

# LM431

## Adjustable Precision Zener Shunt Regulator

### General Description

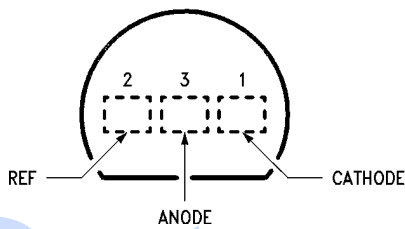
The LM431 is a 3-terminal adjustable shunt regulator with guaranteed temperature stability over the entire temperature range of operation. The output voltage may be set at any level greater than 2.5V ( $V_{REF}$ ) up to 36V merely by selecting two external resistors that act as a voltage divided network.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

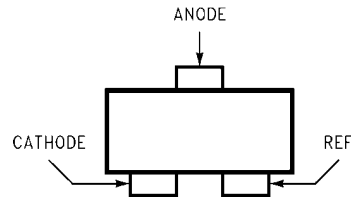
**TO-92: Plastic Package**



**Top View**

1005501

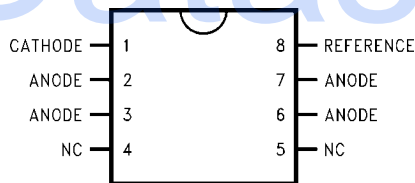
**SOT-23: 3-Lead Small Outline**



**Top View**

1005528

**SO-8: 8-Pin Surface Mount**



**Top view**

1005502

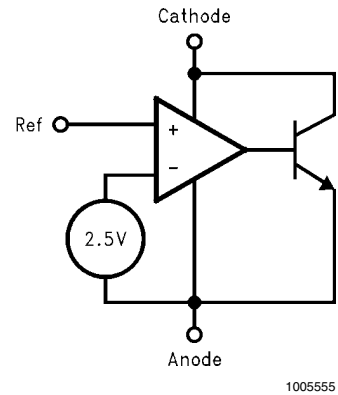
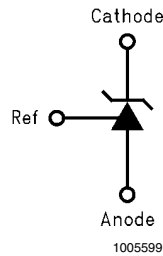
Note: NC = Not internally connected.

Datasheet.Live

## Ordering Information

| Package | Typical Accuracy Order Number/Package Marking |                       |                        | Temperature Range | Transport Media | NSC Drawing |
|---------|---|-----------------------|------------------------|-------------------|-----------------|-------------|
|         | 0.5%  | 1%                    | 2%                     |                   |                 |             |
| TO-92   | LM431CCZ/<br>LM431CCZ                         | LM431BCZ/<br>LM431BCZ | LM431ACZ/<br>LM431ACZ  | 0°C to +70°C      | Rails           | Z03A        |
|         | LM431CIZ/<br>LM431CIZ                         | LM431BIZ/<br>LM431BIZ | LM431AIZ/<br>LM431AIZ  | -40°C to +85°C    |                 |             |
| SO-8    | LM431CCM/<br>431CCM                           | LM431BCM/<br>431BCM   | LM431ACM/<br>LM431ACM  | 0°C to +70°C      | Rails           | M08A        |
|         | LM431CCMX/<br>431CCM                          | LM431BCMX/<br>431BCM  | LM431ACMX/<br>LM431ACM |                   | Tape & Reel     |             |
|         | LM431CIM/<br>431CIM                           | LM431BIM/<br>431BIM   | LM431AIM/<br>LM431AIM  | -40°C to +85°C    | Rails           |             |
|         | LM431CIMX/<br>431CIM                          | LM431BIMX/<br>431BIM  | LM431AIMX/<br>LM431AIM |                   | Tape & Reel     |             |
| SOT-23  | LM431CCM3/<br>N1B                             | LM431BCM3/<br>N1D     | LM431ACM3/<br>N1F      | 0°C to +70°C      | Rails           | MF03A       |
|         | LM431CCM3X/<br>N1B                            | LM431BCM3X/<br>N1D    | LM431ACM3X/<br>N1F     |                   | Tape & Reel     |             |
|         | LM431CIM3<br>N1A                              | LM431BIM3<br>N1C      | LM431AIM3<br>N1E       | -40°C to +85°C    | Rails           |             |
|         | LM431CIM3X<br>N1A                             | LM431BIM3X<br>N1C     | LM431AIM3X<br>N1E      |                   | Tape & Reel     |             |

