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# LM431

## Adjustable Precision Zener Shunt Regulator

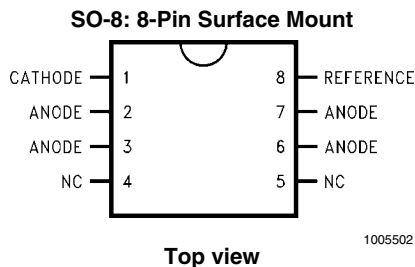
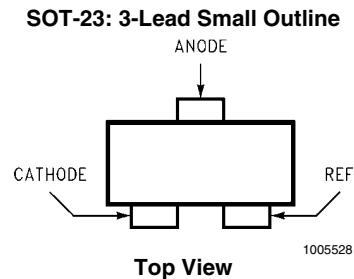
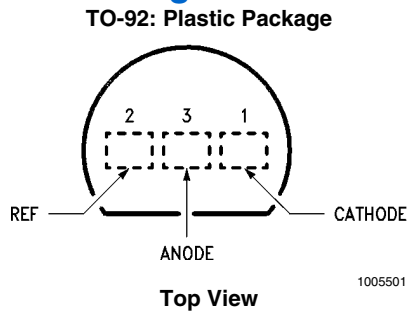
### General Description

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

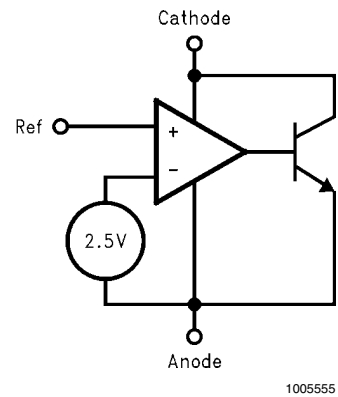
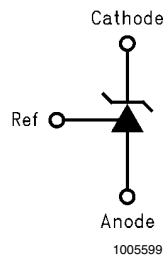


Note: NC = Not internally connected.

## 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



## DC Test Circuits

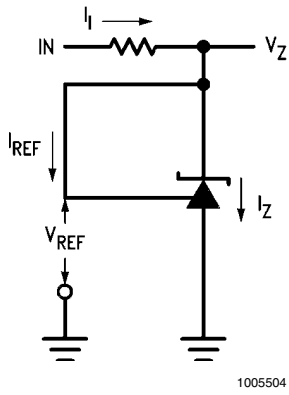
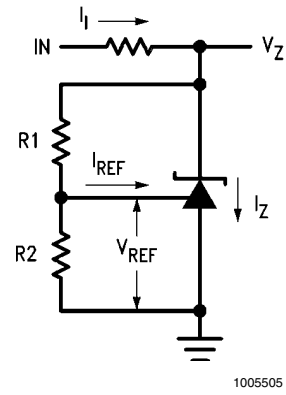


FIGURE 1. Test Circuit for  $V_Z = V_{REF}$



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

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

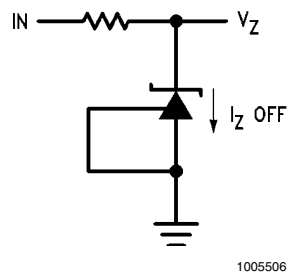


FIGURE 3. Test Circuit for Off-State Current

## 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 <i>(Note 2, Note 3)</i>	
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

