𝒩 *National Semiconductor*

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
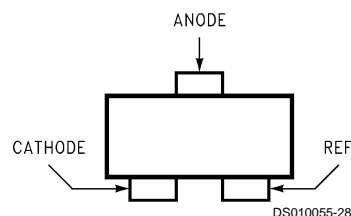
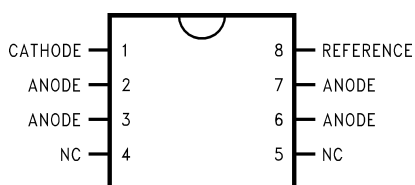## Connection Diagrams

TO-92: Plastic Package

DS010055-1

Top View

SO-8: 8-Pin Surface Mount
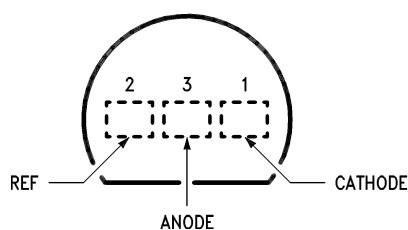
DS010055-2

Top view

SOT-23: 3-Lead Small Outline

DS010055-28

Top View

4-Bump micro SMD
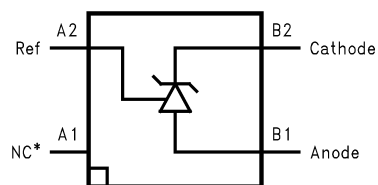
DS010055-54

**Top View
(bump side down)**

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

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 and Tape &Reel	M08A
	LM431CIM/ 431CIM	LM431BIM/ 431BIM	LM431AIM/ LM431AIM	−40˚C to +85˚C		
SOT-23	LM431CCM3/ N1B	LM431BCM3/ N1D	LM431ACM3/ N1F	0˚C to +70˚C	Rails and Tape &Reel	MF03A
	LM431CIM3 N1A	LM431BIM3 N1C	LM431AIM3 N1E	−40˚C to +85˚C		
micro SMD	–	–	LM431AIBP LM431AIBPX(Note 1)	−40˚C to +85˚C	250 Units Tape and Reel 3k Units Tape and Reel	BPA04AFB

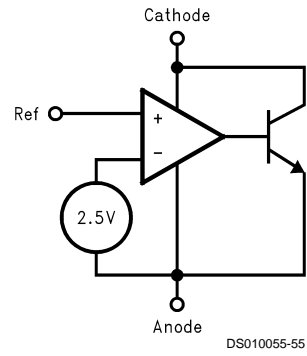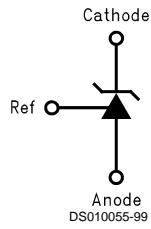**Note 1:** The micro SMD package marking is a 1 digit manufacturing Date Code only

micro SMD Top View Marking Example

X = Date Code
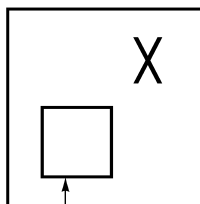
Pin A1 Identifier
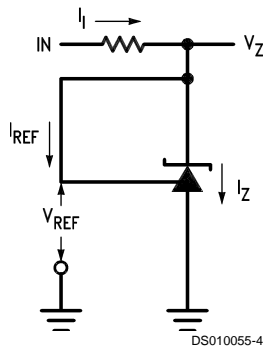DS010055-56

Symbol and Functional Diagrams

DS010055-99

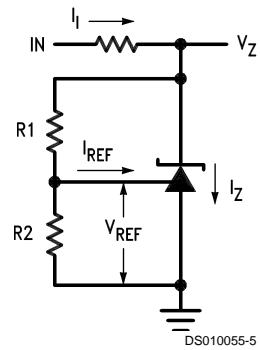DS010055-55

DC Test Circuits

DS010055-4

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

DS010055-5

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

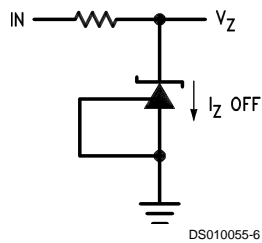**FIGURE 2. Test Circuit for $V_Z > V_{REF}$**

DS010055-6

FIGURE 3. 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
$\dfrac{\Delta V_{REF}}{\Delta V_Z}$	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, $R_2 = \infty$, 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 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)