## Symbol and Functional Diagrams



## DC Test Circuits

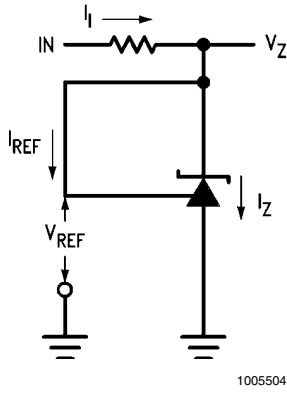
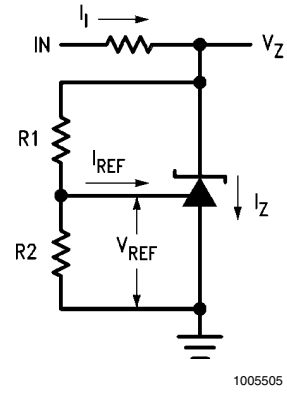


FIGURE 1. Test Circuit for  $V_Z = V_{REF}$



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

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

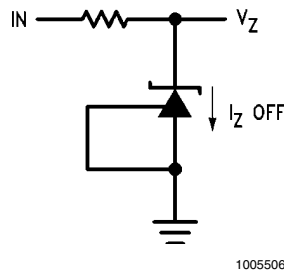


FIGURE 3. Test Circuit for Off-State Current

## 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

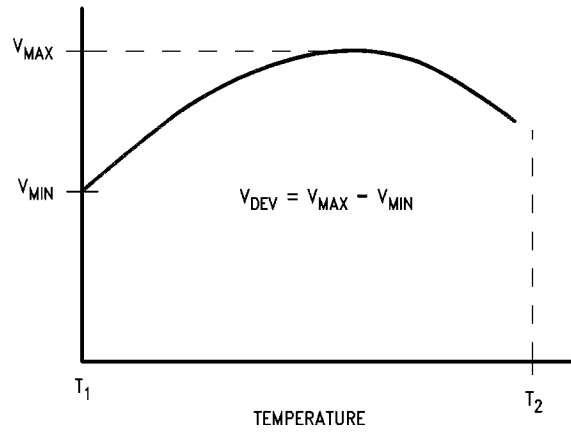
| Symbol                              | Parameter   | Conditions  | Min                         | Typ   | Max   | Units         |
|-------------------------------------|---|---|-----------------------------|-------|-------|---------------|
| $V_{REF}$                           | Reference Voltage   | $V_Z = V_{REF}$ , $I_1 = 10\text{ mA}$<br>LM431A <i>(Figure 1)</i>  | 2.440                       | 2.495 | 2.550 | V             |
|                                     |   | $V_Z = V_{REF}$ , $I_1 = 10\text{ mA}$<br>LM431B <i>(Figure 1)</i>  | 2.470                       | 2.495 | 2.520 | V             |
|                                     |   | $V_Z = V_{REF}$ , $I_1 = 10\text{ mA}$<br>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>     | $V_Z = V_{REF}$ , $I_1 = 10\text{ mA}$ ,<br>$T_A = \text{Full Range}$ <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 | $I_2 = 10\text{ mA}$<br><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   | $R_1 = 10\text{ k}\Omega$ , $R_2 = \infty$ ,<br>$I_1 = 10\text{ mA}$ <i>(Figure 2)</i>                                |                             | 2.0   | 4.0   | $\mu\text{A}$ |
| $I_{REF}$                           | Deviation of Reference Input Current over Temperature                     | $R_1 = 10\text{ k}\Omega$ , $R_2 = \infty$ ,<br>$I_1 = 10\text{ mA}$ ,<br>$T_A = \text{Full Range}$ <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,<br>Frequency = 0 Hz <i>(Figure 1)</i>   |                             |       | 0.75  | $\Omega$      |
|                                     |   | $V_Z = V_{REF}$ , LM431B, LM431C<br>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.



1005507

The average temperature coefficient of the reference input voltage,  $V_{REF}$ , is defined as:

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

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

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

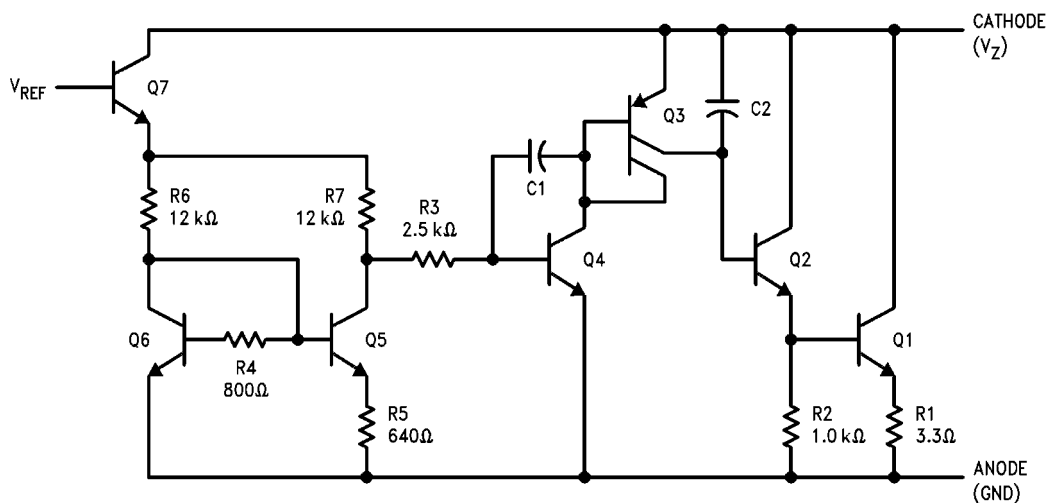
**Note 5:** The dynamic output impedance,  $r_z$ , is defined as:

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

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:

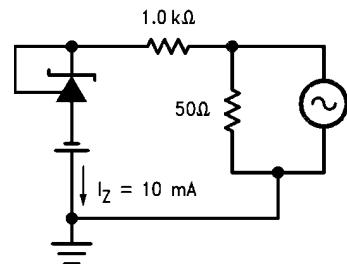
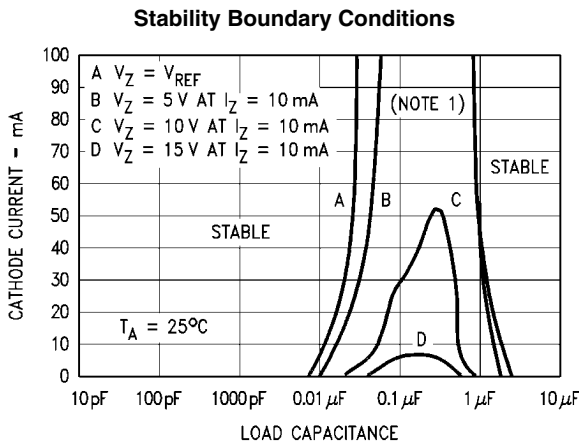
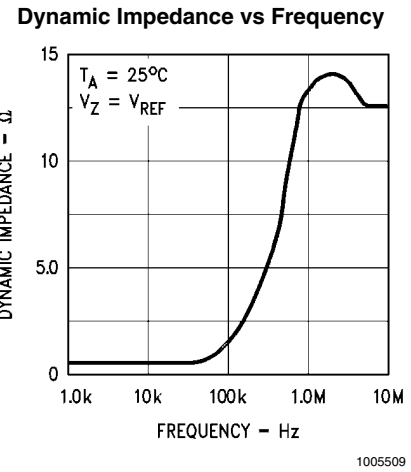
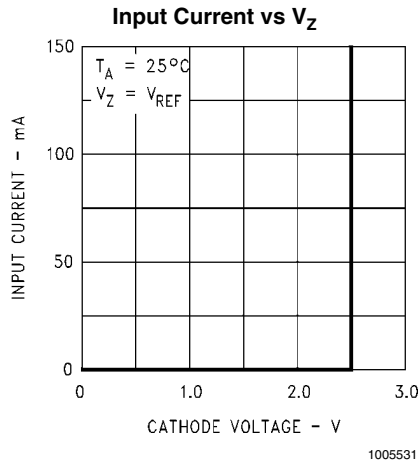
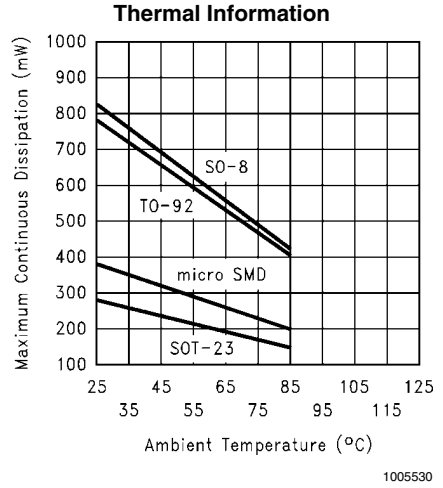
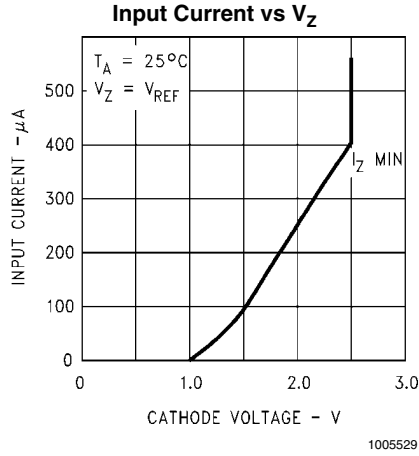
$$r_z = \frac{\Delta V_Z}{\Delta I_Z} \approx \left[ r_z \left( 1 + \frac{R1}{R2} \right) \right]$$

