LM431

LM431 Adjustable Precision Zener Shunt Regulator

Literature Number: SNVS020F

September 2, 2010

National Semiconductor

LM431

Adjustable Precision Zener Shunt Regulator

General Description

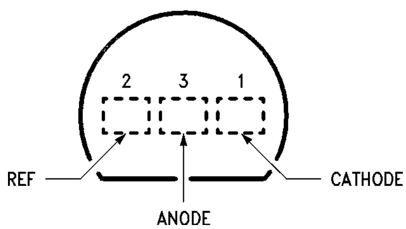
The LM431 is a 3-terminal adjustable shunt regulator with guaranteed temperature stability over the entire temperature range of operation. The output voltage may be set at any level greater than 2.5V (V_{REF}) up to 36V merely by selecting two external resistors that act as a voltage divided network.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



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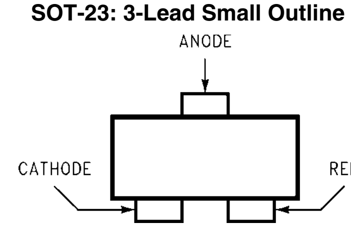
Top View

SOT-23: 3-Lead Small Outline



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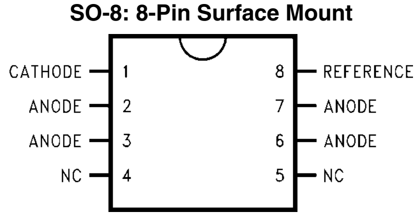
Top View

SO-8: 8-Pin Surface Mount



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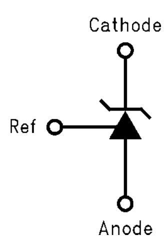
Top view

Note: NC = Not internally connected.

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	

Symbol and Functional Diagrams



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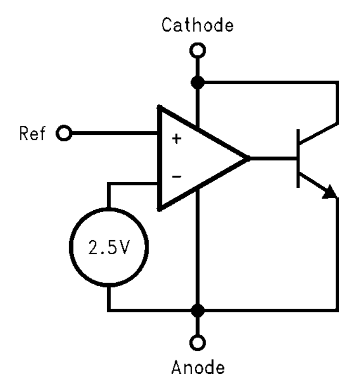

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DC Test Circuits

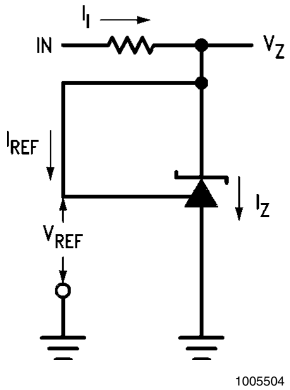
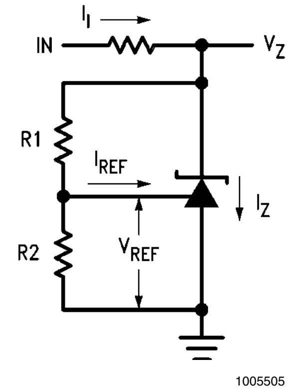


FIGURE 1. Test Circuit for $V_Z = V_{REF}$



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

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

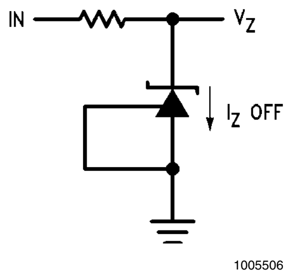


FIGURE 3. Test Circuit for Off-State Current

Absolute Maximum Ratings (Note 1)

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 (Note 2, Note 3)	
TO-92 Package	0.78W
SO-8 Package	0.81W
SOT-23 Package	0.28W

