National Semiconductor

April 1998

LM431
Adjustable Precision Zener Shunt Regulator

General Description

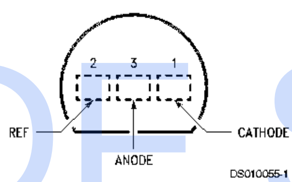
The LM431 is a 3-terminal adjustable shunt regulator with guaranteed temperature stability over the entire temperature range of operation. The output voltage may be set at any level greater than 2.5V (V_{REF}) up to 36V merely by selecting two external resistors that act as a voltage divided network.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

Features

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

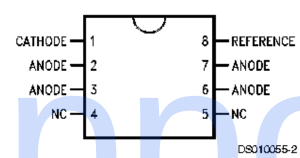
Connection Diagrams

TO-92: Plastic Package



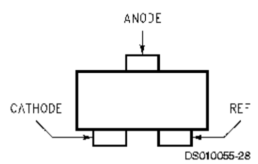
Top View
Order Number LM431ACZ, LM431AIZ, LM431BCZ, LM431BIZ, LM431CCZ or LM431CIZ

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˚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 5)	$V_Z = V_{REF}$, 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	V_Z from V_{REF} to 10V		−1.4	−2.7	mV/V
		(Figure 2)	V_Z from 10V to 36V		−1.0	−2.0	
I_{REF}	Reference Input Current	R_1 = 10 kΩ, $R_2 = \infty$, I_I = 10 mA *(Figure 2)*			2.0	4.0	µA
$\propto I_{REF}$	Deviation of Reference Input Current over Temperature	R_1 = 10 kΩ, $R_2 = \infty$, 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 6)	$V_Z = V_{REF}$, LM431A, Frequency = 0 Hz *(Figure 1)*				0.75	Ω
		$V_Z = V_{REF}$, LM431B, LM431C Frequency = 0 Hz *(Figure 1)*				0.50	Ω

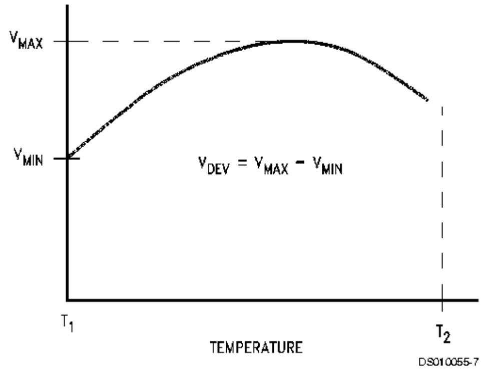
Note 2: Absolute Maximum Ratings indicate limits beyond which damage to the device may occur. Electrical specifications do not apply when operating the device beyond its rated operating conditions.

Note 3: $T_{J\ Max}$ = 150˚C.

Note 4: 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.

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, $\propto V_{REF}$, is defined as:

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

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.

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

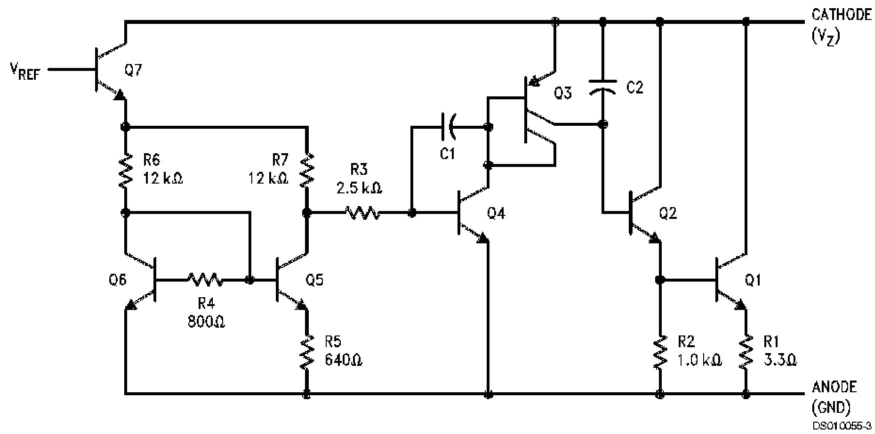
Note 6: The dynamic output impedance, r_Z, is defined as:

