National Semiconductor

December 1996

LM431
Adjustable Precision Zener Shunt Regulator

General Description

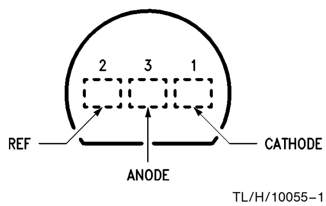
The LM431 is a 3-terminal adjustable shunt regulator with guaranteed temperature stability over the entire temperature range of operation. The output voltage may be set at any level greater than 2.5V (V_{REF}) up to 36V merely by selecting two external resistors that act as a voltage divided network.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

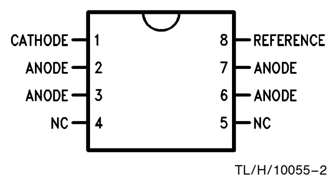
TO-92: Plastic Package



Top View

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

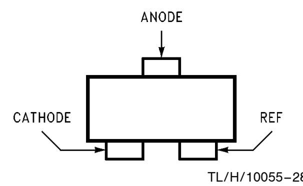
SO-8: 8-Pin Surface Mount



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.

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 appy 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.

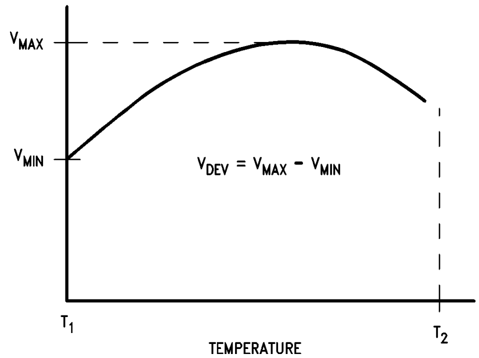
LM431

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	$R_1 = 10\ k\Omega$, $R_2 = \infty$, $I_I = 10$ mA *(Figure 2)*			2.0	4.0	μA
$\propto I_{REF}$	Deviation of Reference Input Current over Temperature	$R_1 = 10\ k\Omega$, $R_2 = \infty$, $I_I = 10$ 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

Electrical Characteristics $T_A = 25°C$ 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, $\propto V_{REF}$, is defined as:

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

Where:

$T_2 - T_1 =$ full temperature change.

$\propto V_{REF}$ 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.

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

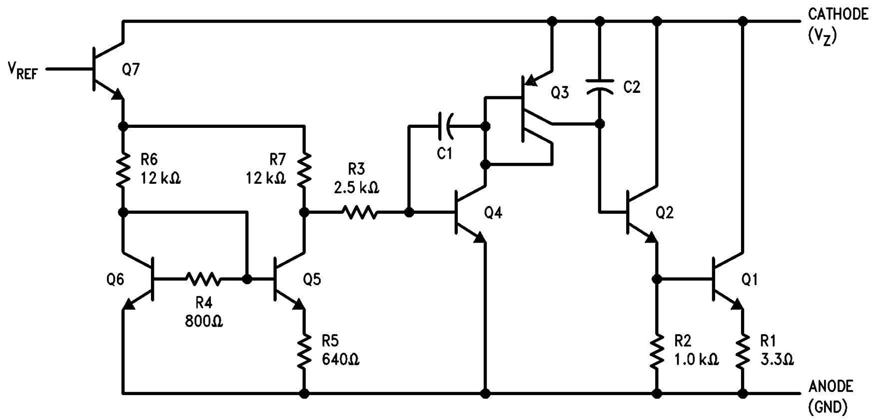
Note 4: The dynamic output impedance, r_Z, is defined as:

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

When the device is programmed with two external resistors, 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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DC Test Circuits

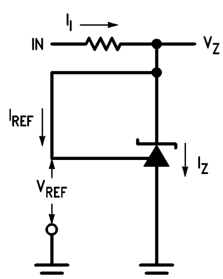

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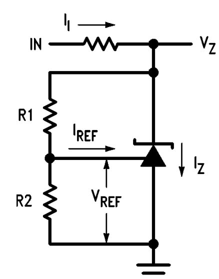
FIGURE 1. Test Circuit for $V_Z = V_{REF}$



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

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

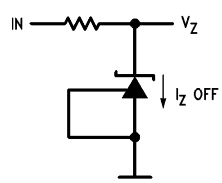

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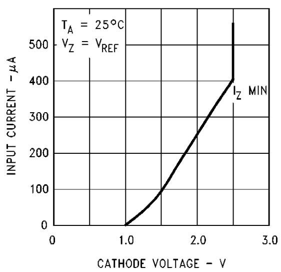
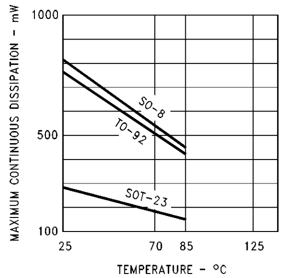
FIGURE 3. Test Circuit for Off-State Current