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

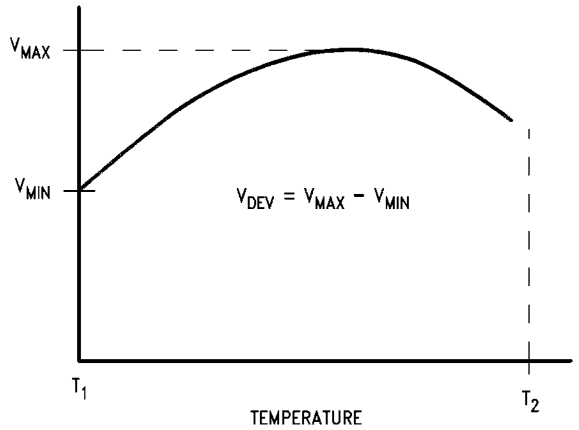
Symbol	Parameter	Conditions		Min	Typ	Max	Units
V_{REF}	Reference Voltage	$V_Z = V_{REF}$, I_I = 10 mA LM431A (Figure 1)		2.440	2.495	2.550	V
		$V_Z = V_{REF}$, I_I = 10 mA LM431B (Figure 1)		2.470	2.495	2.520	V
		$V_Z = V_{REF}$, I_I = 10 mA LM431C (Figure 1)		2.485	2.500	2.510	V
V_{DEV}	Deviation of Reference Input Voltage Over Temperature (Note 4)	$V_Z = V_{REF}$, 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, $R_2 = \infty$, I_I = 10 mA (Figure 2)			2.0	4.0	µA
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 5)	$V_Z = V_{REF}$, LM431A, Frequency = 0 Hz (Figure 1)				0.75	Ω
		$V_Z = V_{REF}$, LM431B, LM431C Frequency = 0 Hz (Figure 1)				0.50	Ω

Note 1: 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 2: $T_{J\ Max}$ = 150°C.

Note 3: 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.

Note 4: 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, V_{REF}, is defined as:

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

Where:

$T_2 - T_1$ = full temperature change (0-70°C).

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.

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

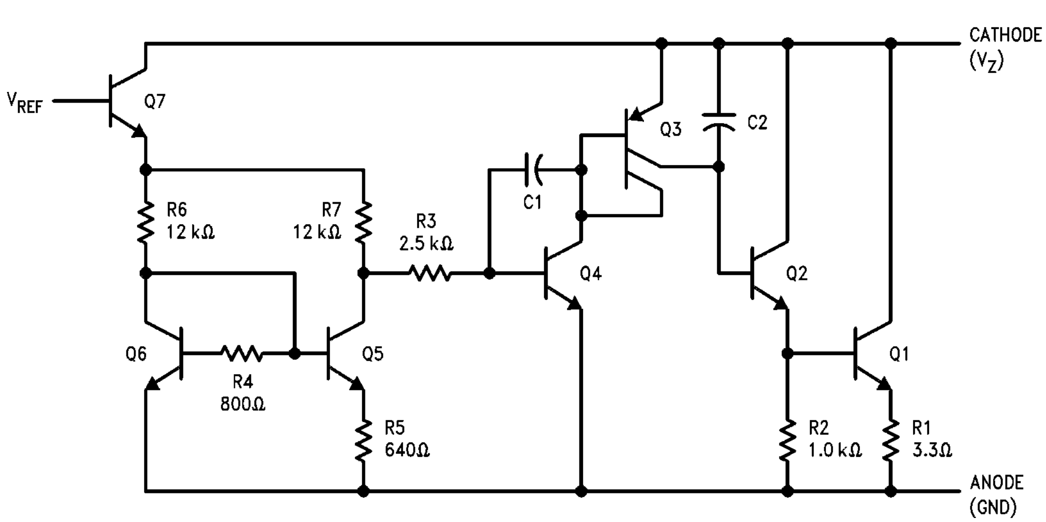
Note 5: The dynamic output impedance, r_Z, is defined as:

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

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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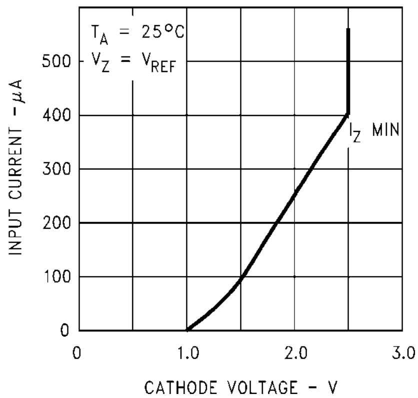
Typical Performance Characteristics

Input Current vs V_Z



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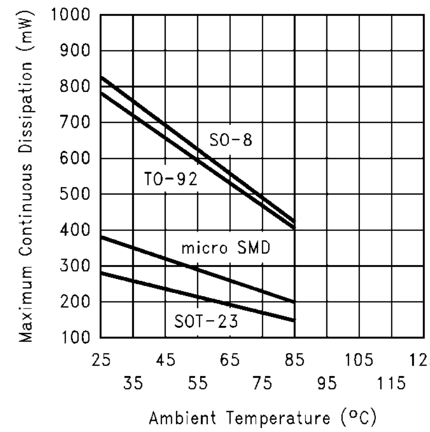
Thermal Information