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

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

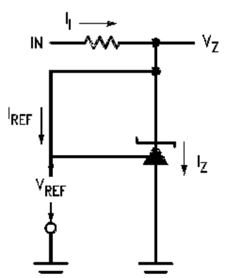
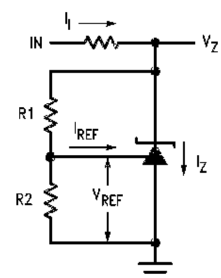


FIGURE 1. Test Circuit for $V_Z = V_{REF}$



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

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

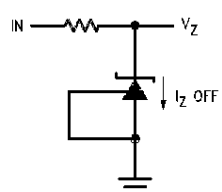
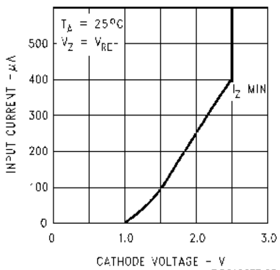


FIGURE 3. Test Circuit for Off-State Current

Typical Performance Characteristics

Input Current vs V_Z



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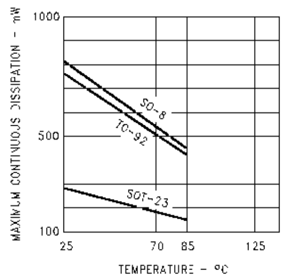
Thermal Information



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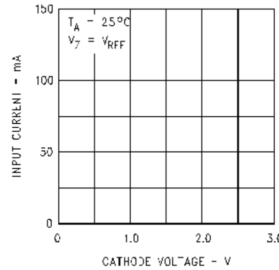
Input Current vs V_Z



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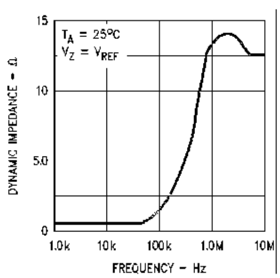
Dynamic Impedance vs Frequency



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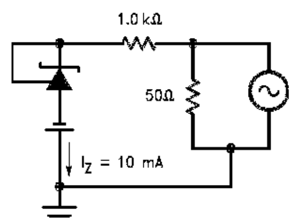

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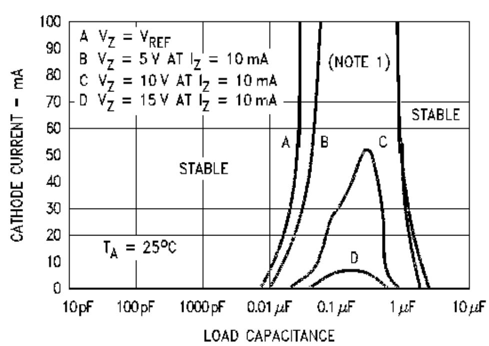
Stability Boundary Conditions



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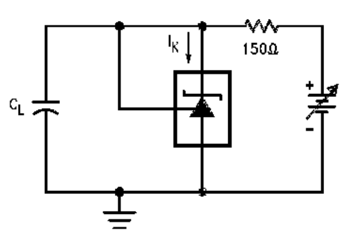
Note: The areas under the curves represent conditions that may cause the device to oscillate. For curves B, C, and D, R2 and V^+ were adjusted to establish the initial V_Z and I_Z conditions with C_L = 0. V^+ and C_L were then adjusted to determine the ranges of stability.

