrical Characteristics T_A = 25°C unless otherwise specified

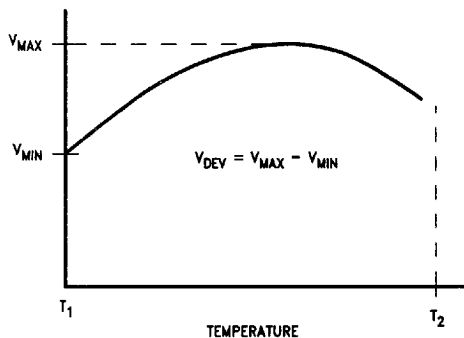
Symbol	Parameter	Conditions	Min	Typ	Max	Units	
V _{REF}	Reference Voltage	V _Z = V _{REF} , I _I = 10 mA LM431A (Figure 1)	2.440	2.495	2.550	V	
		V _Z = V _{REF} , I _I = 10 mA LM431B (Figure 1)	2.470	2.495	2.520	V	
		V _Z = V _{REF} , I _I = 10 mA LM431C (Figure 1)	2.485	2.500	2.510	V	
V _{DEV}	Deviation of Reference Input Voltage Over Temperature (Note 3)	V _Z = V _{REF} , I _I = 10 mA, 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 = ∞, I _I = 10 mA (Figure 2)		2.0	4.0	μA	
α I _{REF}	Deviation of Reference Input Current over Temperature	R ₁ = 10 kΩ, R ₂ = ∞, I _I = 10 mA, 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 4)	V _Z = V _{REF} , LM431A, Frequency = 0 Hz (Figure 1)			0.75	Ω	
		V _Z = V _{REF} , LM431B, LM431C Frequency = 0 Hz (Figure 1)			0.50	Ω	

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LM431

Electrical Characteristics $T_A = 25^\circ\text{C}$ unless otherwise specified (Continued)

Note 3: 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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The average temperature coefficient of the reference input voltage, αV_{REF} , is defined as:

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

Where:

$T_2 - T_1 =$ full temperature change.

αV_{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.

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

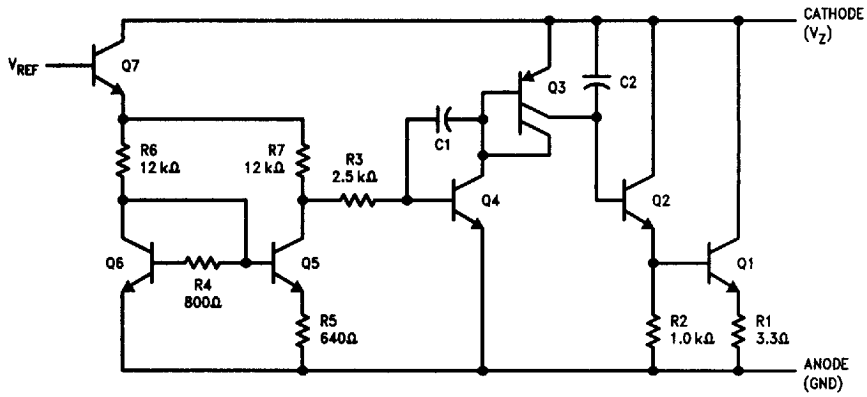
Note 4: The dynamic output impedance, r_z , is defined as:

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

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:

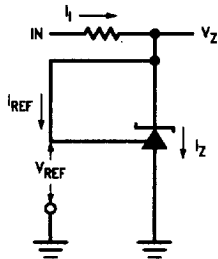
$$r_z = \frac{\Delta V_Z}{\Delta I_Z} \approx \left[r_z \left(1 + \frac{R_1}{R_2} \right) \right]$$

Equivalent Circuit



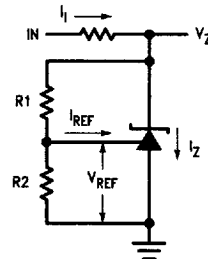
TL/H/10055-3

DC Test Circuits



TL/H/10055-4

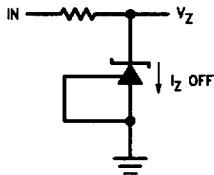
FIGURE 1. Test Circuit for $V_Z = V_{REF}$