## Equivalent Circuit



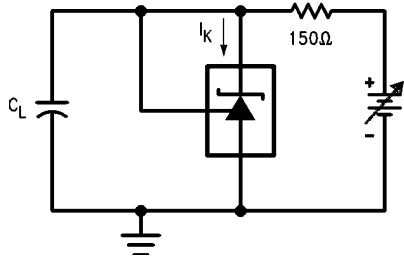
1005503

# Typical Performance Characteristics



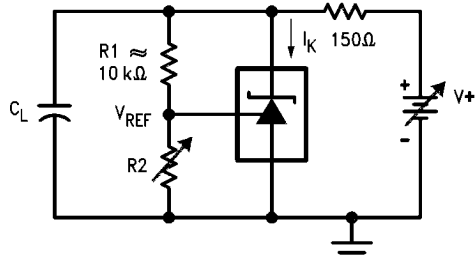
**Note:** The areas under the curves represent conditions that may cause the device to oscillate. For curves B, C, and D, R2 and V+ were adjusted to establish the initial  $V_Z$  and  $I_Z$  conditions with  $C_L = 0$ . V+ and  $C_L$  were then adjusted to determine the ranges of stability.

Test Circuit for Curve A Above



1005512

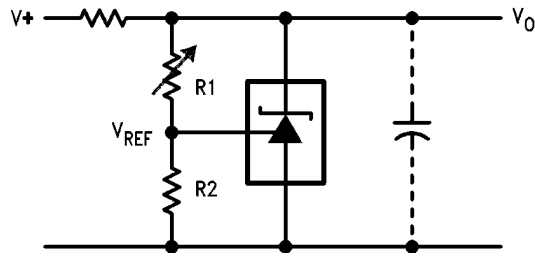
Test Circuit for Curves B, C and D Above



1005513

## Typical Applications

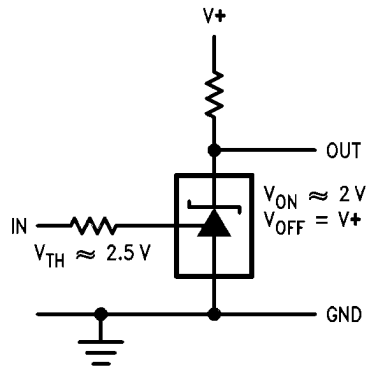
Shunt Regulator



1005514

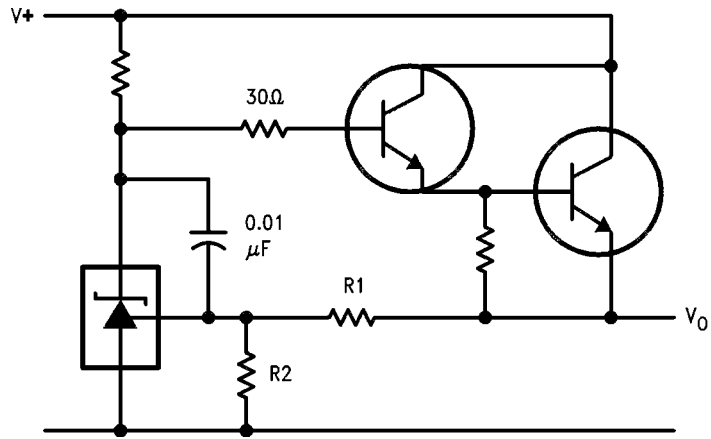
$$V_O \approx \left(1 + \frac{R1}{R2}\right) V_{REF}$$