Test Circuit for Curve A Above



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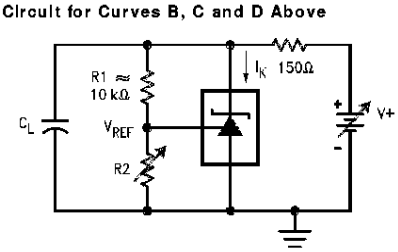
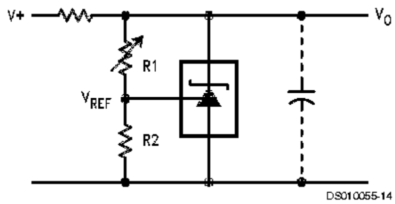
Test Circuit for Curves B, C and D Above



DS010055-13

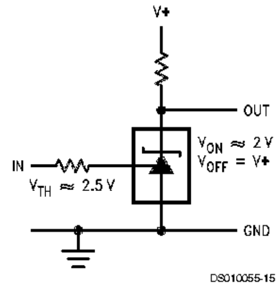
Typical Applications

Shunt Regulator

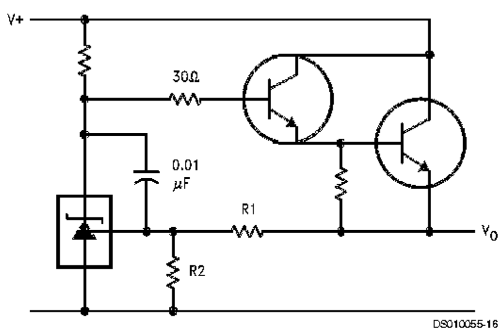


$$V_O \approx \left(1 + \frac{R1}{R2}\right) V_{REF}$$

Single Supply Comparator with Temperature Compensated Threshold

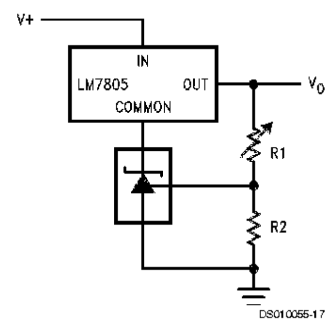


Series Regulator



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

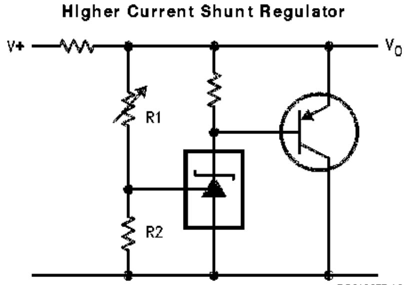
Output Control of a Three Terminal Fixed Regulator



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

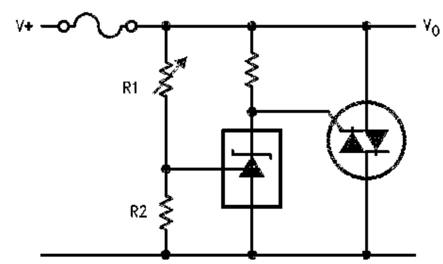
$$V_{O\ MIN} = V_{REF} + 5V$$

Higher Current Shunt Regulator



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

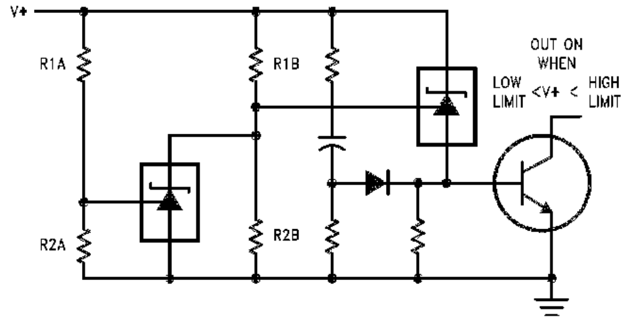
Crow Bar



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

Typical Applications (Continued)

Over Voltage/Under Voltage Protection Circuit



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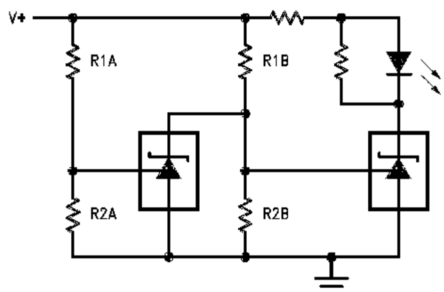
$$\text{LOW LIMIT} \approx V_{REF}\left(1 + \frac{R1B}{R2B}\right) + V_{BE}$$

