National Semiconductor

March 2005

LM431
Adjustable Precision Zener Shunt Regulator

General Description

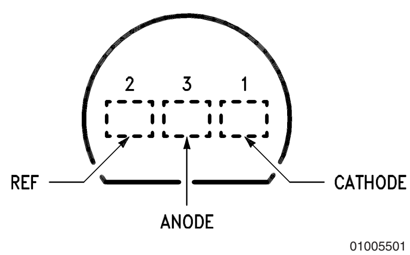
The LM431 is a 3-terminal adjustable shunt regulator with guaranteed temperature stability over the entire temperature range of operation. It is now available in a chip sized package (4-Bump micro SMD) using National's micro SMD package technology. The output voltage may be set at any level greater than 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
- LM431 in micro SMD package
- See AN-1112 for micro SMD considerations

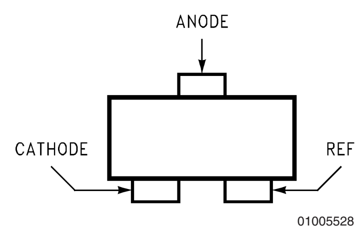
Connection Diagrams

TO-92: Plastic Package



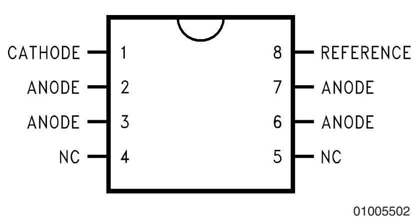
Top View

SOT-23: 3-Lead Small Outline



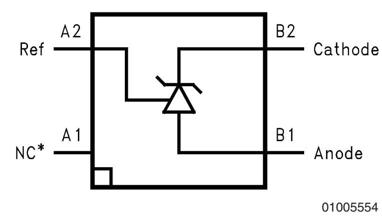
Top View

SO-8: 8-Pin Surface Mount



Top view

4-Bump micro SMD



Top View
(bump side down)

Note: *NC = Not internally connected. Must be electrically isolated from the rest of the circuit for the microSMD package.

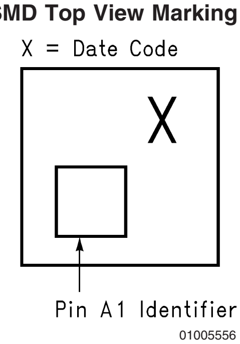
 DS010055 www.national.com

Ordering Information

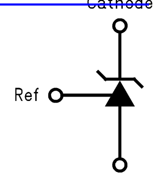
Package	Typical Accuracy Order Number/Package Marking			Temperature Range	Transport Media	NSC Drawing
	0.5%	1%	2%			
TO-92	LM431CCZ/ LM431CCZ	LM431BCZ/ LM431BCZ	LM431ACZ/ LM431ACZ	0˚C to +70˚C	Rails	Z03A
	LM431CIZ/ LM431CIZ	LM431BIZ/ LM431BIZ	LM431AIZ/ LM431AIZ	−40˚C to +85˚C		
SO-8	LM431CCM/ 431CCM	LM431BCM/ 431BCM	LM431ACM/ LM431ACM	0˚C to +70˚C	Rails	M08A
	LM431CCMX/ 431CCM	LM431BCMX/ 431BCM	LM431ACMX/ LM431ACM		Tape & Reel	
	LM431CIM/ 431CIM	LM431BIM/ 431BIM	LM431AIM/ LM431AIM	−40˚C to +85˚C	Rails	
	LM431CIMX/ 431CIM	LM431BIMX/ 431BIM	LM431AIMX/ LM431AIM		Tape &Reel	
SOT-23	LM431CCM3/ N1B	LM431BCM3/ N1D	LM431ACM3/ N1F	0˚C to +70˚C	Rails	MF03A
	LM431CCM3X/ N1B	LM431BCM3X/ N1D	LM431ACM3X/ N1F		Tape & Reel	
	LM431CIM3 N1A	LM431BIM3 N1C	LM431AIM3 N1E	−40˚C to +85˚C	Rails	
	LM431CIM3X N1A	LM431BIM3X N1C	LM431AIM3X N1E		Tape &Reel	
micro SMD	–	–	LM431AIBP LM431AIBPX (Note 1)	−40˚C to +85˚C	250 Units Tape and Reel 3k Units Tape and Reel	BPA04AFB