$T_A = 25^\circ\text{C}$  unless otherwise specified

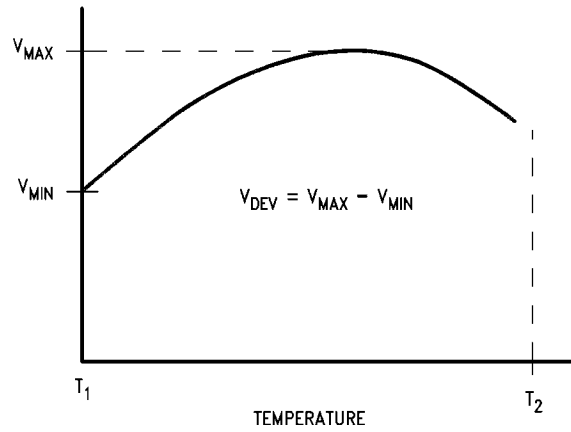
Symbol	Parameter	Conditions	Min	Typ	Max	Units
$V_{REF}$	Reference Voltage	$V_Z = V_{REF}$ , $I_1 = 10\text{ mA}$ LM431A <i>(Figure 1)</i>	2.440	2.495	2.550	V
		$V_Z = V_{REF}$ , $I_1 = 10\text{ mA}$ LM431B <i>(Figure 1)</i>	2.470	2.495	2.520	V
		$V_Z = V_{REF}$ , $I_1 = 10\text{ mA}$ LM431C <i>(Figure 1)</i>	2.485	2.500	2.510	V
$V_{DEV}$	Deviation of Reference Input Voltage Over Temperature <i>(Note 4)</i>	$V_Z = V_{REF}$ , $I_1 = 10\text{ mA}$ , $T_A = \text{Full Range}$ <i>(Figure 1)</i>		8.0	17	mV
$\frac{\Delta V_{REF}}{\Delta V_Z}$	Ratio of the Change in Reference Voltage to the Change in Cathode Voltage	$I_2 = 10\text{ mA}$ <i>(Figure 2)</i>	$V_Z$ 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	$R_1 = 10\text{ k}\Omega$ , $R_2 = \infty$ , $I_1 = 10\text{ mA}$ <i>(Figure 2)</i>		2.0	4.0	$\mu\text{A}$
$I_{REF}$	Deviation of Reference Input Current over Temperature	$R_1 = 10\text{ k}\Omega$ , $R_2 = \infty$ , $I_1 = 10\text{ mA}$ , $T_A = \text{Full Range}$ <i>(Figure 2)</i>		0.4	1.2	$\mu\text{A}$
$I_{Z(MIN)}$	Minimum Cathode Current for Regulation	$V_Z = V_{REF}$ <i>(Figure 1)</i>		0.4	1.0	mA
$I_{Z(OFF)}$	Off-State Current	$V_Z = 36\text{V}$ , $V_{REF} = 0\text{V}$ <i>(Figure 3)</i>		0.3	1.0	$\mu\text{A}$
$r_z$	Dynamic Output Impedance <i>(Note 5)</i>	$V_Z = V_{REF}$ , LM431A, Frequency = 0 Hz <i>(Figure 1)</i>			0.75	$\Omega$
		$V_Z = V_{REF}$ , LM431B, LM431C Frequency = 0 Hz <i>(Figure 1)</i>			0.50	$\Omega$

**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:**  $T_{J\text{Max}} = 150^\circ\text{C}$ .

**Note 3:** Ratings apply to ambient temperature at  $25^\circ\text{C}$ . Above this temperature, derate the TO-92 at  $6.2\text{ mW}/^\circ\text{C}$ , the SO-8 at  $6.5\text{ mW}/^\circ\text{C}$ , the SOT-23 at  $2.2\text{ mW}/^\circ\text{C}$ .

**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:

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

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:  $V_{\text{DEV}} = 8.0 \text{ mV}$ ,  $V_{\text{REF}} = 2495 \text{ mV}$ ,  $T_2 - T_1 = 70^{\circ}\text{C}$ , slope is positive.