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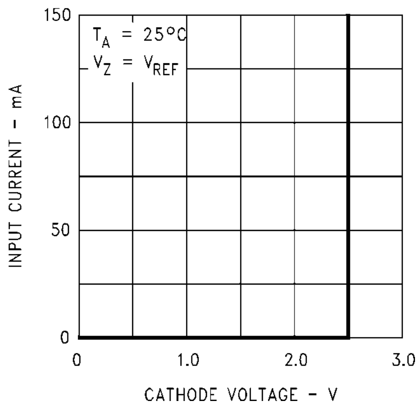
Input Current vs V_Z



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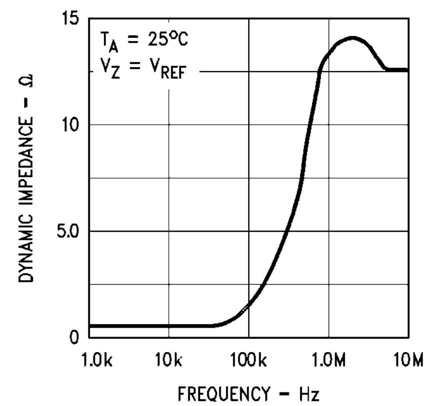
Dynamic Impedance vs Frequency



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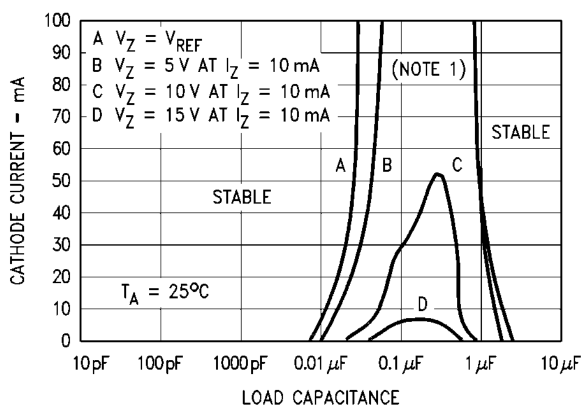
Stability Boundary Conditions



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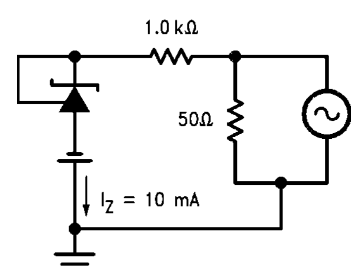

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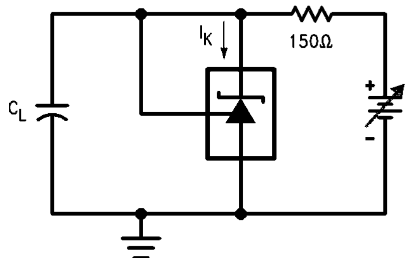
Note: The areas under the curves represent conditions that may cause the device to oscillate. For curves B, C, and D, R2 and V+ were adjusted to establish the initial V_Z and I_Z conditions with $C_L = 0$. V+ and C_L were then adjusted to determine the ranges of stability.

Test Circuit for Curve A Above



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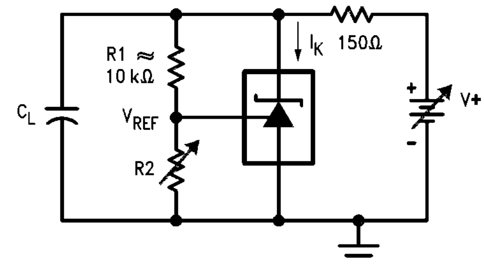
Test Circuit for Curves B, C and D Above



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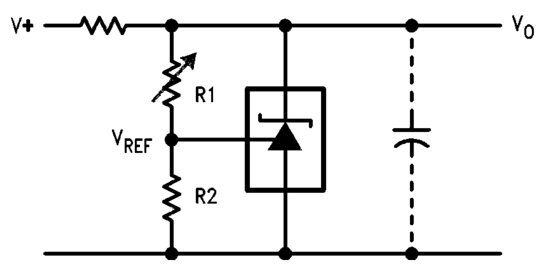
Typical Applications