Note 1: The micro SMD package marking is a 1 digit manufacturing Date Code only

micro SMD Top View Marking Example



Symbol and Functional Diagrams



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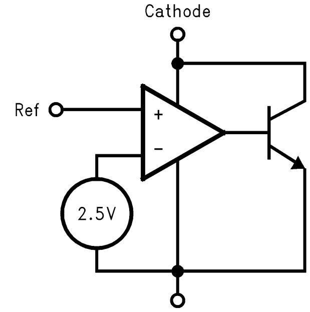

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DC Test Circuits

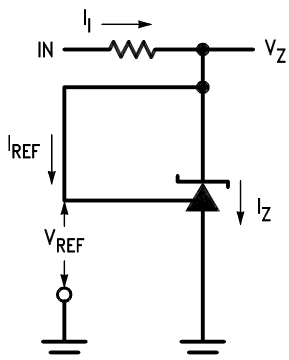

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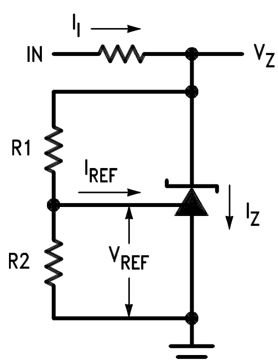
FIGURE 1. Test Circuit for $V_Z = V_{REF}$



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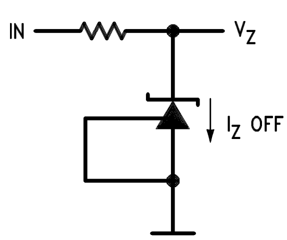
Note: $V_Z = V_{REF} (1 + R1/R2) + I_{REF} \bullet R1$

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



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Test Circuit for Off-State Current

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
Soldering Information	
Infrared or Convection (20 sec.)	235˚C
Wave Soldering (10 sec.)	260˚C (lead temp.)
Cathode Voltage	37V
Continuous Cathode Current	−10 mA to +150 mA
Reference Voltage	−0.5V
Reference Input Current	10 mA
Internal Power Dissipation (Notes 3, 4)	
TO-92 Package	0.78W
SO-8 Package	0.81W
SOT-23 Package	0.28W
micro SMD Package	0.30W

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 *(Figure 2)*, V_Z from V_{REF} to 10V		−1.4	−2.7	mV/V
		I_Z = 10 mA *(Figure 2)*, V_Z from 10V to 36V		−1.0	−2.0	mV/V
I_{REF}	Reference Input Current	R_1 = 10 kΩ, R_2 = ∞, 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 = ∞, 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 *NO TARGET FOR fi*)*		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

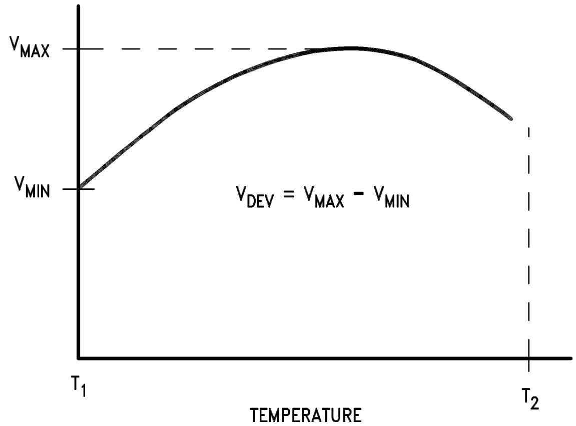
Note 2: Absolute Maximum Ratings indicate limits beyond which damage to the device may occur. Electrical specifications do not apply when operating the device beyond its rated operating conditions.

Note 3: $T_{J\ Max}$ = 150˚C.

Note 4: Ratings 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, the SOT-23 at 2.2 mW/˚C and the micro SMD at 3mW/˚C.

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.

LM431
Electrical Characteristics (Continued)



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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 (0-70˚C).

$\propto V_{REF}$ 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.