Single Supply Comparator with Temperature Compensated Threshold



1005515

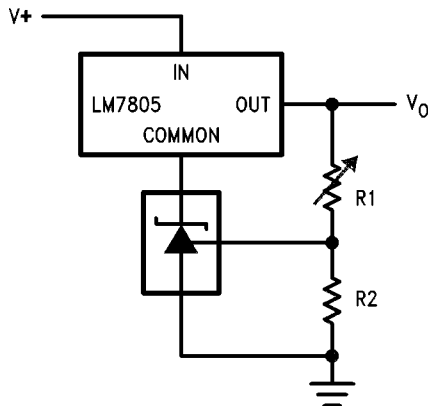
**Series Regulator**



1005516

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

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

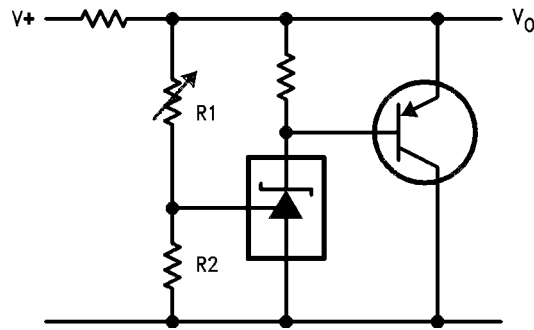


1005517

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

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

**Higher Current Shunt Regulator**

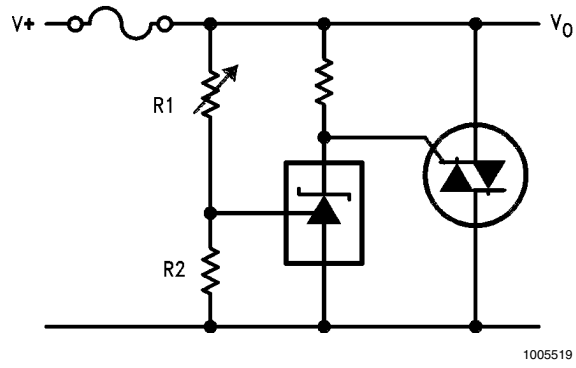


1005518

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

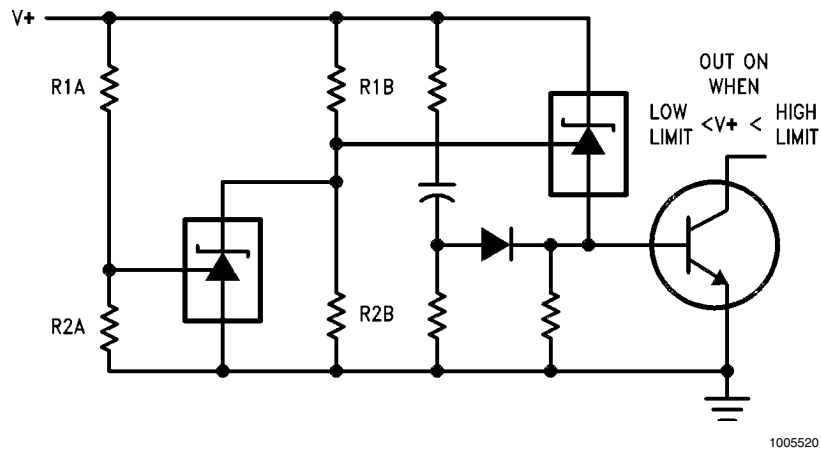


## Crow Bar



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

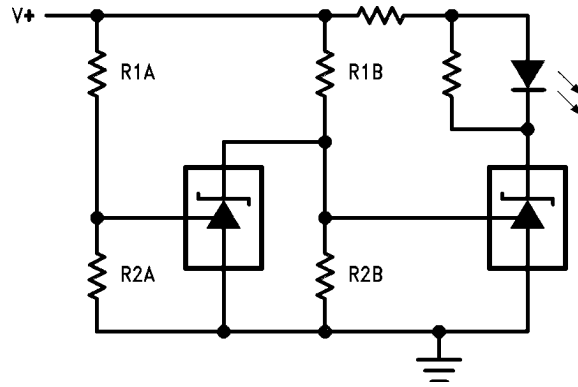
## Over Voltage/Under Voltage Protection Circuit



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

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

Voltage Monitor

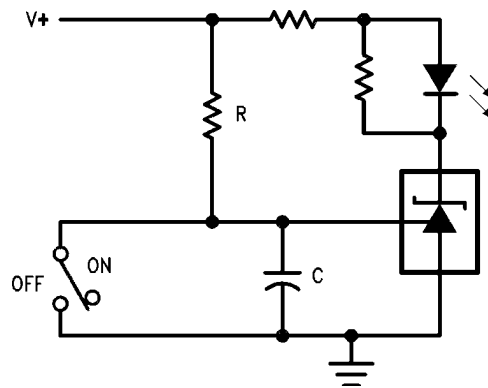


1005521

LOW LIMIT  $\approx V_{REF} \left( 1 + \frac{R1B}{R2B} \right)$  LED ON WHEN LOW LIMIT  $< V^+ <$  HIGH LIMIT