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

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

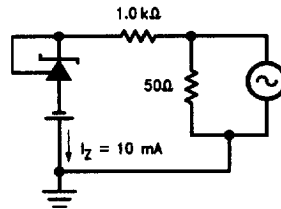
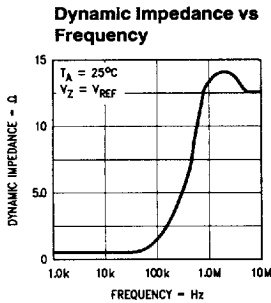
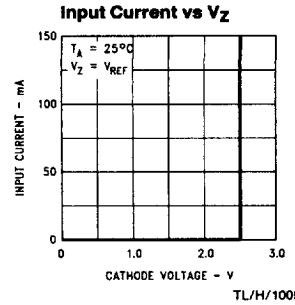
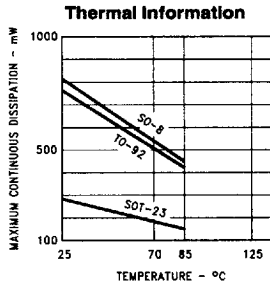
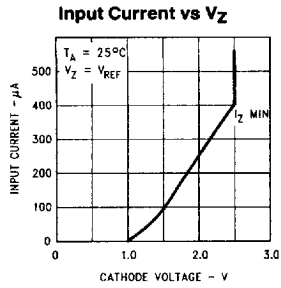


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FIGURE 3. Test Circuit for Off-State Current

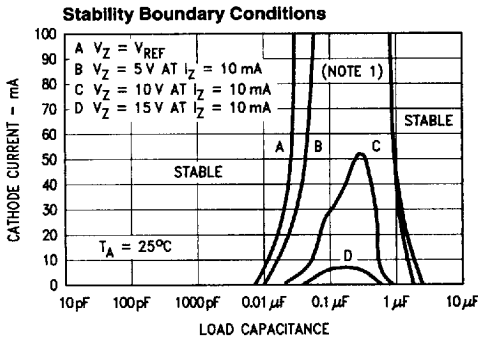
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Typical Performance Characteristics



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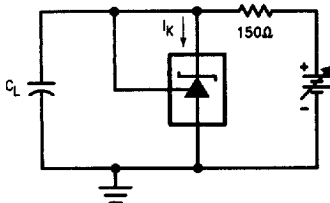
TL/H/10055-10



TL/H/10055-11

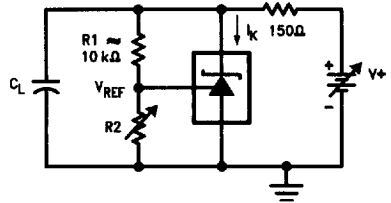
Note 1: The areas under the curves represent conditions that may cause the device to oscillate. For curves B, C, and D, R₂ and V⁺ were adjusted to establish the initial V_Z and I_Z conditions with C_L = 0. V⁺ and C_L were then adjusted to determine the ranges of stability.

Test Circuit for Curve A Above



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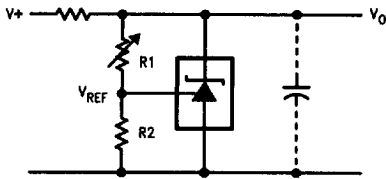
Test Circuit for Curves B, C and D Above



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Typical Applications

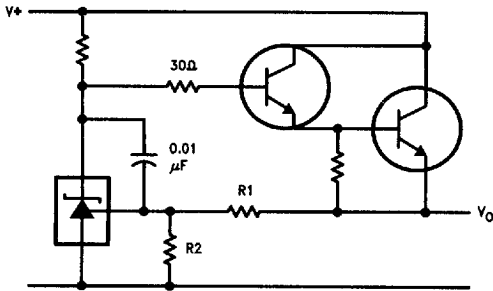
Shunt Regulator



TL/H/10055-14

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

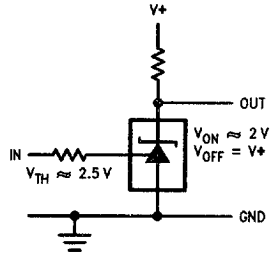
Series Regulator



TL/H/10055-16

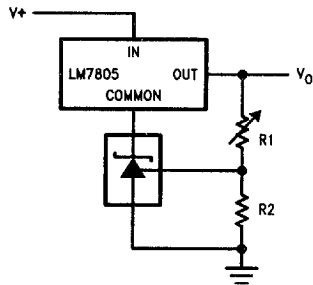
$$V_O \approx \left(1 + \frac{R1}{R2}\right) V_{REF}$$