DS010055-7
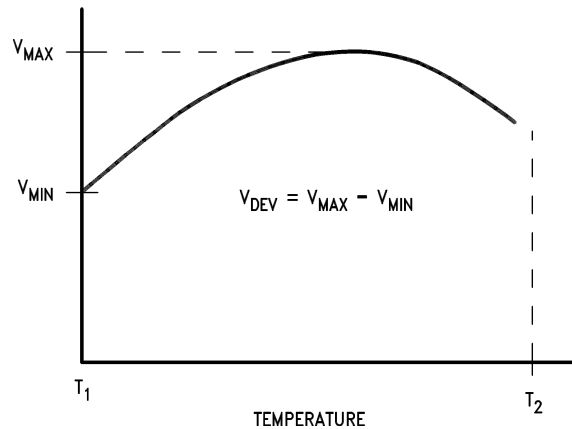
The average temperature coefficient of the reference input voltage, $\propto V_{REF}$, is defined as:

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

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.

$$\propto V_{REF} = \frac{\left[\dfrac{8.0\,mV}{2495\,mV}\right]10^6}{70°C} = +46\,ppm/°C$$
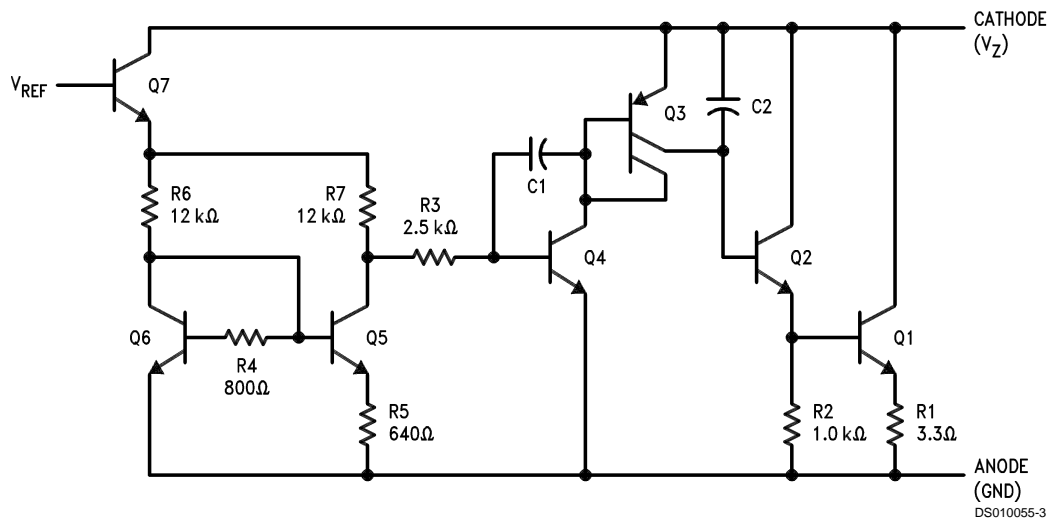
Note 6: The dynamic output impedance, r_Z, is defined as:

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

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:
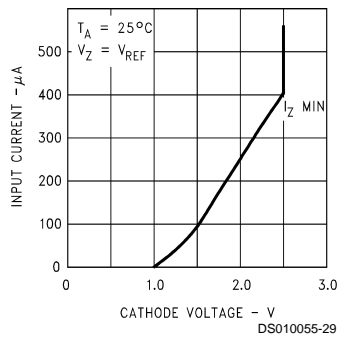
$$r_Z = \frac{\Delta V_Z}{\Delta I_Z} \cong \left[r_Z\left(1 + \frac{R1}{R2}\right)\right]$$
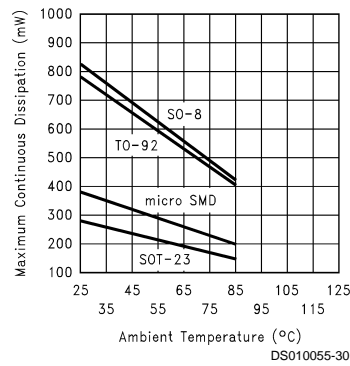
Equivalent Circuit