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

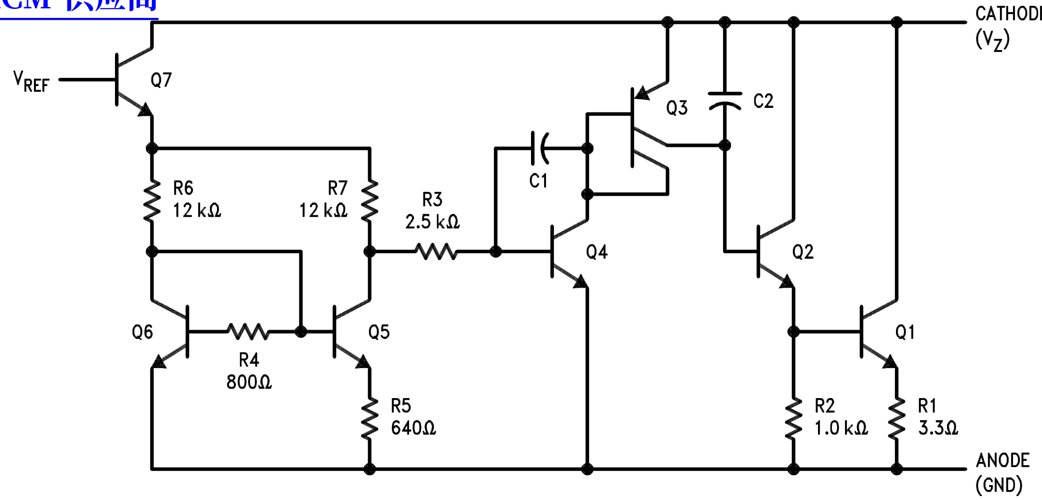
Note 6: The dynamic output impedance, r_Z, is defined as:

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

When the device is programmed with two external resistors, 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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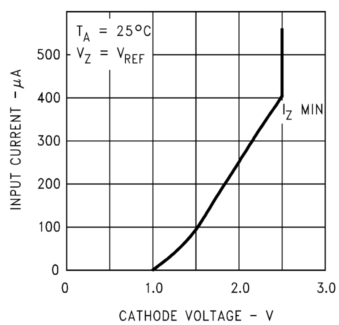
Typical Performance Characteristics

Input Current vs V_Z



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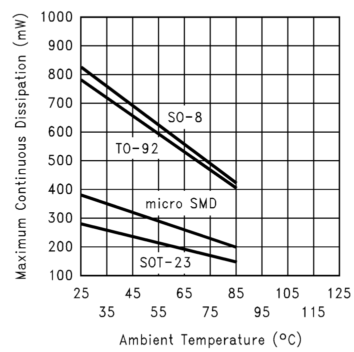
Thermal Information



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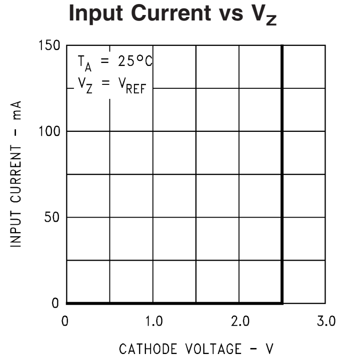
Input Current vs V_Z



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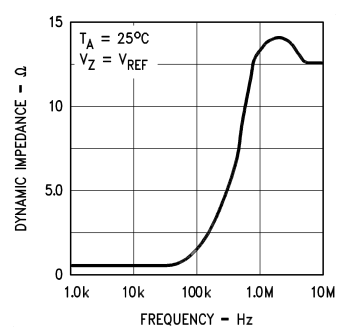
Dynamic Impedance vs Frequency



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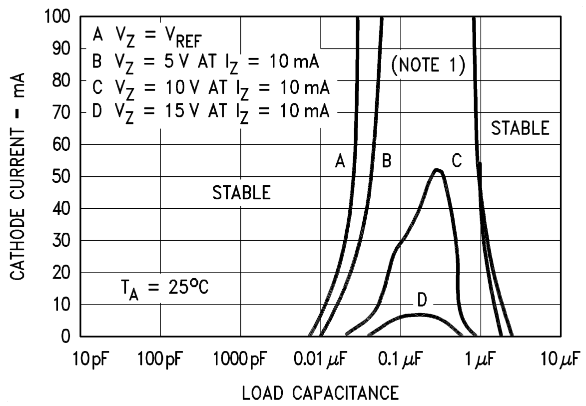
Typical Performance Characteristics (Continued)

Stability Boundary Conditions



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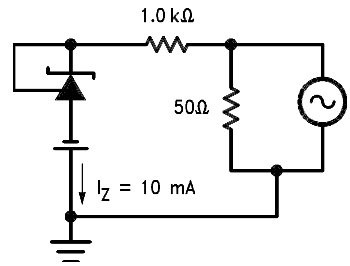