Shunt Regulator



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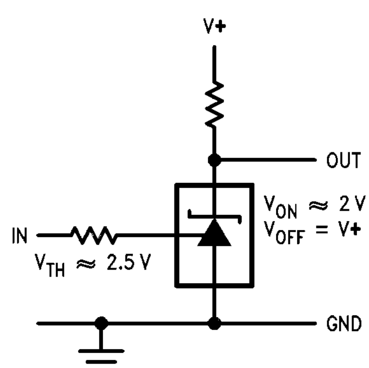
$$V_O \approx \left(1 + \frac{R1}{R2}\right) V_{REF}$$

Single Supply Comparator with Temperature Compensated Threshold



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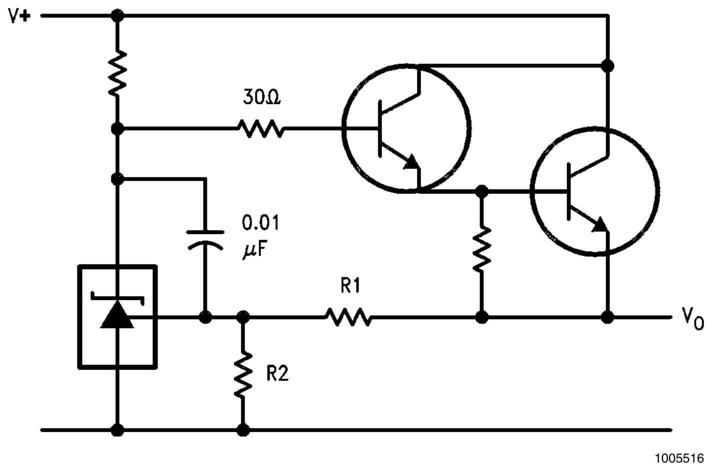
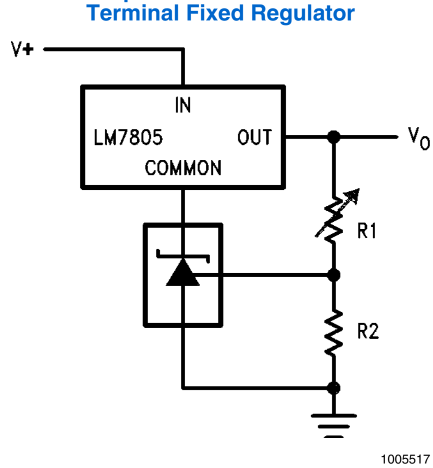
Series Regulator



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

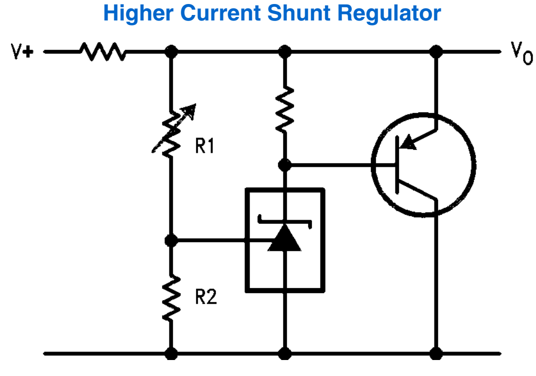
Output Control of a Three Terminal Fixed Regulator