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

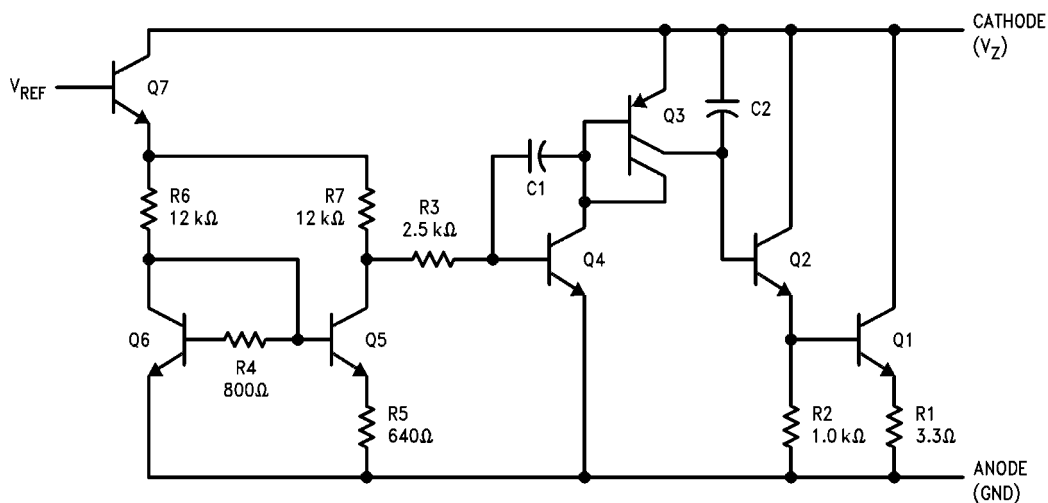
**Note 5:** The dynamic output impedance,  $r_z$ , is defined as:

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

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:

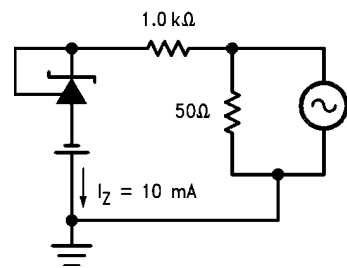
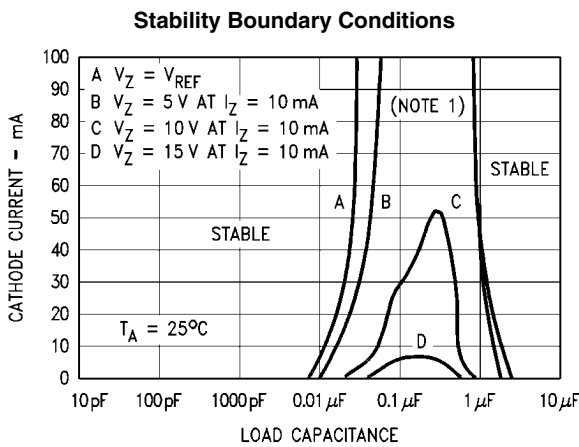
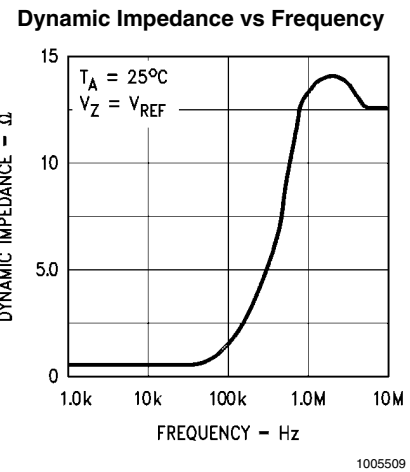
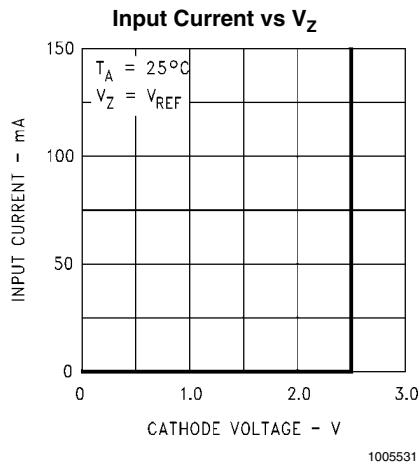
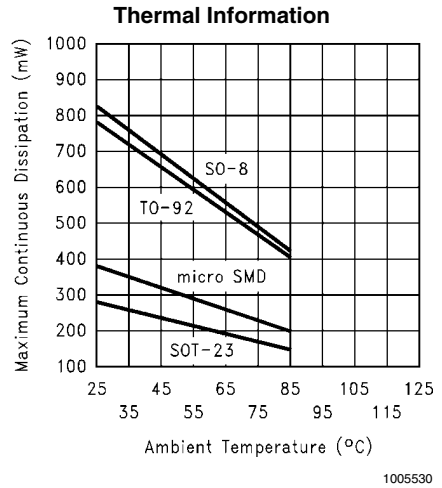
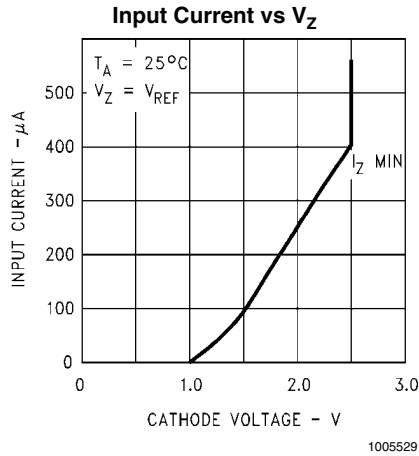
$$r_z = \frac{\Delta V_Z}{\Delta I_Z} \approx \left[ r_z \left( 1 + \frac{R1}{R2} \right) \right]$$

