

## LM431A

### Adjustable Precision Zener Shunt Regulator

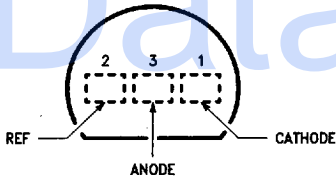
#### General Description

The LM431A 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

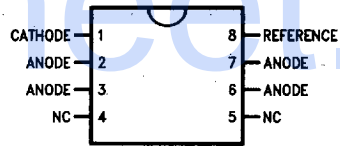
#### Connection Diagrams



Top View

Order Number LM431ACZ or LM431AIZ  
See NS Package Number Z03A

TL/H/10055-1



Top View

Order Number LM431ACM or LM431AIM  
See NS Package Number M08A

TL/H/10055-2

## Absolute Maximum Ratings

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 (LM431AI)	-40°C to +85°C
Commercial (LM431AC)	0°C to +70°C
Lead Temperature	
TO-92 Package/SO-8 Package	
(Soldering, 10 sec.)	265°C
Internal Power Dissipation (Notes 1, 2)	
TO-92 Package	0.78W
SO-8 Package	0.81W

Cathode Voltage	37V
Continuous Cathode Current	-10 mA to +150 mA
Reference Voltage	-0.5V
Reference Input Current	10 mA
Operating Conditions	<b>Min</b> <b>Max</b>
Cathode Voltage	V <sub>REF</sub> 37V
Cathode Current	1.0 mA      100 mA

Note 1: T<sub>J Max</sub> = 150°C.

Note 2: Ratings apply to ambient temperature at 25°C. Above this temperature, derate the TO-92 at 6.2 mW/°C, and the SO-8 at 6.5 mW/°C.

## LM431A

### Electrical Characteristics T<sub>A</sub> = 25°C unless otherwise specified

Symbol	Parameter	Conditions	Min	Typ	Max	Units
V <sub>REF</sub>	Reference Voltage	V <sub>Z</sub> = V <sub>REF</sub> , I <sub>I</sub> = 10 mA (Figure 1)	2.440	2.495	2.550	V
V <sub>DEV</sub>	Deviation of Reference Input Voltage Over Temperature (Note 3)	V <sub>Z</sub> = V <sub>REF</sub> , I <sub>I</sub> = 10 mA, T <sub>A</sub> = Full Range (Figure 1)		8.0	17	mV
ΔV <sub>REF</sub> ΔV <sub>Z</sub>	Ratio of the Change in Reference Voltage to the Change in Cathode Voltage	I <sub>Z</sub> = 10 mA (Figure 2)		-1.4	-2.7	mV/V
		V <sub>Z</sub> from V <sub>REF</sub> to 10V				
		V <sub>Z</sub> from 10V to 36V		-1.0	-2.0	
I <sub>REF</sub>	Reference Input Current	R <sub>1</sub> = 10 kΩ, R <sub>2</sub> = ∞, I <sub>I</sub> = 10 mA (Figure 2)		2.0	4.0	μA
α I <sub>REF</sub>	Deviation of Reference Input Current over Temperature	R <sub>1</sub> = 10 kΩ, R <sub>2</sub> = ∞, I <sub>I</sub> = 10 mA, T <sub>A</sub> = Full Range (Figure 2)		0.4	1.2	μA
I <sub>Z(MIN)</sub>	Minimum Cathode Current for Regulation	V <sub>Z</sub> = V <sub>REF</sub> (Figure 1)		0.4	1.0	mA
I <sub>Z(OFF)</sub>	Off-State Current	V <sub>Z</sub> = 36V, V <sub>REF</sub> = 0V (Figure 3)		0.3	1.0	μA
r <sub>Z</sub>	Dynamic Output Impedance (Note 4)	V <sub>Z</sub> = V <sub>REF</sub> , Frequency = 0 Hz (Figure 1)			0.75	Ω

Note 3: Deviation of reference input voltage, V<sub>DEV</sub>, is defined as the maximum variation of the reference input voltage over the full temperature range.

The average temperature coefficient of the reference input voltage, α V<sub>REF</sub>, is defined as:

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

Where:

T<sub>2</sub> - T<sub>1</sub> = full temperature change.