Typical Performance Characteristics

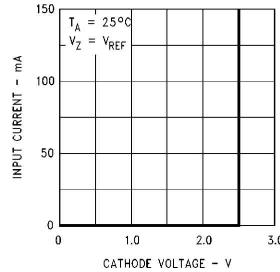
Input Current vs V_Z



Thermal Information



Input Current vs V_Z



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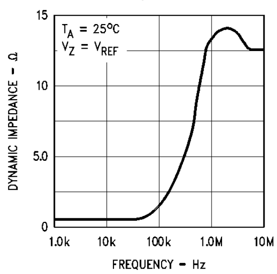
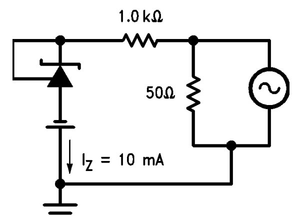
Dynamic Impedance vs Frequency

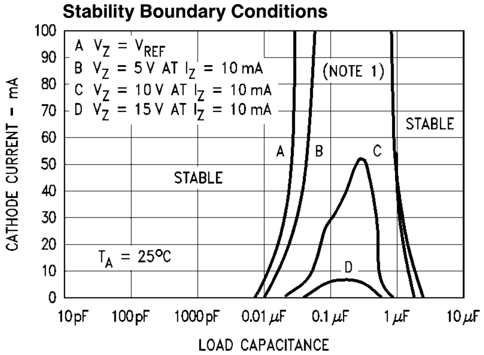


TL/H/10055–9



TL/H/10055–10

Stability Boundary Conditions



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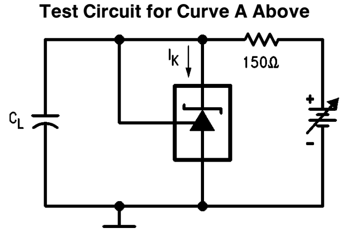
Note 1: The areas under the curves represent conditions that may cause the device to oscillate. For curves B, C, and D, R2 and V^+ were adjusted to establish the initial V_Z and I_Z conditions with $C_L = 0$. V^+ and C_L were then adjusted to determine the ranges of stability.

Test Circuit for Curve A Above



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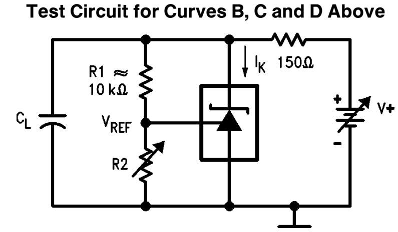
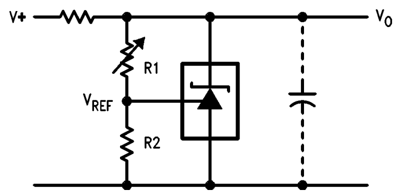
Test Circuit for Curves B, C and D Above



TL/H/10055–13

Typical Applications

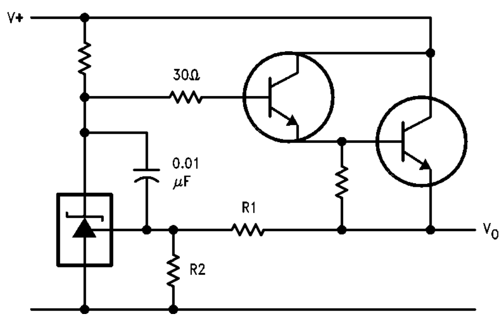
Shunt Regulator



TL/H/10055–14

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

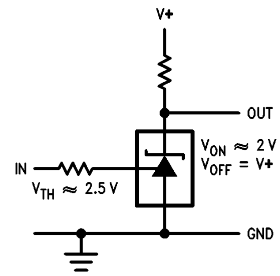
Series Regulator



TL/H/10055–16

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

Single Supply Comparator with Temperature Compensated Threshold



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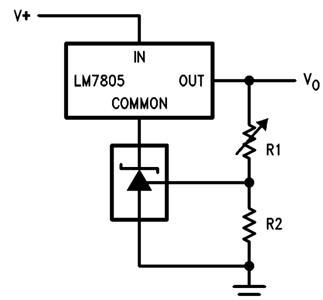
Output Control of a Three Terminal Fixed Regulator



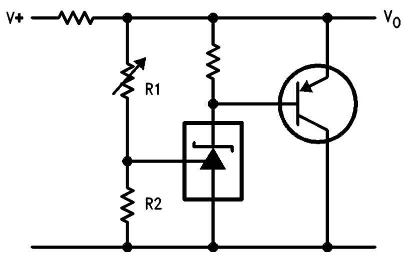
TL/H/10055–17

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

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

Typical Applications (Continued)