## Equivalent Circuit



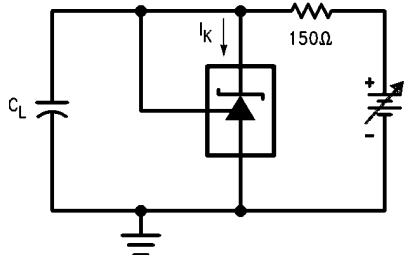
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# Typical Performance Characteristics



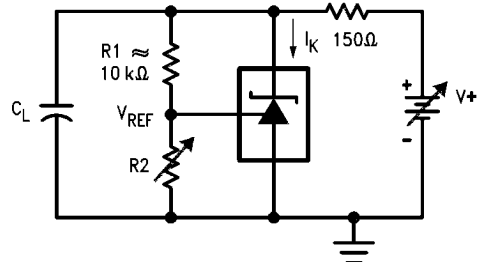
**Note:** The areas under the curves represent conditions that may cause the device to oscillate. For curves B, C, and D, R2 and V+ were adjusted to establish the initial  $V_Z$  and  $I_Z$  conditions with  $C_L = 0$ . V+ and  $C_L$  were then adjusted to determine the ranges of stability.

Test Circuit for Curve A Above



1005512

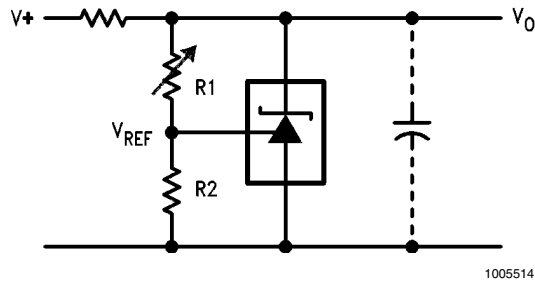
Test Circuit for Curves B, C and D Above