DS010055-3

www.national.com

Typical Performance Characteristics

Input Current vs V_Z

DS010055-29

Thermal Information

DS010055-30

Input Current vs V_Z

DS010055-31
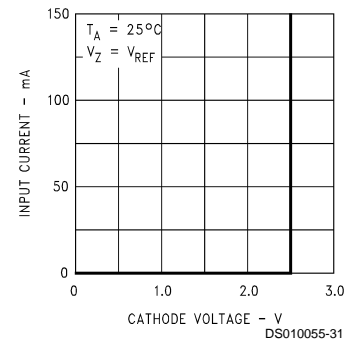
Dynamic Impedance vs Frequency

DS010055-9

DS010055-10
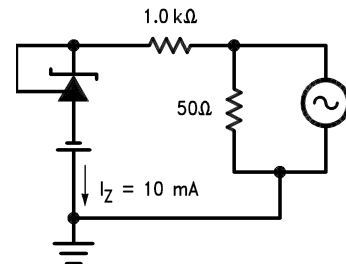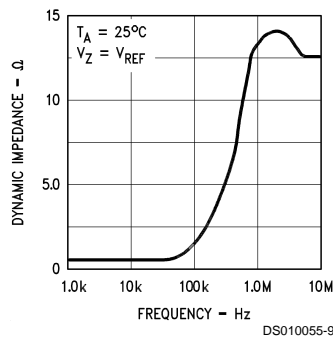
Stability Boundary Conditions

A $V_Z = V_{REF}$
B $V_Z = 5$ V AT $I_Z = 10$ mA
C $V_Z = 10$ V AT $I_Z = 10$ mA
D $V_Z = 15$ V AT $I_Z = 10$ mA

(NOTE 1)

STABLE

STABLE

$T_A = 25°C$

DS010055-11
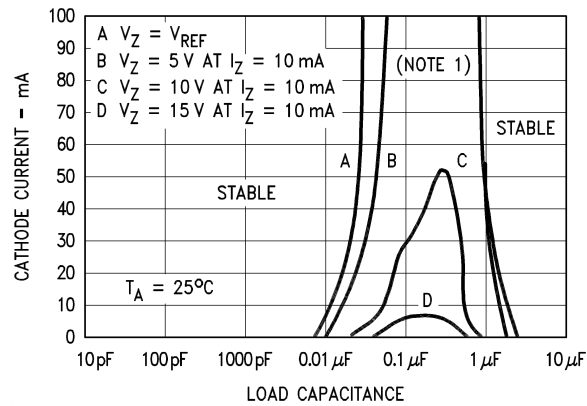
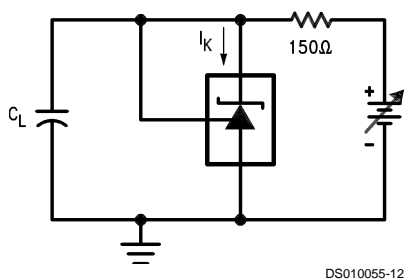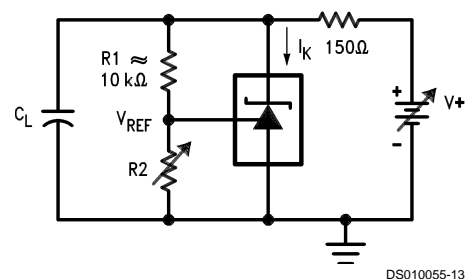**Note:** The areas under the curves represent conditions that may cause the device to oscillate. For curves B, C, and D, R2 and V$^+$ were adjusted to establish the initial V_Z and I_Z conditions with $C_L = 0$. V$^+$ and C_L were then adjusted to determine the ranges of stability.
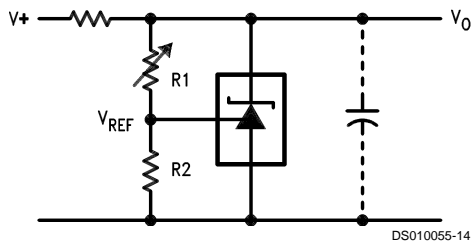
Test Circuit for Curve A Above