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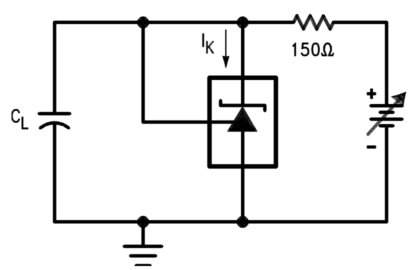
Note: The areas under the curves represent conditions that may cause the device to oscillate. For curves B, C, and D, R2 and V^+ were adjusted to establish the initial V_Z and I_Z conditions with $C_L = 0$. V^+ and C_L were then adjusted to determine the ranges of stability.

Test Circuit for Curve A Above



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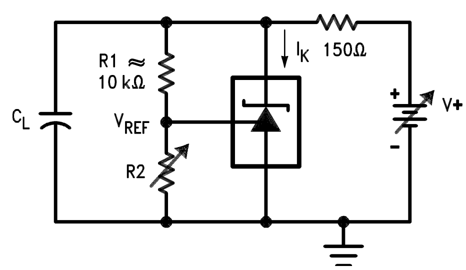
Test Circuit for Curves B, C and D Above



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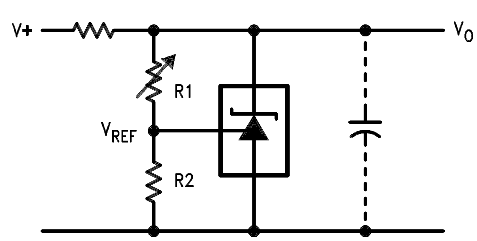
Typical Applications

Shunt Regulator



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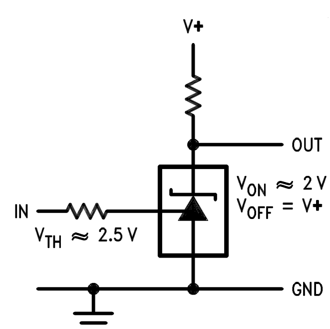
$$V_O \approx \left(1 + \frac{R1}{R2}\right) V_{REF}$$

Single Supply Comparator with Temperature Compensated Threshold



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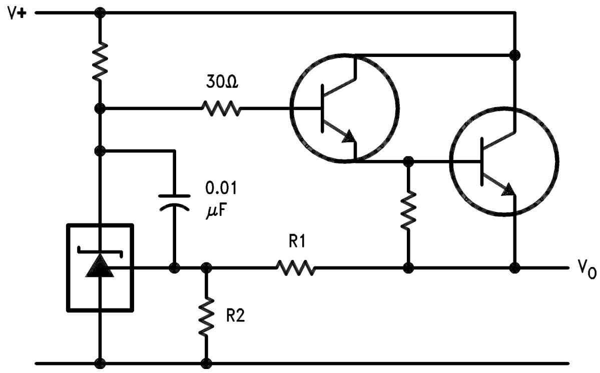
Typical Applications (Continued)

Series Regulator



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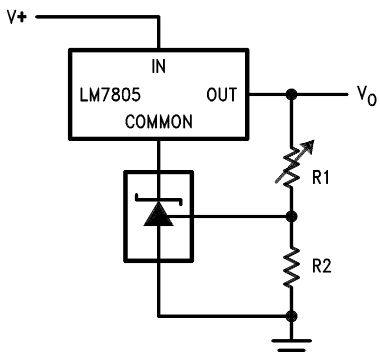
$$V_O \approx \left(1 + \frac{R1}{R2}\right) V_{REF}$$

Output Control of a Three Terminal Fixed Regulator



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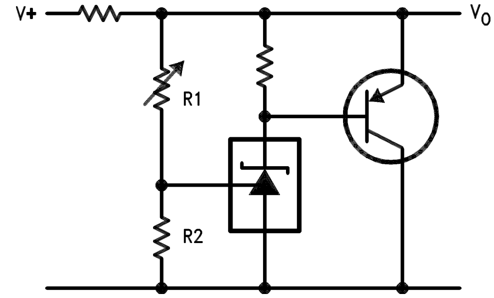
$$V_O = \left(1 + \frac{R1}{R2}\right) V_{REF}$$