Single Supply Comparator with Temperature Compensated Threshold



TL/H/10055-15

Output Control of a Three Terminal Fixed Regulator



TL/H/10055-17

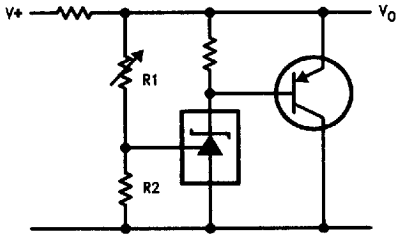
$$V_O = \left(1 + \frac{R1}{R2}\right) V_{REF}$$

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

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Typical Applications (Continued)

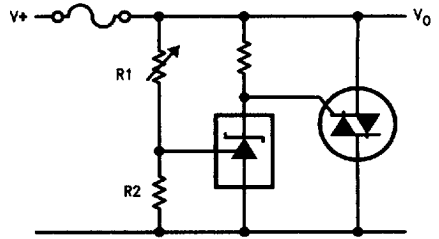
Higher Current Shunt Regulator



TL/H/10055-18

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

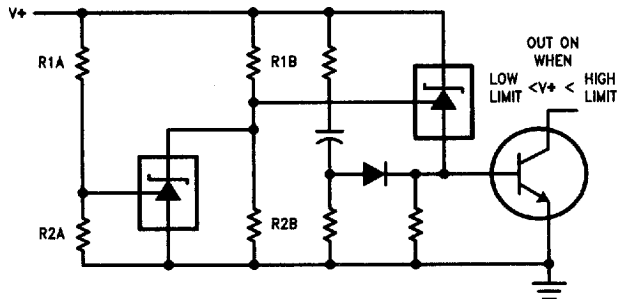
Crow Bar



TL/H/10055-19

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

Over Voltage/Under Voltage Protection Circuit

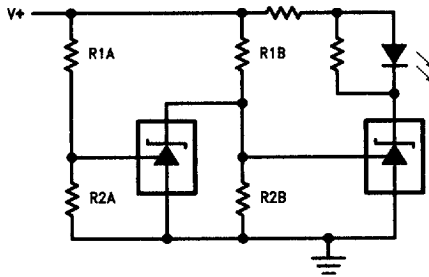


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$$LOW\ LIMIT \approx V_{REF} \left(1 + \frac{R_{1B}}{R_{2B}}\right) + V_{BE}$$

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

Voltage Monitor

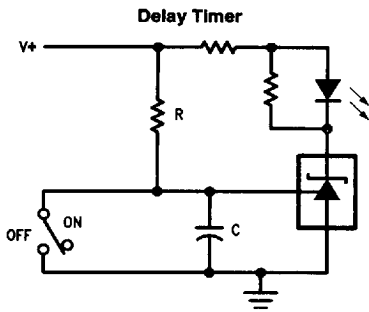


TL/H/10055-21

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

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

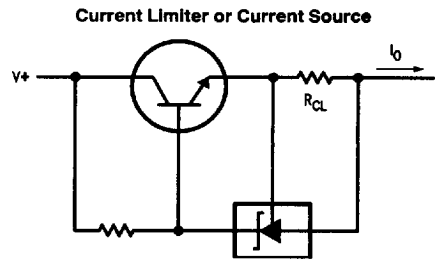
Typical Applications (Continued)



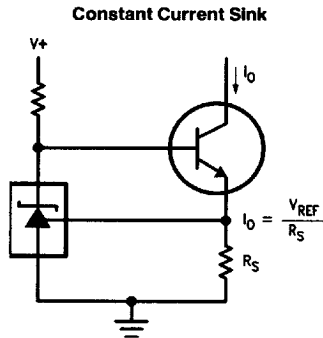
$$\text{DELAY} = R \cdot C \cdot \ln \frac{V^+}{(V^+) - V_{REF}}$$