DS010055-12

Test Circuit for Curves B, C and D Above
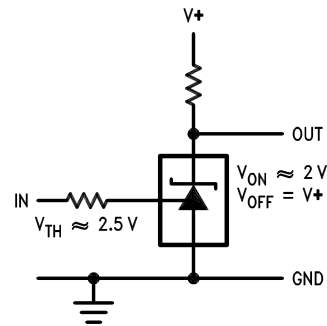
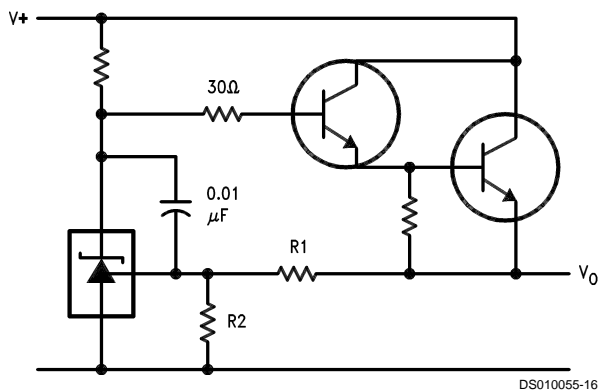DS010055-13

Typical Applications

Shunt Regulator

DS010055-14

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

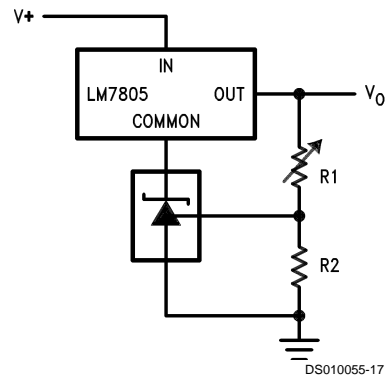### Single Supply Comparator with Temperature Compensated Threshold

$V_{ON} \approx 2\,V$
$V_{OFF} = V+$
$V_{TH} \approx 2.5\,V$

DS010055-15

Series Regulator

DS010055-16

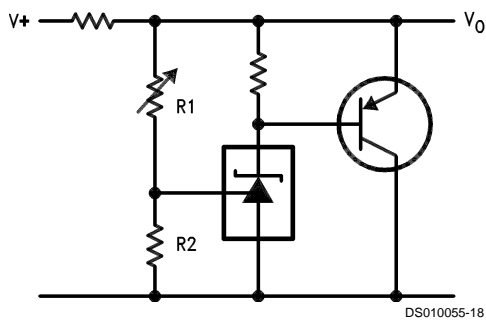$$V_O \approx \left(1 + \frac{R1}{R2}\right) V_{REF}$$

Output Control of a Three Terminal Fixed Regulator

DS010055-17

$$V_O = \left(1 + \frac{R1}{R2}\right) V_{REF}$$
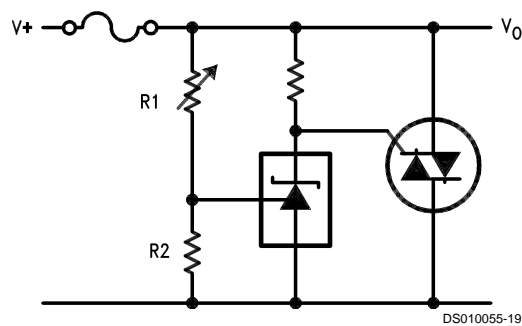
$$V_{O\,MIN} = V_{REF} + 5V$$

Higher Current Shunt Regulator

DS010055-18

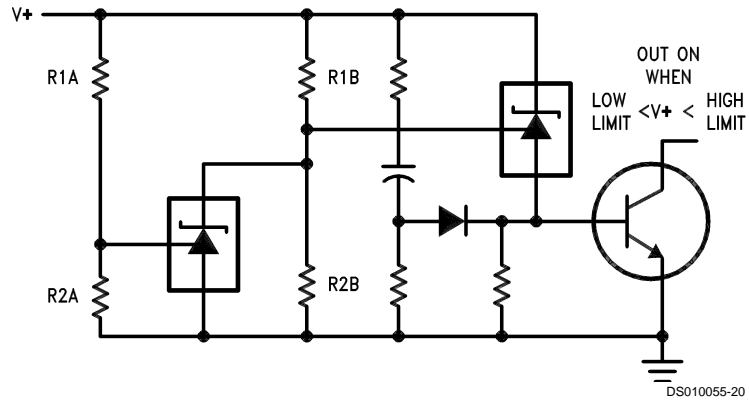$$V_O \approx \left(1 + \frac{R1}{R2}\right) V_{REF}$$

Crow Bar

DS010055-19

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

Typical Applications (Continued)