Higher Current Shunt Regulator



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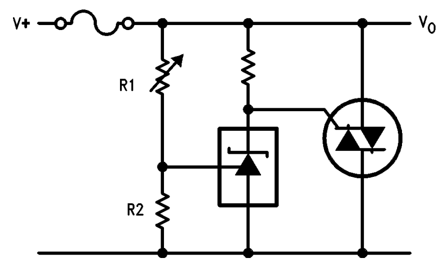
$$V_O = \left(1 + \frac{R1}{R2}\right) V_{REF}$$

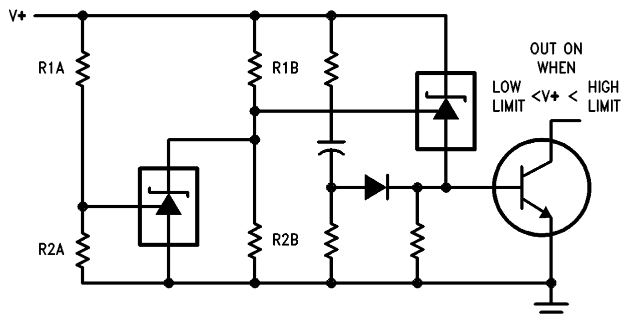
Crow Bar



TL/H/10055–19

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

Over Voltage/Under Voltage Protection Circuit

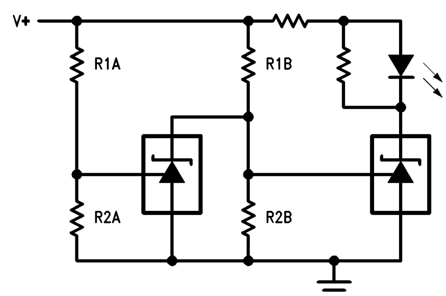


TL/H/10055–20

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

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

Voltage Monitor



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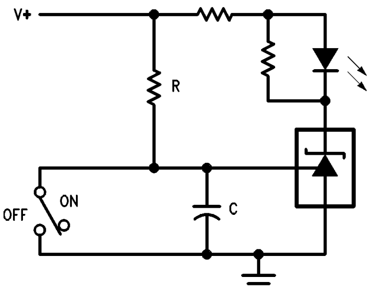
$$\text{LOW LIMIT} \approx V_{REF}\left(1 + \frac{R1B}{R2B}\right)$$

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

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

Typical Applications (Continued)

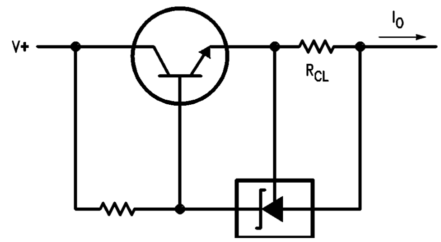
Delay Timer



TL/H/10055–22

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

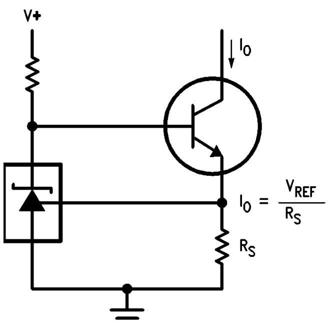
Current Limiter or Current Source



TL/H/10055–23

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

Constant Current Sink



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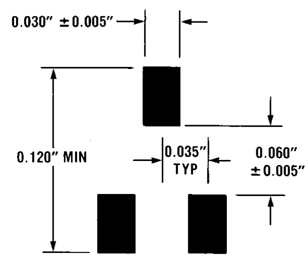
Recommended Solder Pads for SOT-23 Package