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

Higher Current Shunt Regulator



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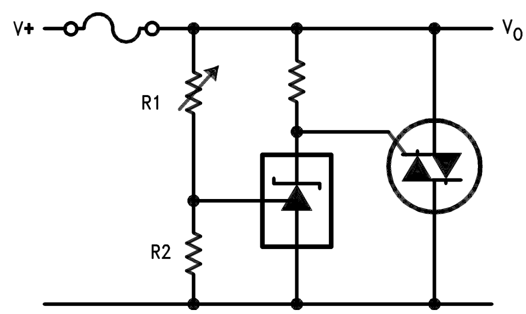
$$V_O \approx \left(1 + \frac{R1}{R2}\right) V_{REF}$$

Crow Bar



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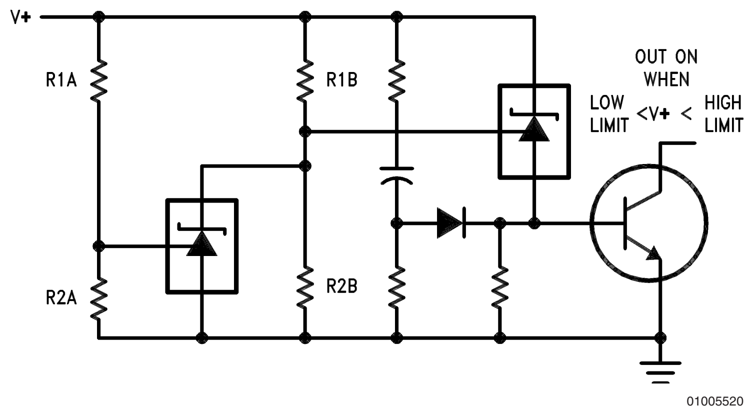
$$V_{LIMIT} \approx \left(1 + \frac{R1}{R2}\right) V_{REF}$$

Typical Applications (Continued)

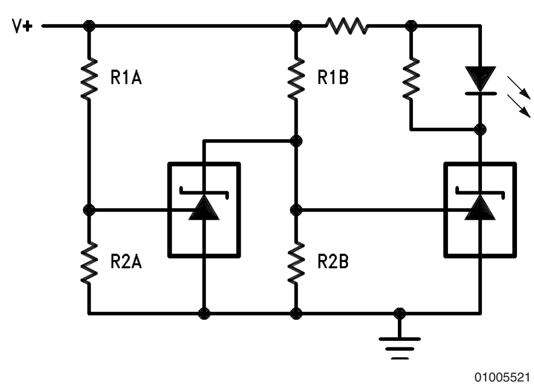
Over Voltage/Under Voltage Protection Circuit



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

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

Voltage Monitor



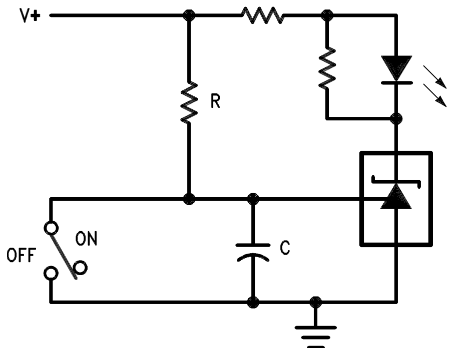
$$\text{LOW LIMIT} \approx V_{REF}\left(1 + \frac{R1B}{R2B}\right)$$

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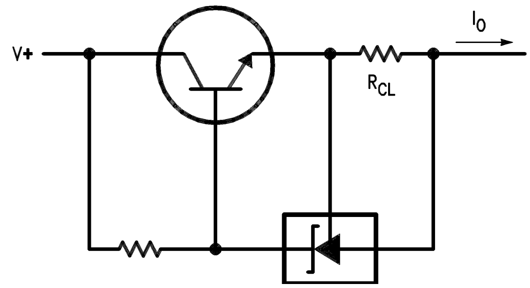
$$DELAY = R \bullet C \bullet \ell n \frac{V+}{(V+) - V_{REF}}$$

Current Limiter or Current Source



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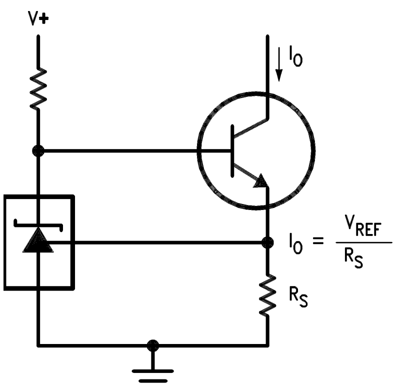
$$I_O = \frac{V_{REF}}{R_{CL}}$$