**Over Voltage/Under Voltage
Protection Circuit**

DS010055-20

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

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

Voltage Monitor

DS010055-21

$$\text{LOW LIMIT} \approx V_{REF}\left(1 + \frac{R1B}{R2B}\right)$$
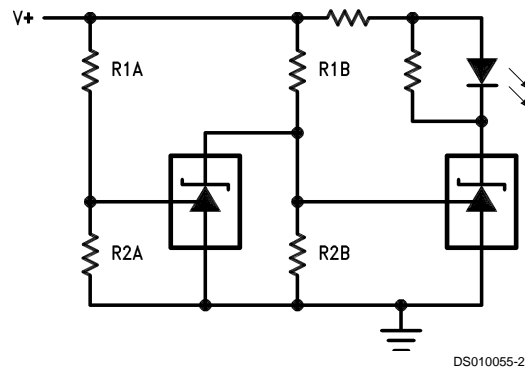
$$\text{HIGH LIMIT} \approx V_{REF}\left(1 + \frac{R1A}{R2A}\right)$$

LED ON WHEN
LOW LIMIT $<$ V$^+$ $<$ HIGH LIMIT
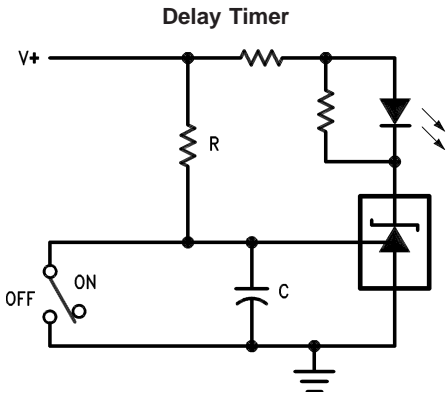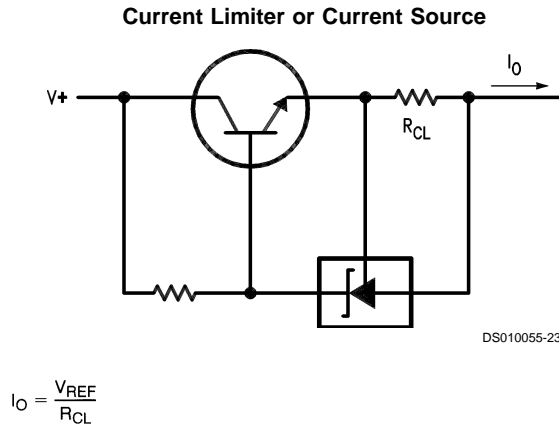
Typical Applications (Continued)

Delay Timer

DS010055-22

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

Current Limiter or Current Source

DS010055-23

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

Constant Current Sink

$$I_O = \frac{V_{REF}}{R_S}$$

DS010055-24
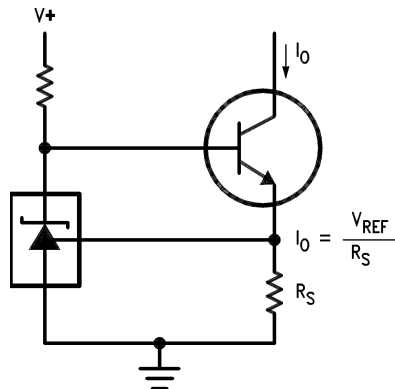
Application Info

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

0.189−0.197
(4.800−5.004)

8 7 6 5

0.228−0.244
(5.791−6.198)

0.010 MAX
(0.254)

LEAD NO. 1
IDENT

1 2 3 4

30°
TYP

0.010−0.020 × 45°
(0.254−0.508)

0.150−0.157
(3.810−3.988)

8° MAX TYP
ALL LEADS

0.004
(0.102)
ALL LEAD TIPS

0.008−0.010
(0.203−0.254)
TYP ALL LEADS

0.016−0.050
(0.406−1.270)
TYP ALL LEADS

0.053−0.069
(1.346−1.753)

0.004−0.010
(0.102−0.254)

SEATING
PLANE

0.014
(0.356)