1005513

## Typical Applications

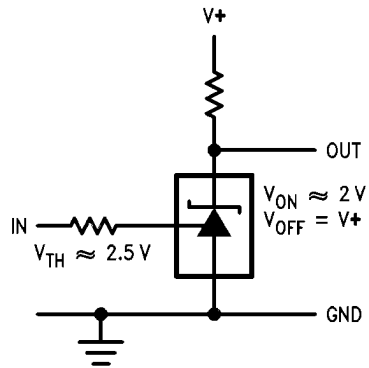
Shunt Regulator



1005514

$$V_O \approx \left(1 + \frac{R_1}{R_2}\right) V_{REF}$$

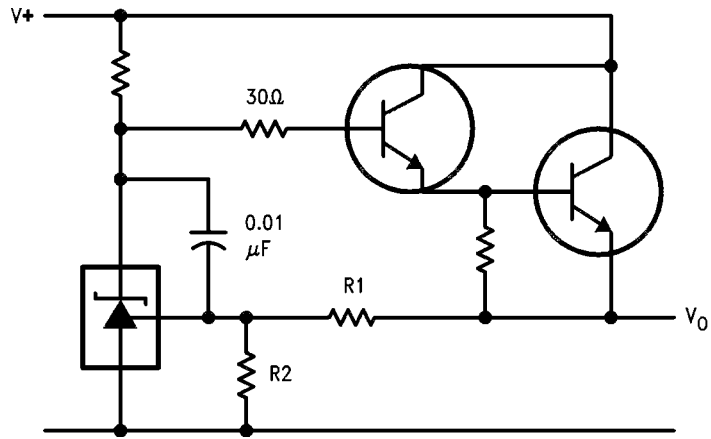
Single Supply Comparator with Temperature Compensated Threshold



1005515



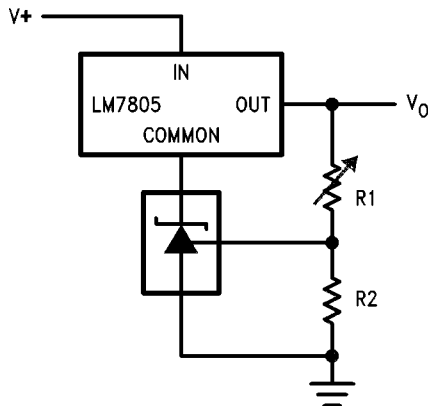
**Series Regulator**



1005516

$$V_O \approx \left( 1 + \frac{R_1}{R_2} \right) V_{REF}$$

**Output Control of a Three Terminal Fixed Regulator**

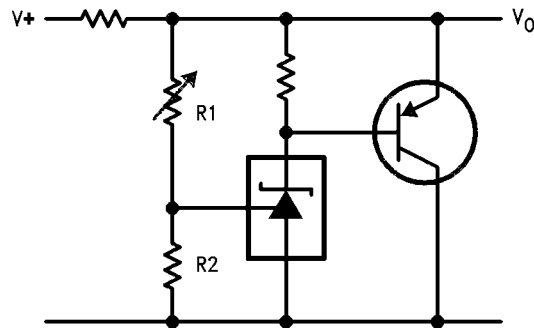


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$$V_O = \left( 1 + \frac{R_1}{R_2} \right) V_{REF}$$