Constant Current Sink



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Application Info

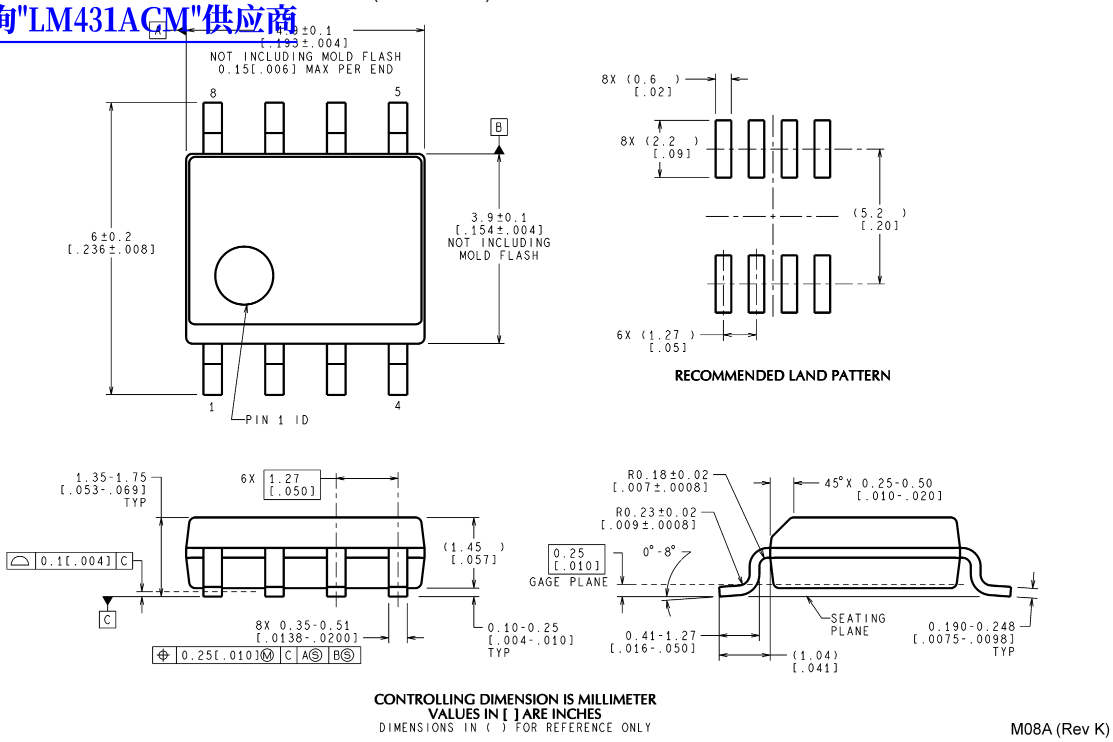
1.0 Mounting

To ensure that the geometry of the micro SMD package maintains good physical contact with the printed circuit board, pin A1 (NC) must be soldered to the pcb. Please see AN-1112 for more detailed information regarding board mounting techniques for the micro SMD package.