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

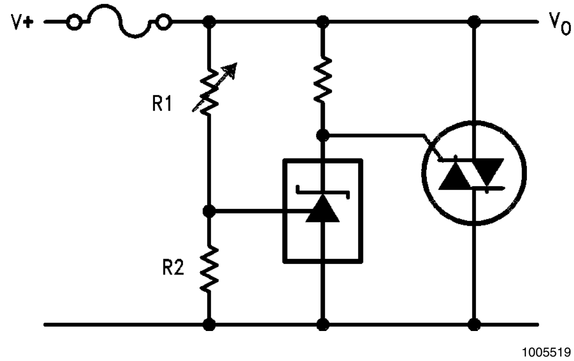
$$V_{O\ MIN} = V_{REF} + 5V$$

Higher Current Shunt Regulator



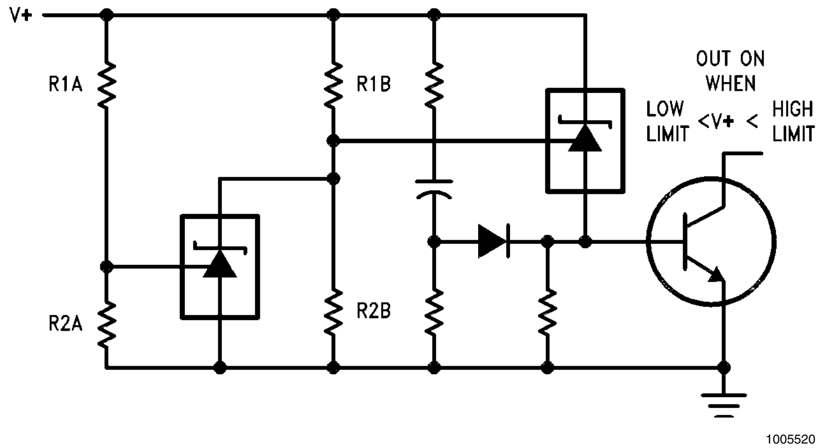
$$V_O \approx \left(1 + \frac{R1}{R2}\right) V_{REF}$$

Crow Bar



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

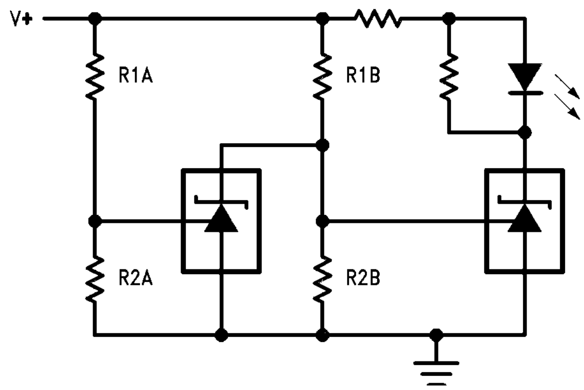
Over Voltage/Under Voltage Protection Circuit



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

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

Voltage Monitor



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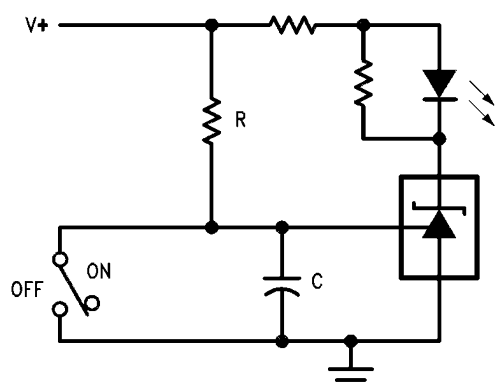
$$\text{LOW LIMIT} \approx V_{REF}\left(1 + \frac{R1B}{R2B}\right)$$

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

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

Delay Timer



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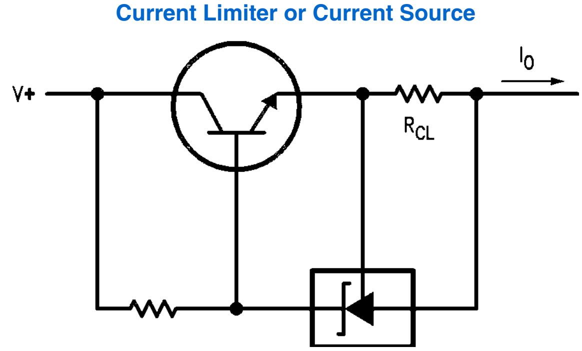
$$\text{DELAY} = R \bullet C \bullet \ell n \frac{V+}{(V^{+}) - V_{REF}}$$

Current Limiter or Current Source



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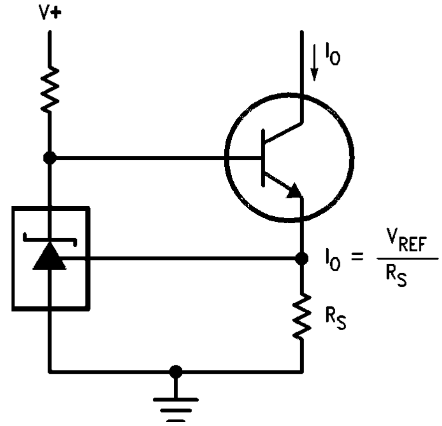
$$I_O = \frac{V_{REF}}{R_{CL}}$$