$$V_O \text{ MIN} = V_{REF} + 5V$$

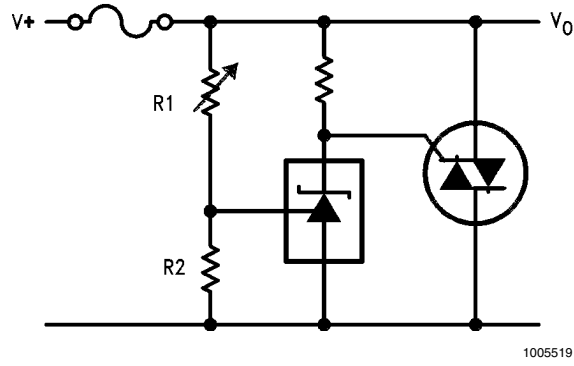
**Higher Current Shunt Regulator**



1005518

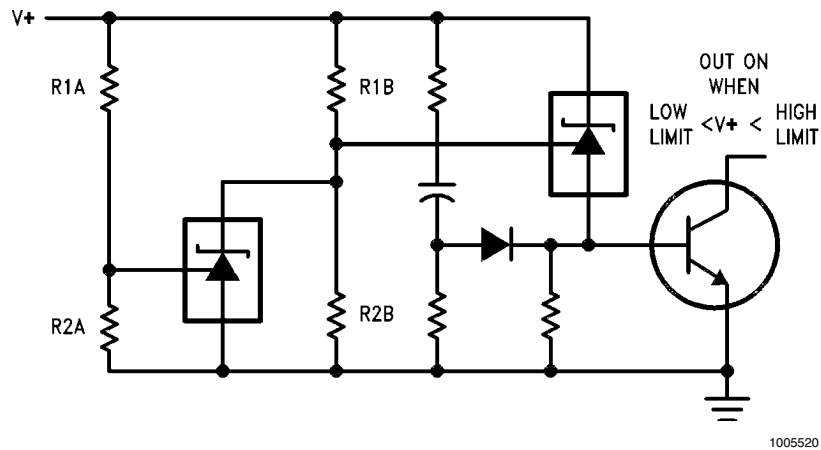
$$V_O \approx \left( 1 + \frac{R_1}{R_2} \right) V_{REF}$$

## Crow Bar



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

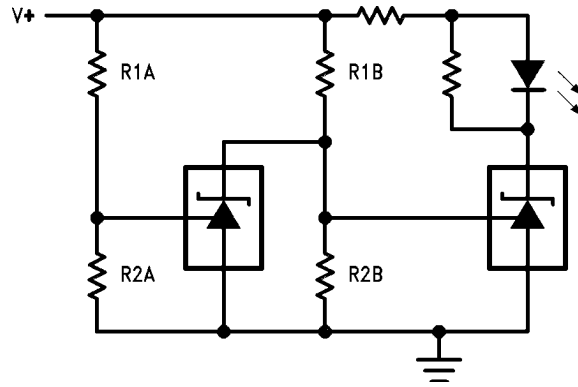
## Over Voltage/Under Voltage Protection Circuit



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

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

## Voltage Monitor



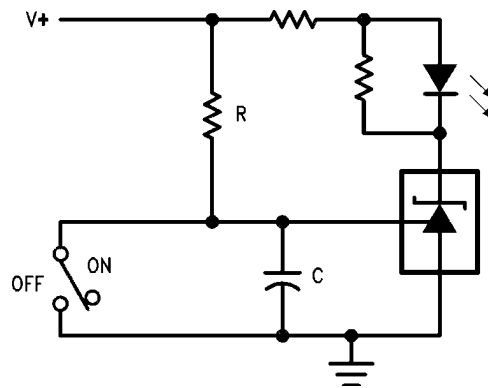
1005521

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

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

LED ON WHEN  
LOW LIMIT < V<sup>+</sup> < HIGH LIMIT

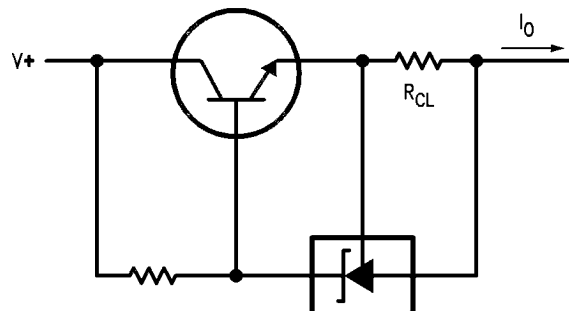
## Delay Timer



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$$\text{DELAY} = R \cdot C \cdot \ln \frac{V^+}{(V^+) - V_{\text{REF}}}$$