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

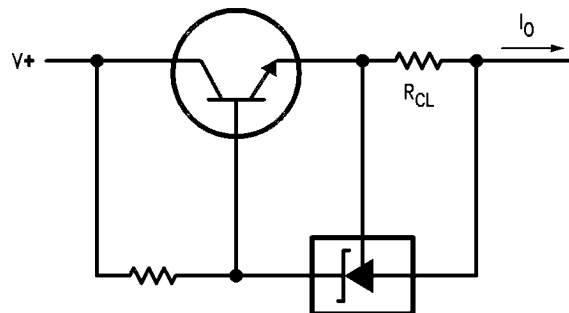
Delay Timer



1005522

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

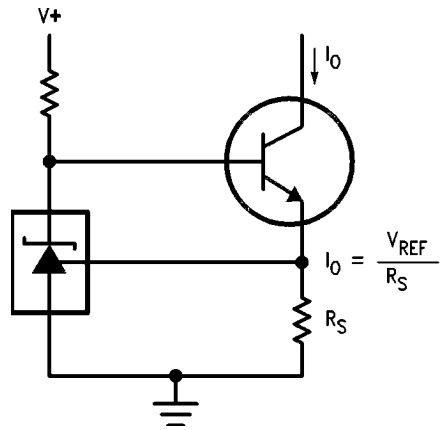
Current Limiter or Current Source



1005523

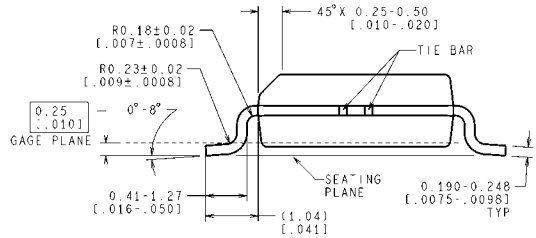
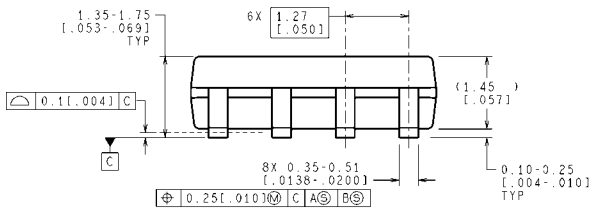
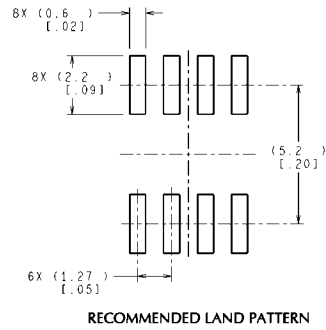
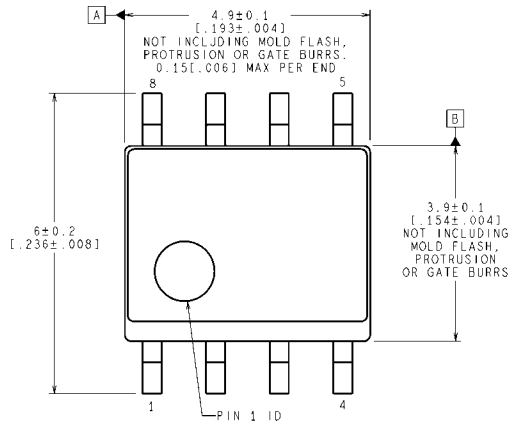
$$I_o = \frac{V_{REF}}{R_{CL}}$$

## Constant Current Sink



1005524

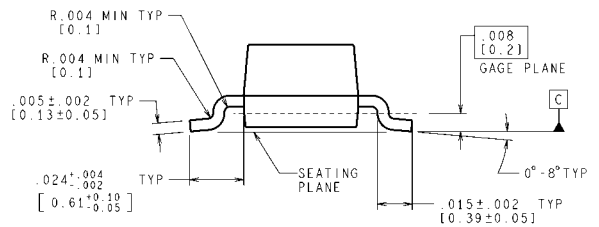
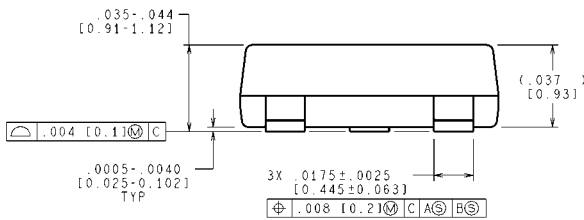
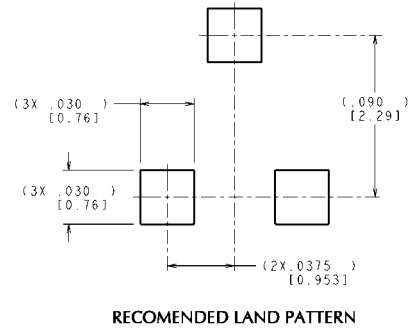
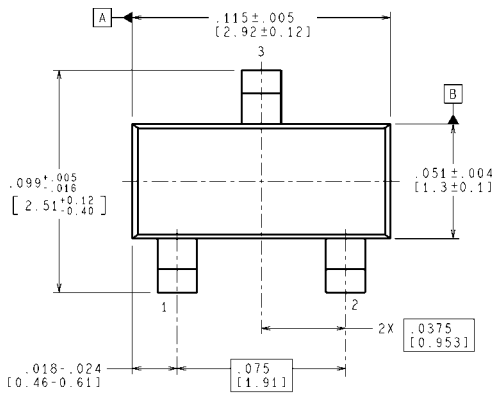
**Physical Dimensions** inches (millimeters) unless otherwise noted