Constant Current Sink



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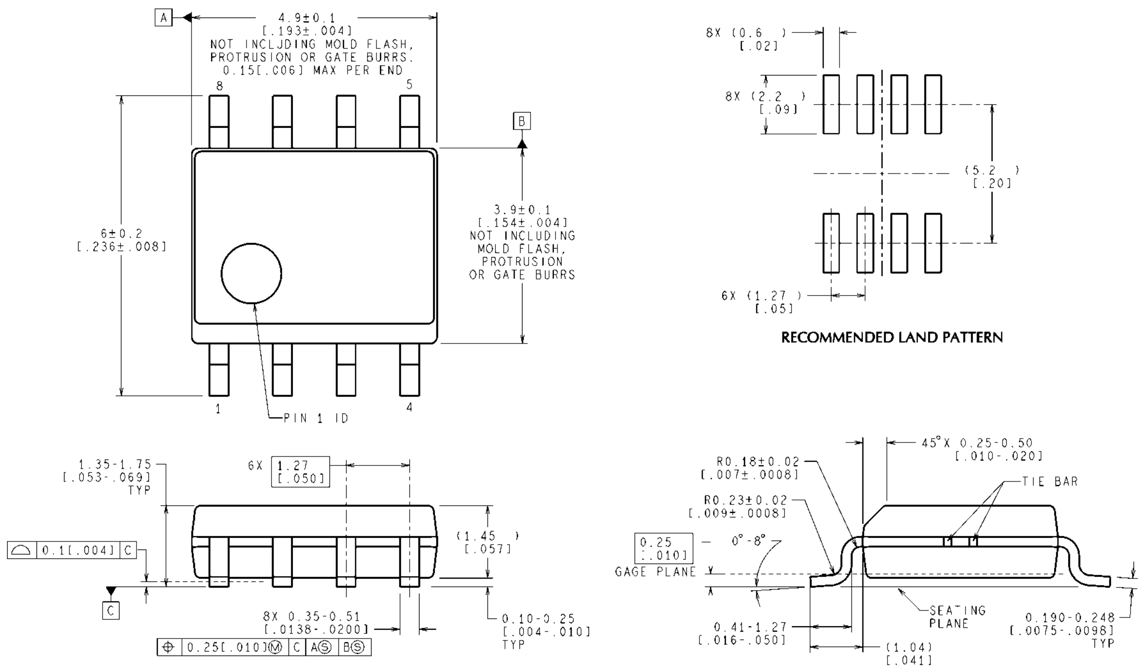
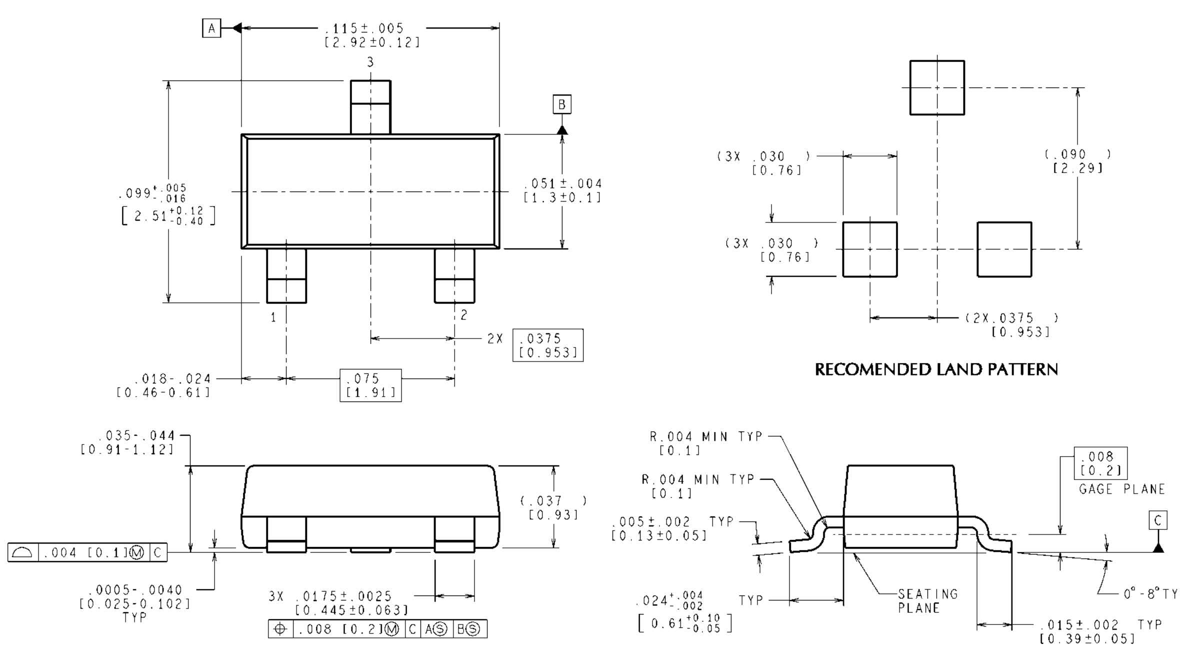
Physical Dimensions inches (millimeters) unless otherwise noted