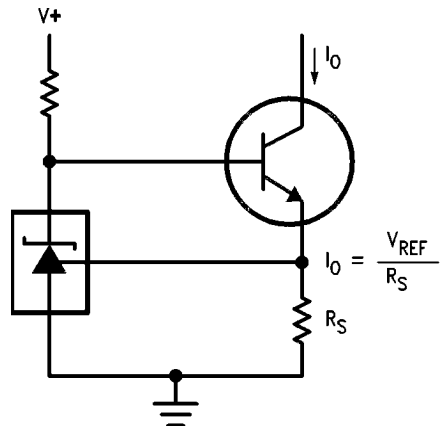
## Current Limiter or Current Source



1005523

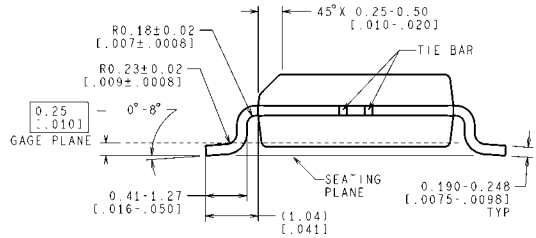
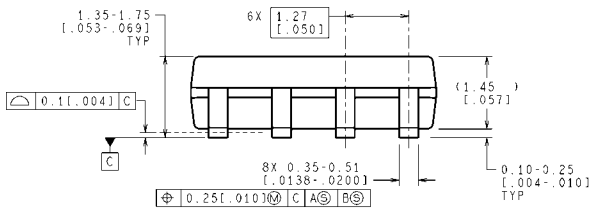
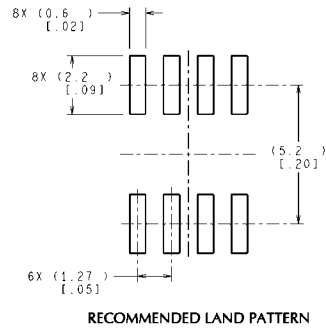
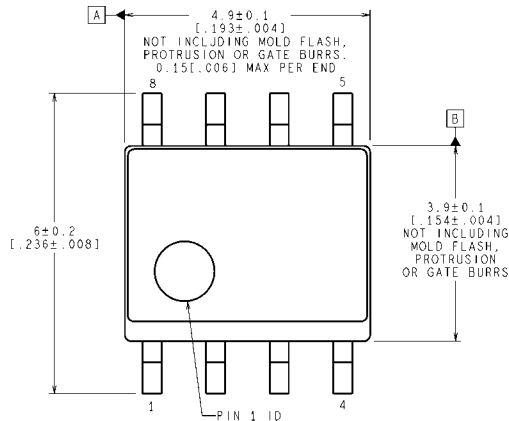
$$I_o = \frac{V_{\text{REF}}}{R_{\text{CL}}}$$

## Constant Current Sink



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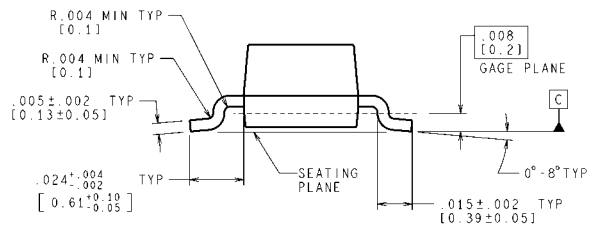
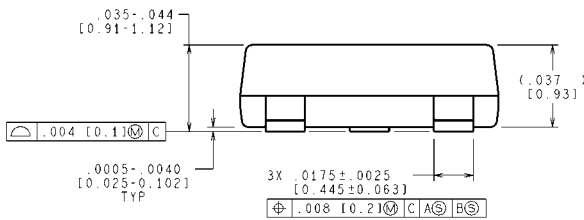
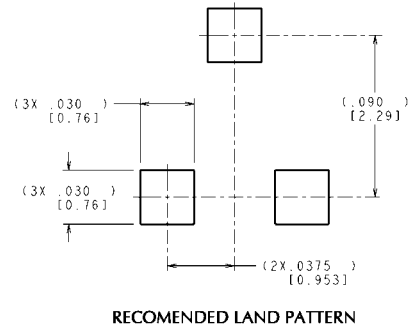
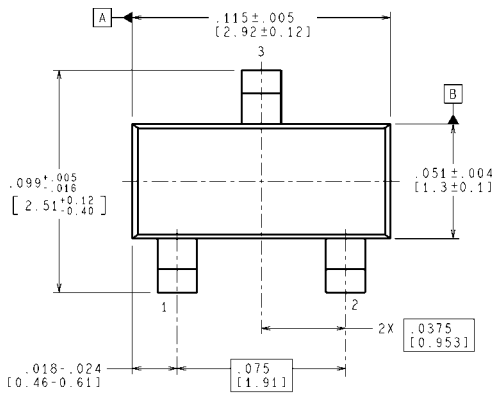
**Physical Dimensions** inches (millimeters) unless otherwise noted