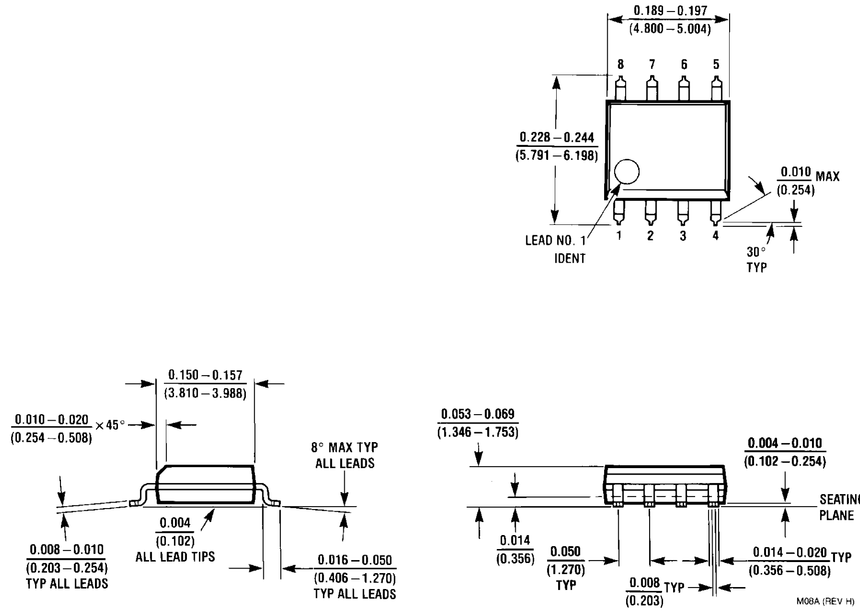


TL/H/10055–27

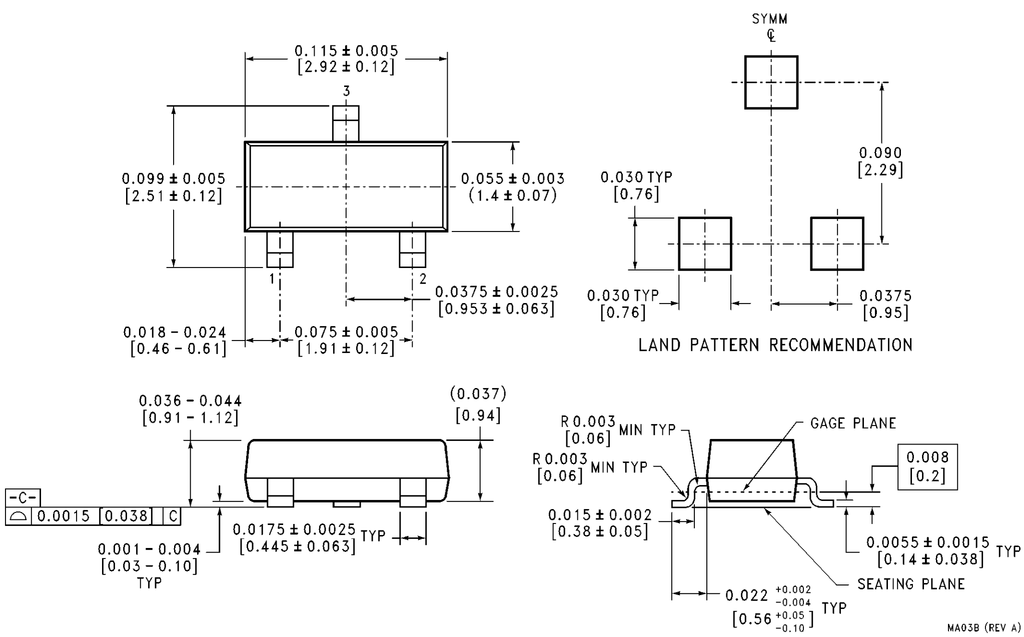
TABLE 1. Package Marking for SOT-23

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

Physical Dimensions inches (millimeters) unless otherwise noted

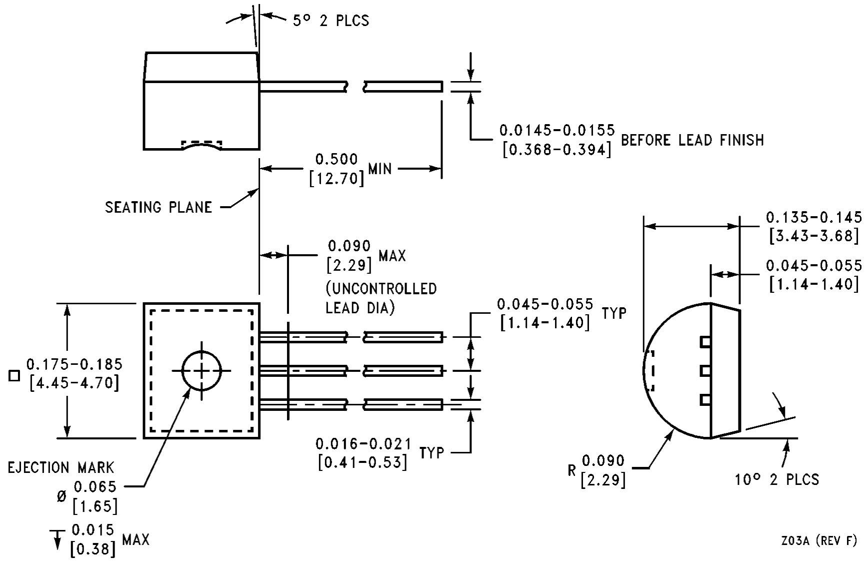


Order Number LM431ACM or LM431AIM
NS Package Number M08A



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

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



Order Number LM431ACZ or LM431AIZ
NS Package Number Z03A

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