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

M08A (Rev M)

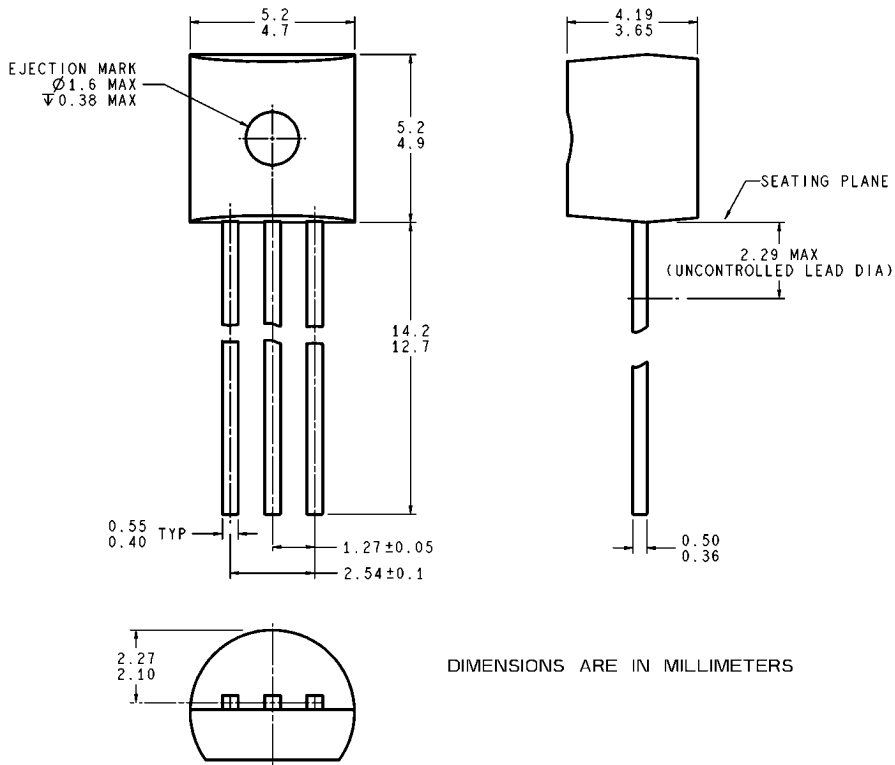
**8-Pin SOIC  
NS Package Number M08A**



CONTROLLING DIMENSION IS INCH  
VALUES IN [ ] ARE MILLIMETERS

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

## Notes

For more National Semiconductor product information and proven design tools, visit the following Web sites at:  
[www.national.com](http://www.national.com)

| Products                       |  | Design Support               |  |
|--------------------------------|--|------------------------------|--|
| Amplifiers                     | <a href="http://www.national.com/amplifiers">www.national.com/amplifiers</a> | WEBENCH® Tools               | <a href="http://www.national.com/webench">www.national.com/webench</a>             |
| Audio                          | <a href="http://www.national.com/audio">www.national.com/audio</a>           | App Notes                    | <a href="http://www.national.com/appnotes">www.national.com/appnotes</a>           |
| Clock and Timing               | <a href="http://www.national.com/timing">www.national.com/timing</a>         | Reference Designs            | <a href="http://www.national.com/refdesigns">www.national.com/refdesigns</a>       |
| Data Converters                | <a href="http://www.national.com/adc">www.national.com/adc</a>               | Samples                      | <a href="http://www.national.com/samples">www.national.com/samples</a>             |
| Interface                      | <a href="http://www.national.com/interface">www.national.com/interface</a>   | Eval Boards                  | <a href="http://www.national.com/evalboards">www.national.com/evalboards</a>       |
| LVDS                           | <a href="http://www.national.com/lvds">www.national.com/lvds</a>             | Packaging                    | <a href="http://www.national.com/packaging">www.national.com/packaging</a>         |
| 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> |
| Switching Regulators           | <a href="http://www.national.com/switchers">www.national.com/switchers</a>   | Distributors                 | <a href="http://www.national.com/contacts">www.national.com/contacts</a>           |
| 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>         |
| Serial Digital Interface (SDI) | <a href="http://www.national.com/sdi">www.national.com/sdi</a>               | Mil/Aero                     | <a href="http://www.national.com/milaero">www.national.com/milaero</a>             |
| Temperature Sensors            | <a href="http://www.national.com/tempensors">www.national.com/tempensors</a> | SolarMagic™                  | <a href="http://www.national.com/solarmagic">www.national.com/solarmagic</a>       |
| PLL/VCO                        | <a href="http://www.national.com/wireless">www.national.com/wireless</a>     | PowerWise® Design University | <a href="http://www.national.com/training">www.national.com/training</a>           |