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

Voltage Monitor



DS010055-21

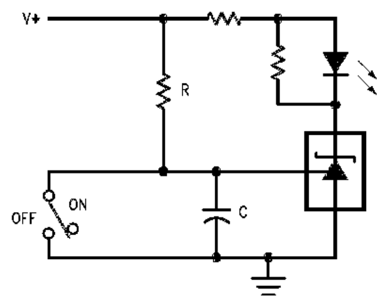
$$\text{LOW LIMIT} \approx V_{REF}\left(1 + \frac{R1B}{R2B}\right)$$

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



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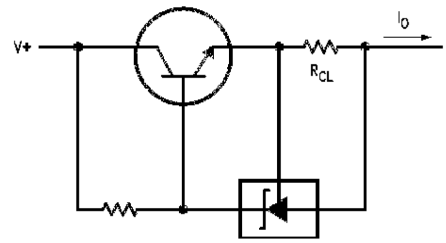
$$\text{DELAY} = R \bullet C \bullet \ell n \frac{V^{+}}{(V^{+}) - V_{REF}}$$

Current Limiter or Current Source



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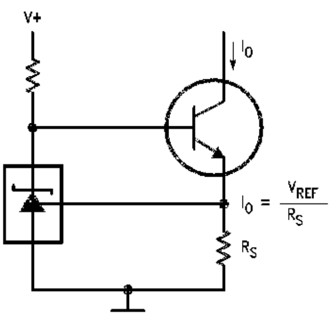
$$I_O = \frac{V_{REF}}{R_{CL}}$$

Constant Current Sink



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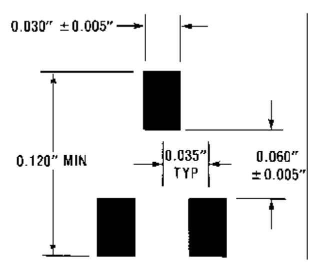
Recommended Solder Pads for SOT-23 Package