0.050
(1.270)
TYP

0.008 TYP
(0.203)

0.014−0.020 TYP
(0.356−0.508)
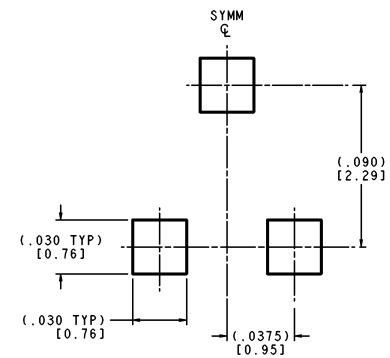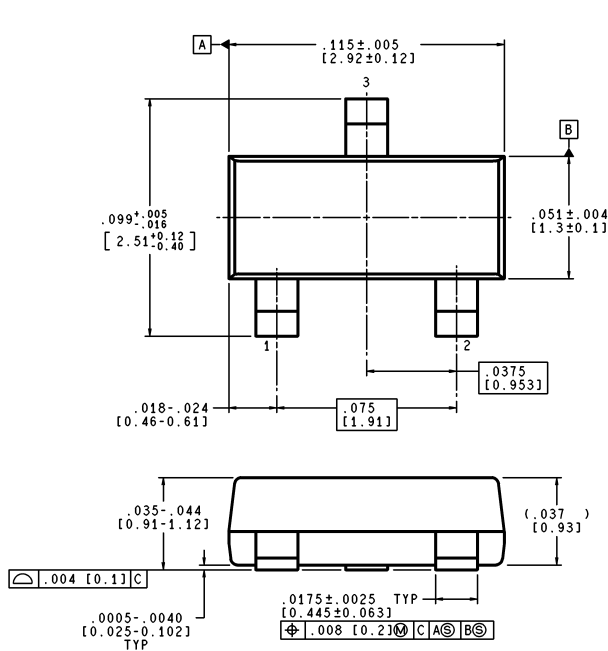
M08A (REV H)

NS Package Number M08A

A

.115±.005
[2.92±0.12]

3

B

.099+.005−.016
[2.51+0.12−0.40]

.051±.004
[1.3±0.1]

1   2

.018−.024
[0.46−0.61]

.075
[1.91]

.0375
[0.953]

.035−.044
[0.91−1.12]

(.037)
[0.93]

.004 [0.1] C

.0005−.0040
[0.025−0.102]
TYP

.0175±.0025 TYP
[0.445±0.063]

⊕ .008 [0.2] Ⓜ C AⓈ BⓈ

CONTROLLING DIMENSION IS INCH
VALUES IN [ ] ARE MILLIMETERS

SYMM
₵

(.090)
[2.29]

(.030 TYP)
[0.76]

(.030 TYP)
[0.76]

(.0375)
[0.95]

LAND PATTERN RECOMMENDATION

R.004 MIN TYP
[0.1]

R.004 MIN TYP
[0.1]

.005±.002 TYP
[0.13±0.05]

.024+.004−.002
[0.61+0.10−0.05]
TYP

SEATING
PLANE

.008
[0.2]
GAGE PLANE

C

0°−8° TYP

.015±.002
[0.39±0.05]

MF03A (Rev A)

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

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

5° 2 PLCS

0.0145-0.0155
[0.368-0.394] BEFORE LEAD FINISH

0.500
[12.70] MIN

SEATING PLANE

0.090
[2.29] MAX
(UNCONTROLLED
LEAD DIA)

0.045-0.055
[1.14-1.40] TYP

0.135-0.145
[3.43-3.68]

0.045-0.055
[1.14-1.40]

0.175-0.185
[4.45-4.70]

0.016-0.021
[0.41-0.53] TYP

EJECTION MARK
Ø 0.065
[1.65]

0.015
[0.38] MAX

R 0.090
[2.29]