THE CONTENTS OF THIS DOCUMENT ARE PROVIDED IN CONNECTION WITH NATIONAL SEMICONDUCTOR CORPORATION ("NATIONAL") PRODUCTS. NATIONAL MAKES NO REPRESENTATIONS OR WARRANTIES WITH RESPECT TO THE ACCURACY OR COMPLETENESS OF THE CONTENTS OF THIS PUBLICATION AND RESERVES THE RIGHT TO MAKE CHANGES TO SPECIFICATIONS AND PRODUCT DESCRIPTIONS AT ANY TIME WITHOUT NOTICE. NO LICENSE, WHETHER EXPRESS, IMPLIED, ARISING BY ESTOPPEL OR OTHERWISE, TO ANY INTELLECTUAL PROPERTY RIGHTS IS GRANTED BY THIS DOCUMENT.

TESTING AND OTHER QUALITY CONTROLS ARE USED TO THE EXTENT NATIONAL DEEMS NECESSARY TO SUPPORT NATIONAL'S PRODUCT WARRANTY. EXCEPT WHERE MANDATED BY GOVERNMENT REQUIREMENTS, TESTING OF ALL PARAMETERS OF EACH PRODUCT IS NOT NECESSARILY PERFORMED. NATIONAL ASSUMES NO LIABILITY FOR APPLICATIONS ASSISTANCE OR BUYER PRODUCT DESIGN. BUYERS ARE RESPONSIBLE FOR THEIR PRODUCTS AND APPLICATIONS USING NATIONAL COMPONENTS. PRIOR TO USING OR DISTRIBUTING ANY PRODUCTS THAT INCLUDE NATIONAL COMPONENTS, BUYERS SHOULD PROVIDE ADEQUATE DESIGN, TESTING AND OPERATING SAFEGUARDS.

EXCEPT AS PROVIDED IN NATIONAL'S TERMS AND CONDITIONS OF SALE FOR SUCH PRODUCTS, NATIONAL ASSUMES NO LIABILITY WHATSOEVER, AND NATIONAL DISCLAIMS ANY EXPRESS OR IMPLIED WARRANTY RELATING TO THE SALE AND/OR USE OF NATIONAL PRODUCTS INCLUDING LIABILITY OR WARRANTIES RELATING TO FITNESS FOR A PARTICULAR PURPOSE, MERCHANTABILITY, OR INFRINGEMENT OF ANY PATENT, COPYRIGHT OR OTHER INTELLECTUAL PROPERTY RIGHT.

#### LIFE SUPPORT POLICY

**NATIONAL'S PRODUCTS ARE NOT AUTHORIZED FOR USE AS CRITICAL COMPONENTS IN LIFE SUPPORT DEVICES OR SYSTEMS WITHOUT THE EXPRESS PRIOR WRITTEN APPROVAL OF THE CHIEF EXECUTIVE OFFICER AND GENERAL COUNSEL OF NATIONAL SEMICONDUCTOR CORPORATION.** As used herein:

Life support devices or systems are devices 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. A critical component is any component in 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.

National Semiconductor and the National Semiconductor logo are registered trademarks of National Semiconductor Corporation. All other brand or product names may be trademarks or registered trademarks of their respective holders.

Copyright© 2010 National Semiconductor Corporation

For the most current product information visit us at [www.national.com](http://www.national.com)



**National Semiconductor  
Americas Technical  
Support Center**  
Email: [support@nsc.com](mailto:support@nsc.com)  
Tel: 1-800-272-9959

**National Semiconductor Europe  
Technical Support Center**  
Email: [europe.support@nsc.com](mailto:europe.support@nsc.com)

**National Semiconductor Asia  
Pacific Technical Support Center**  
Email: [ap.support@nsc.com](mailto:ap.support@nsc.com)

**National Semiconductor Japan  
Technical Support Center**  
Email: [jpn.feedback@nsc.com](mailto:jpn.feedback@nsc.com)