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

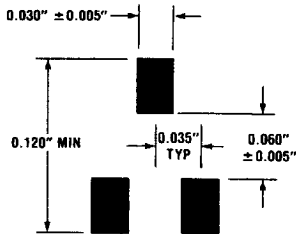


TL/H/10055-23



TL/H/10055-24

Recommended Solder Pads for SOT-23 Package



TL/H/10055-27

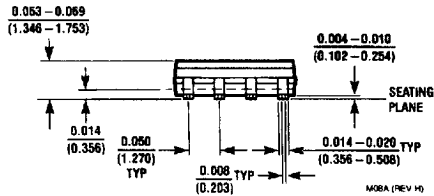
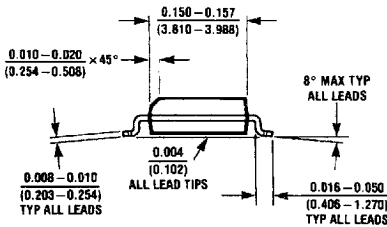
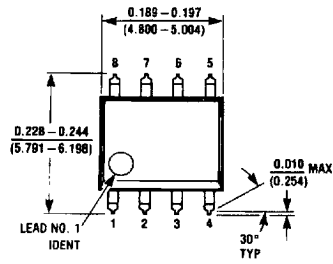
TABLE 1. Package Marking for SOT-23

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

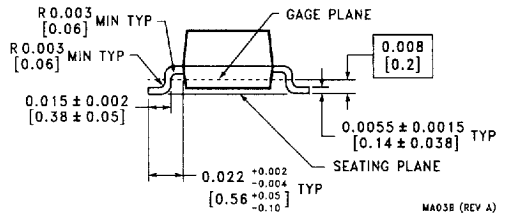
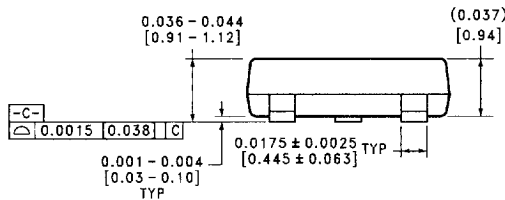
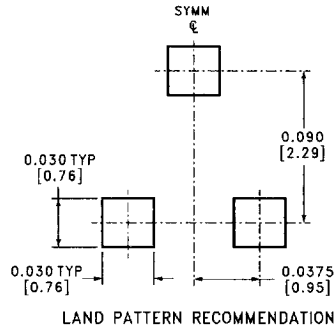
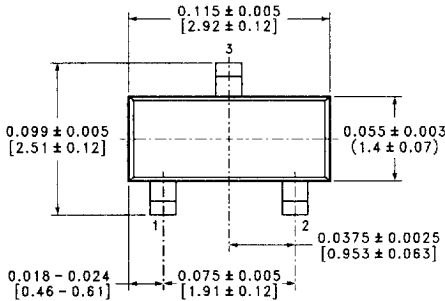
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Physical Dimensions inches (millimeters) unless otherwise noted



Order Number LM431ACM or LM431AIM
NS Package Number M08A



SOT-23 Molded Small Outline Transistor Package (M3)
Order Number LM60BIM3 or LM60CIM3
NS Package Number MA03B

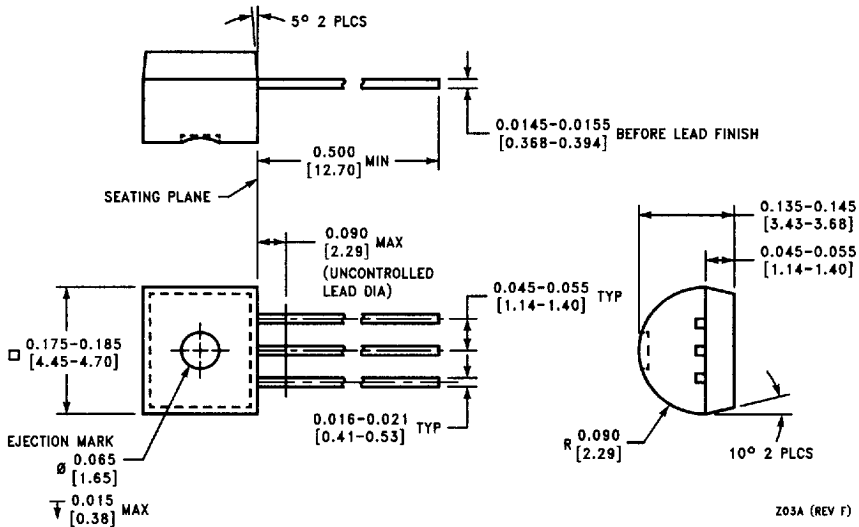
MA03B (REV A)

6501124 0105935 20T

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

Lit # 106475-001



Order Number LM431ACZ or LM431AIZ
NS Package Number Z03A

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