CONTROLLING DIMENSION IS MILLIMETER
VALUES IN [ ] ARE INCHES
DIMENSIONS IN ( ) FOR REFERENCE ONLY

M08A (Rev M)

8-Pin SOIC
NS Package Number M08A



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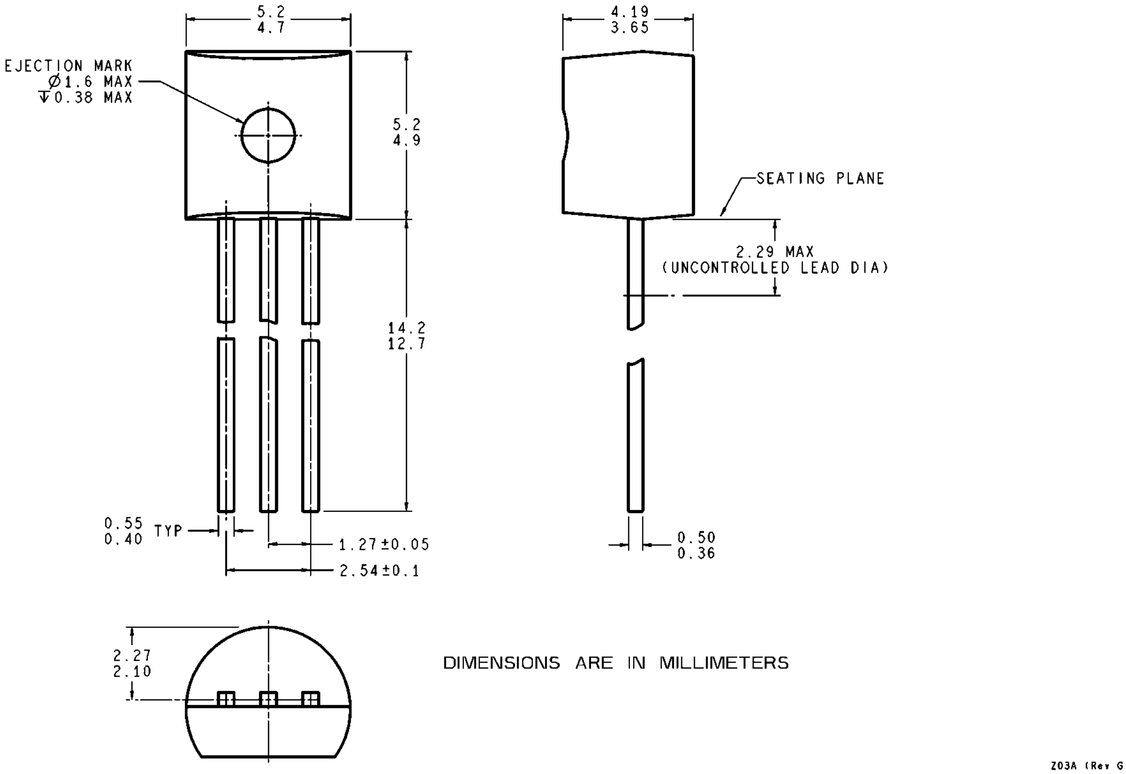
VALUES IN [ ] ARE MILLIMETERS

MF03A (Rev B)

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



NS Package Number Z03A

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LDOs	www.national.com/ldo	Quality and Reliability	www.national.com/quality
LED Lighting	www.national.com/led	Feedback/Support	www.national.com/feedback
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