α V<sub>REF</sub> can be positive or negative depending on whether the slope is positive or negative.

Example: V<sub>DEV</sub> = 8.0 mV, V<sub>REF</sub> = 2495 mV, T<sub>2</sub> - T<sub>1</sub> = 70°C, slope is positive.

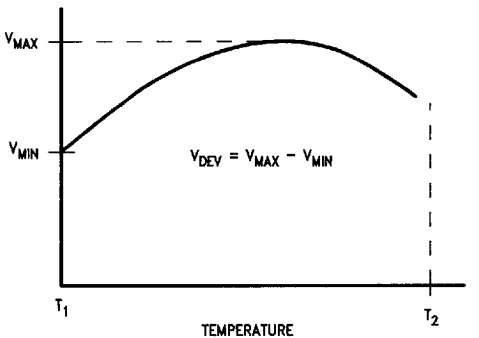
$$\alpha V_{REF} = \frac{\left[ \frac{8.0 \text{ mV}}{2495 \text{ mV}} \right] 10^6}{70^{\circ}\text{C}} = +46 \text{ ppm}/^{\circ}\text{C}$$

Note 4: The dynamic output impedance, r<sub>Z</sub>, is defined as:

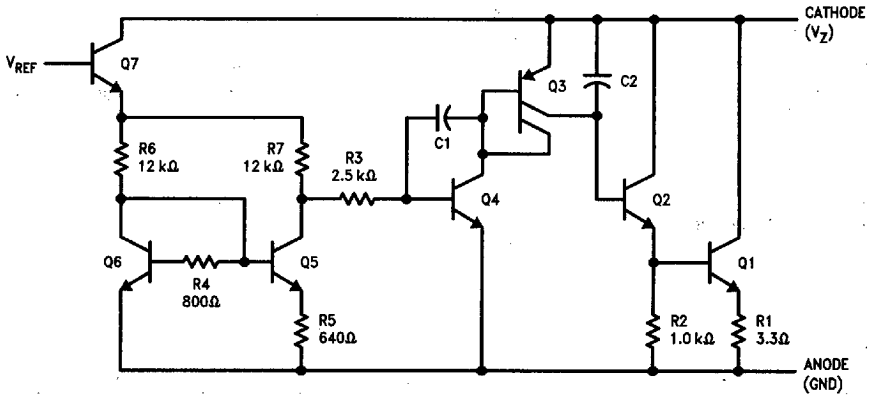
$$r_Z = \frac{\Delta V_Z}{\Delta I_Z}$$

When the device is programmed with two external resistors, R<sub>1</sub> and R<sub>2</sub>, (see Figure 2), the dynamic output impedance of the overall circuit, r<sub>Z</sub>, is defined as:

$$r_Z = \frac{\Delta V_Z}{\Delta I_Z} \approx \left[ r_Z + \frac{R_1}{R_2} \right]$$

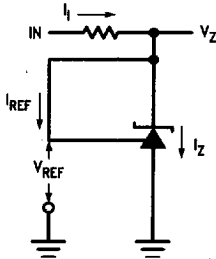


### Equivalent Circuit



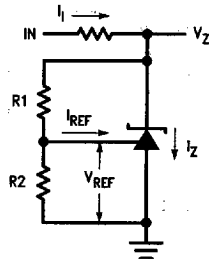
TL/H/10055-3

### DC Test Circuits



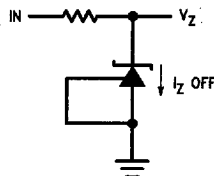
TL/H/10055-4

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



TL/H/10055-5

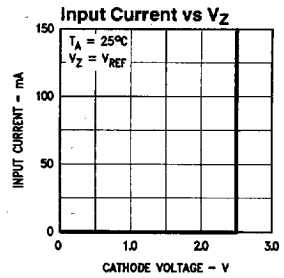
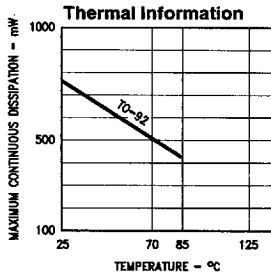
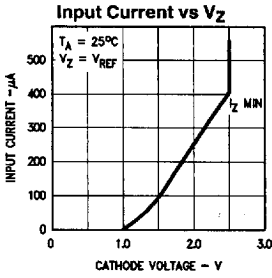
Note:  $V_Z = V_{REF} (1 + R_1/R_2) + I_{REF} \cdot R_1$   
 FIGURE 2. Test Circuit for  $V_Z > V_{REF}$