10° 2 PLCS

Z03A (REV F)
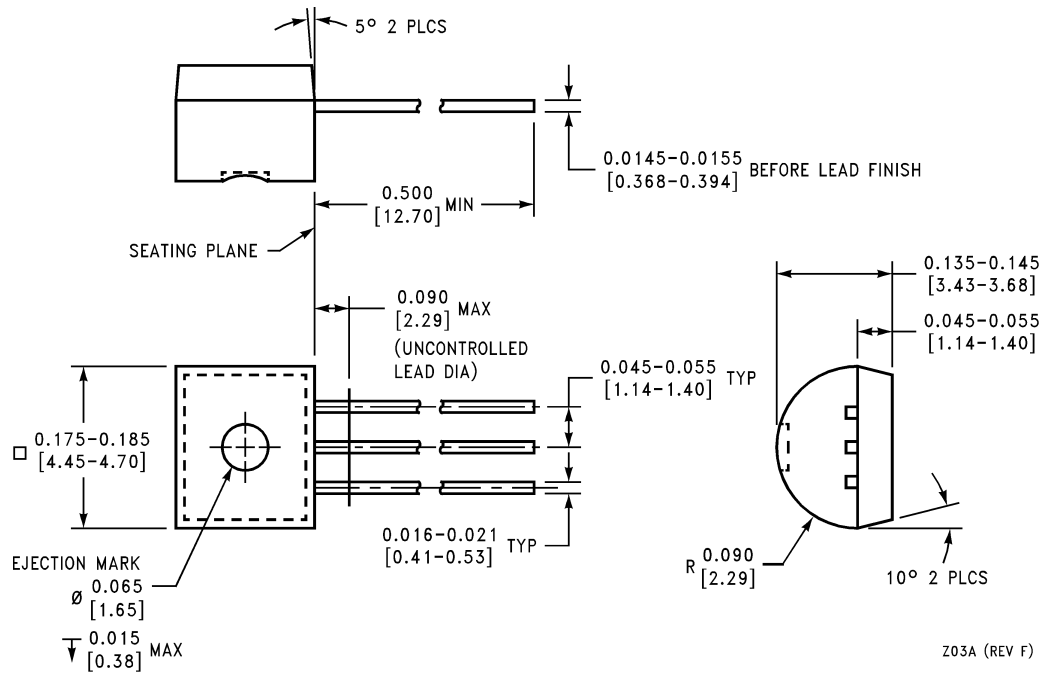
NS Package Number Z03A

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

PKG SYMM ℄

PKG SYMM ℄

(0.5)

(0.5)

(4X Ø $^{0.17}_{0.15}$)
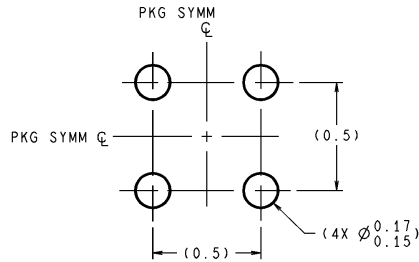
DIMENSIONS ARE IN MILLIMETERS

LAND PATTERN RECOMMENDATION

TOP SIDE COATING

BUMP A1 CORNER

0.125
0.050

X3

C

BUMP

SILICON

0.14
0.11

B

X2

SYMM
℄

0.5

2

SYMM
℄

X1

B   A

A

4X Ø $^{0.18}_{0.16}$

0.5

⊕ | 0.001 ⑤ | C | A ⑤ | B ⑤

BPA04XXX (Rev D)
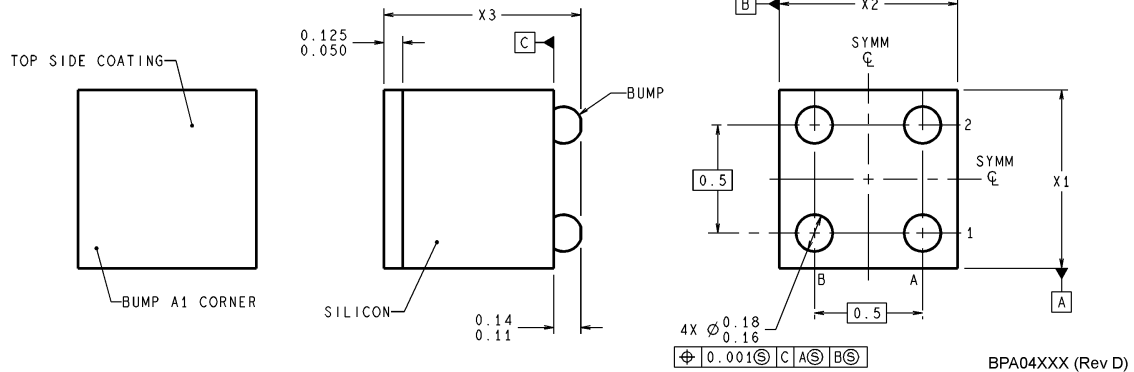
NOTES: UNLESS OTHERWISE SPECIFIED

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

LIFE SUPPORT POLICY

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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 is 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.