2.0 LM431 micro SMD Light Sensitivity

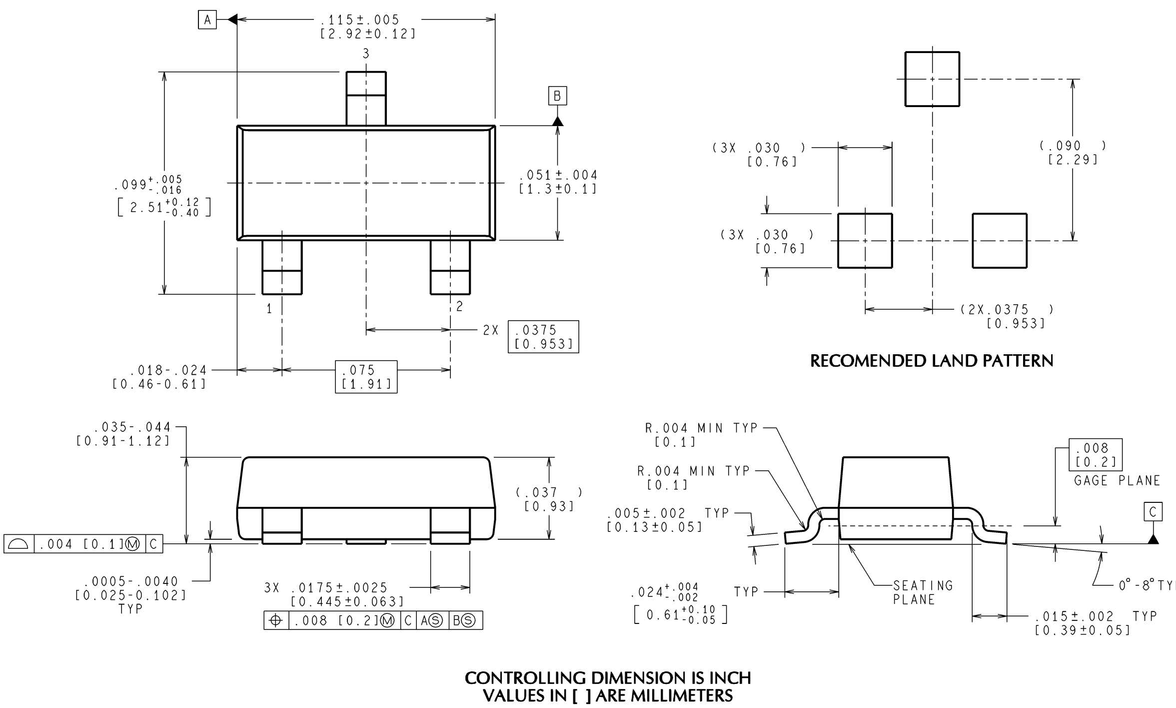
When the LM431 micro SMD package is exposed to bright sunlight, normal office fluorescent light, and other LED's and lasers, it operates within the guaranteed limits specified in the electrical characteristics table.

Physical Dimensions inches (millimeters) unless otherwise noted



M08A (Rev K)

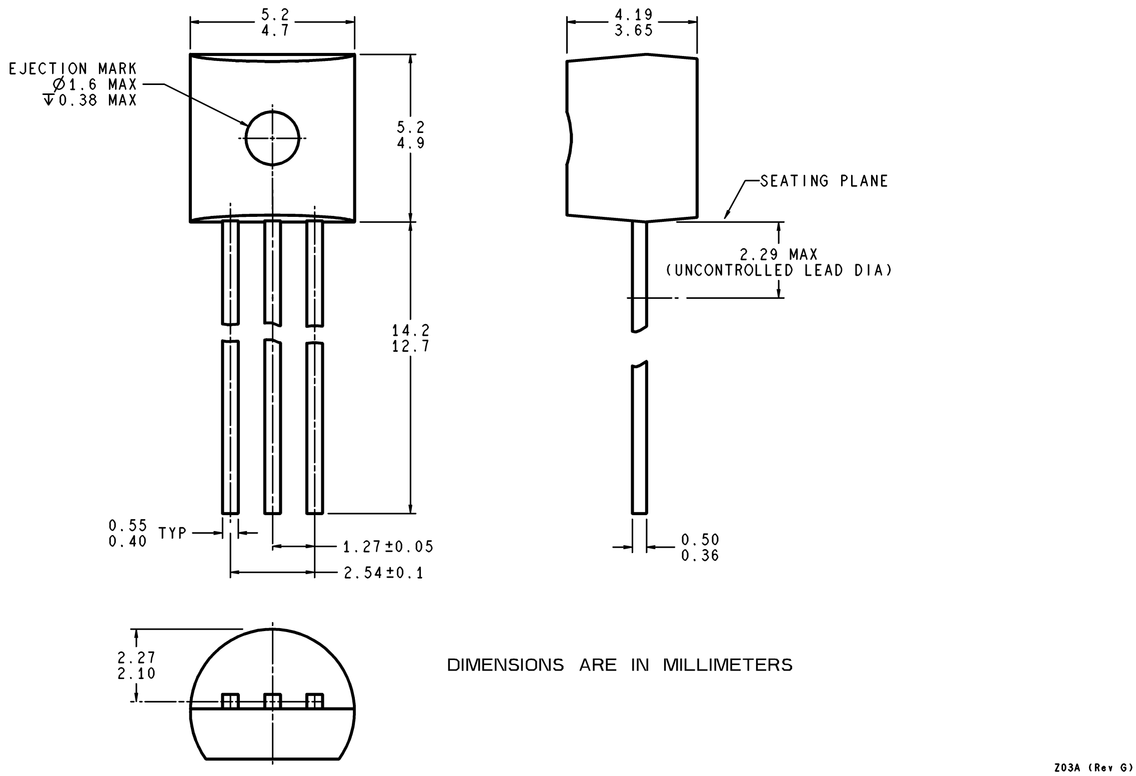
8-Pin SOIC
NS Package Number M08A



MF03A (Rev B)