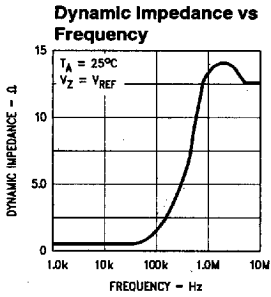
TL/H/10055-6

FIGURE 3. Test Circuit for Off-State Current

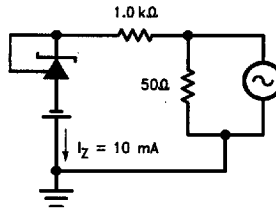
# Typical Performance Characteristics



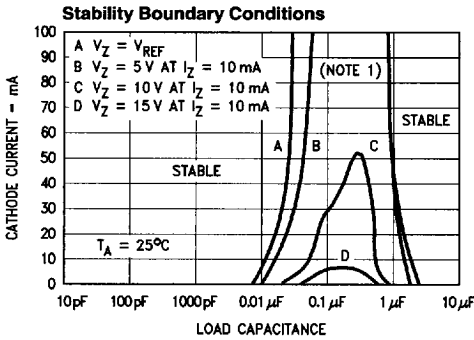
TL/H/10055-8



TL/H/10055-9



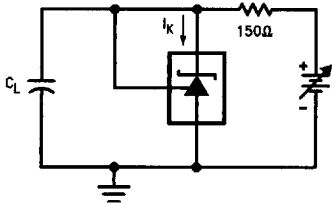
TL/H/10055-10



TL/H/10055-11

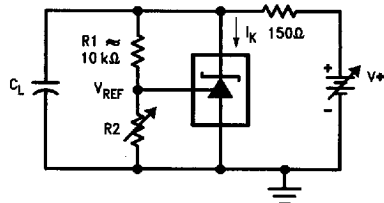
**Note 1:** The areas under the curves represent conditions that may cause the device to oscillate. For curves B, C, and D, R2 and V+ were adjusted to establish the initial Vz and Iz conditions with CL = 0. V+ and CL were then adjusted to determine the ranges of stability.

Test Circuit for Curve A Above



TL/H/10055-12

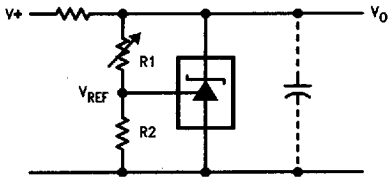
Test Circuit for Curves B, C and D Above



TL/H/10055-13

# Typical Applications

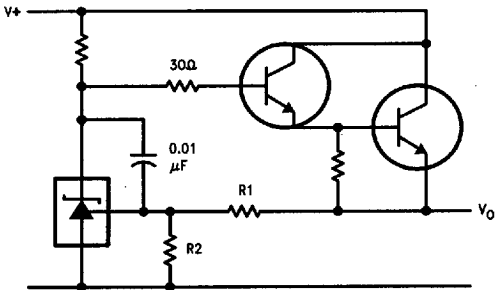
**Shunt Regulator**



TL/H/10055-14

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

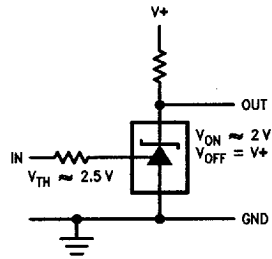
**Series Regulator**



TL/H/10055-16

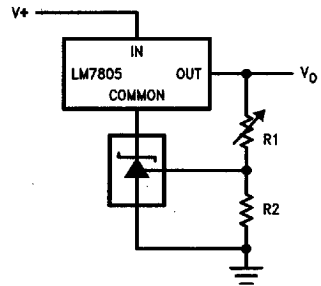
$$V_O \approx \left(1 + \frac{R1}{R2}\right) V_{REF}$$