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

M08A (Rev M)

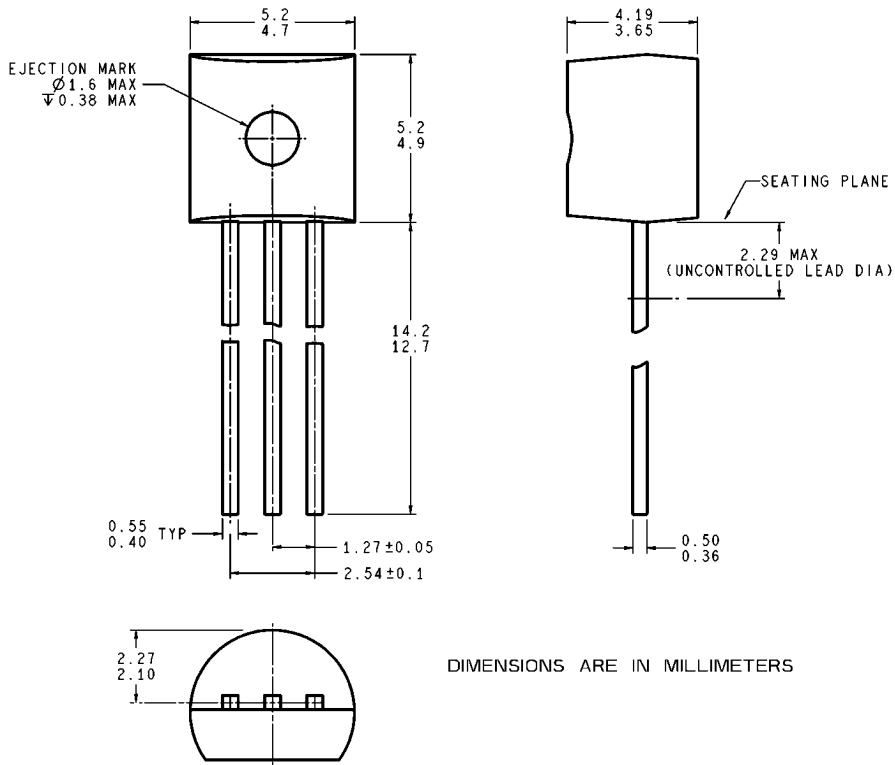
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NS Package Number M08A**



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MF03A (Rev B)

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



DIMENSIONS ARE IN MILLIMETERS

Z03A (Rev G)

NS Package Number Z03A

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Power Management	<a href="http://www.national.com/power">www.national.com/power</a>	Green Compliance	<a href="http://www.national.com/quality/green">www.national.com/quality/green</a>
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LDOs	<a href="http://www.national.com/ldo">www.national.com/ldo</a>	Quality and Reliability	<a href="http://www.national.com/quality">www.national.com/quality</a>
LED Lighting	<a href="http://www.national.com/led">www.national.com/led</a>	Feedback/Support	<a href="http://www.national.com/feedback">www.national.com/feedback</a>
Voltage References	<a href="http://www.national.com/vref">www.national.com/vref</a>	Design Made Easy	<a href="http://www.national.com/easy">www.national.com/easy</a>
PowerWise® Solutions	<a href="http://www.national.com/powerwise">www.national.com/powerwise</a>	Applications & Markets	<a href="http://www.national.com/solutions">www.national.com/solutions</a>
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