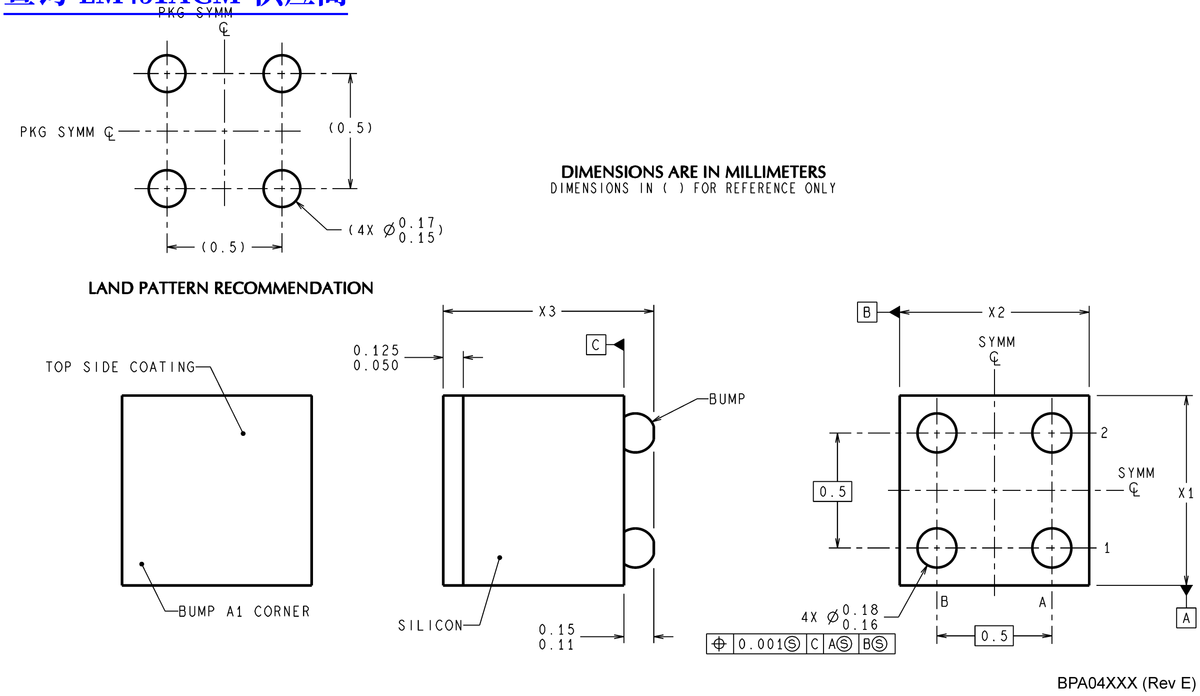
SOT-23 Molded Small Outline Transistor Package (M3)
NS Package Number MF03A

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



NS Package Number Z03A

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



NOTES: UNLESS OTHERWISE SPECIFIED

1. EPOXY COATING
2. 63Sn/37Pb EUTECTIC BUMP
3. RECOMMEND NON-SOLDER MASK DEFINED LANDING PAD.
4. PIN A1 IS ESTABLISHED BY LOWER LEFT CORNER WITH RESPECT TO TEXT ORIENTATION. REMAINING PINS ARE NUMBERED.
5. XXX IN DRAWING NUMBER REPRESENTS PACKAGE SIZE VARIATION WHERE X1 IS PACKAGE WIDTH, X2 IS PACKAGE LENGTH AND X3 IS PACKAGE HEIGHT.
6. REFERENCE JEDEC REGISTRATION MO-211, VARIATION BA.

4-Bump micro SMD
X1 = 0.777 X2 = 0.904 X3 = 0.850
NS Package Number BPA04AFB

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