**Single Supply Comparator with Temperature Compensated Threshold**



TL/H/10055-15

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



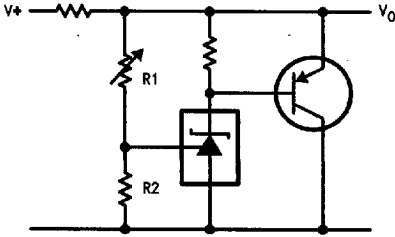
TL/H/10055-17

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

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

**Typical Applications** (Continued)

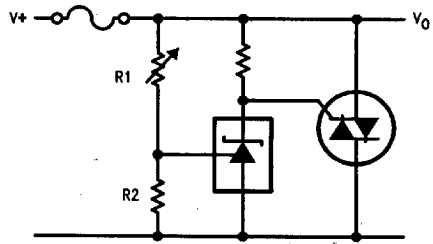
**Higher Current Shunt Regulator**



TL/H/10055-18

$$V_0 = \left(1 + \frac{R_1}{R_2}\right) V_{REF}$$

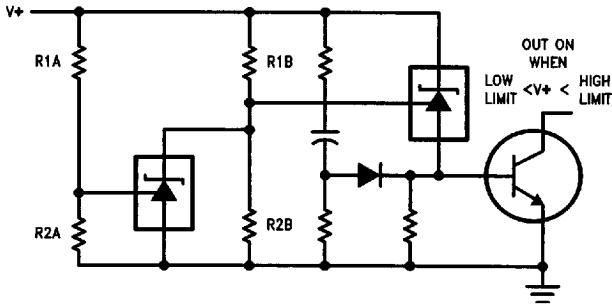
**Crow Bar**



TL/H/10055-19

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

**Over Voltage/Under Voltage Protection Circuit**



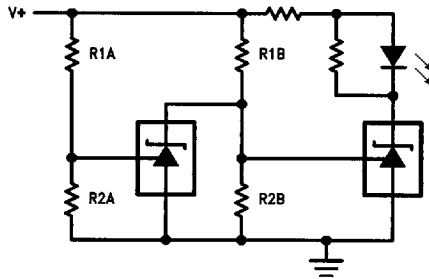
TL/H/10055-20

$$LOW\ LIMIT \approx V_{REF} \left(1 + \frac{R_{1B}}{R_{2B}}\right) + V_{BE}$$

$$HIGH\ LIMIT \approx V_{REF} \left(1 + \frac{R_{1A}}{R_{2A}}\right)$$

OUT ON WHEN  
LOW LIMIT < V+ < HIGH LIMIT

**Voltage Monitor**

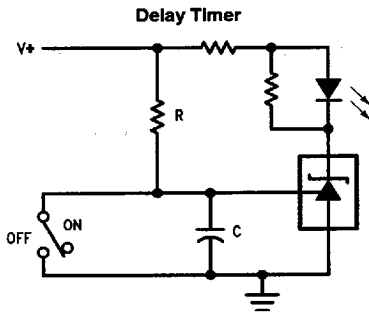


TL/H/10055-21

$$LOW\ LIMIT \approx V_{REF} \left(1 + \frac{R_{1B}}{R_{2B}}\right) \quad LED\ ON\ WHEN\ LOW\ LIMIT < V+ < HIGH\ LIMIT$$

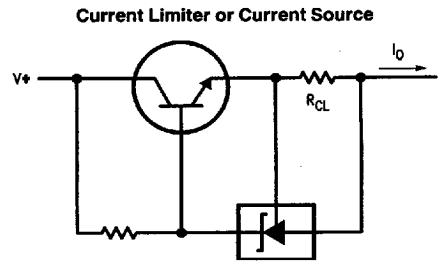
$$HIGH\ LIMIT \approx V_{REF} \left(1 + \frac{R_{1A}}{R_{2A}}\right)$$

## Typical Applications (Continued)



TL/H/10055-22

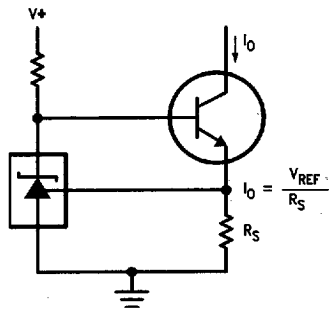
$$\text{DELAY} = R \cdot C \cdot \ln \frac{V^+}{(V^+) - V_{REF}}$$



TL/H/10055-23

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

### Constant Current Sink



TL/H/10055-24

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