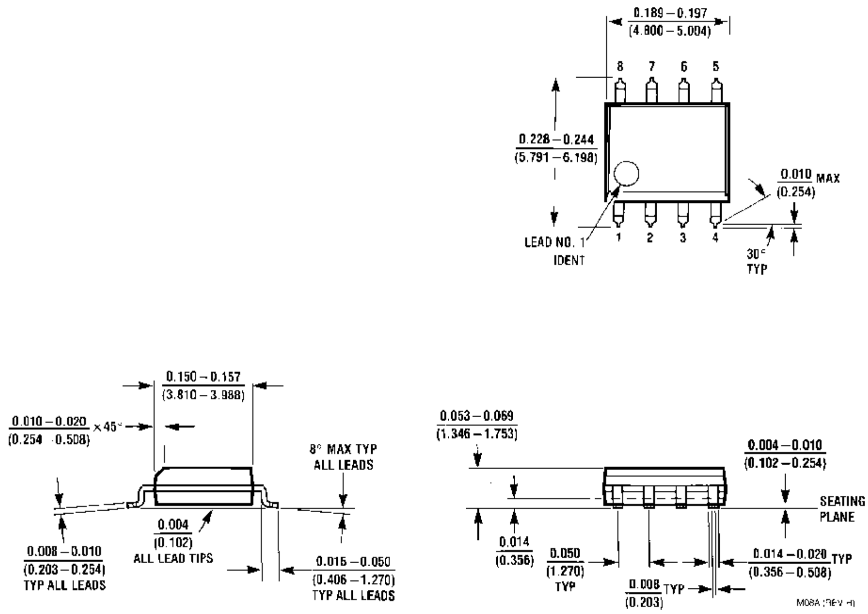


DS010055-27

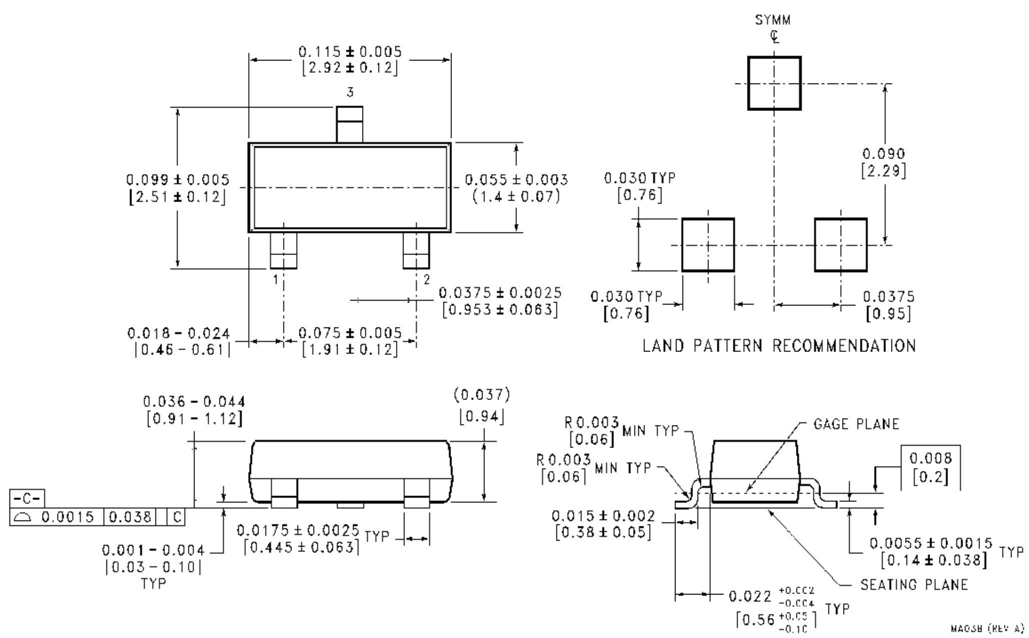
TABLE 1. Package Marking for SOT-23

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

Physical Dimensions inches (millimeters) unless otherwise noted

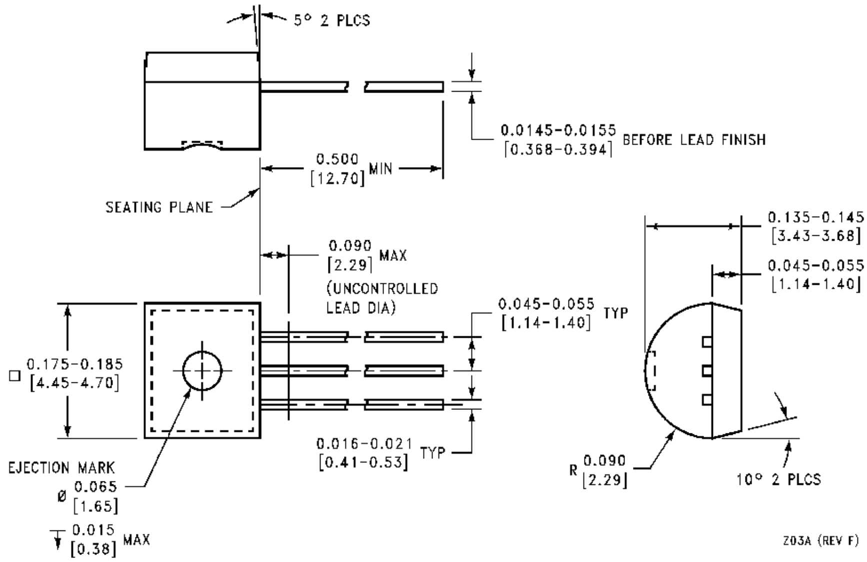


Order Number LM431ACM, LM431AIM, LM431BCM, LM431BIM, LM431CCM, or LM431CIM
NS Package Number M08A



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 Z03A

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

www.national.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