National Semiconductor

LM431A
Adjustable Precision Zener Shunt Regulator

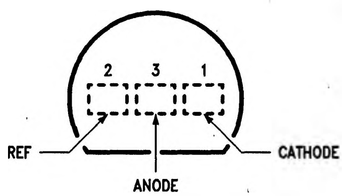
General Description

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



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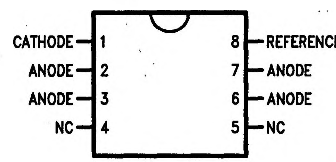
Top View

Order Number LM431ACZ or LM431AIZ
See NS Package Number Z03A



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Top View

Order Number LM431ACM or LM431AIM
See NS Package Number M08A

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	Min	Max
Cathode Voltage	V_{REF}	37V
Cathode Current	1.0 mA	100 mA

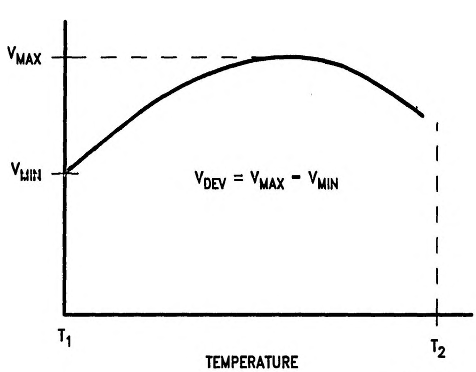
Note 1: $T_{J\,Max}$ = 150°C.

Note 2: Ratings appy 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_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 *(Figure 1)*		2.440	2.495	2.550	V
V_{DEV}	Deviation of Reference Input Voltage Over Temperature (Note 3)	$V_Z = V_{REF}$, 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 = ∞, 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 = ∞, 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 4)	$V_Z = V_{REF}$, Frequency = 0 Hz *(Figure 1)*				0.75	Ω

Note 3: 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, $\propto V_{REF}$, is defined as:

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

Where:

$T_2 - T_1$ = full temperature change.

$\propto V_{REF}$ 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.

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

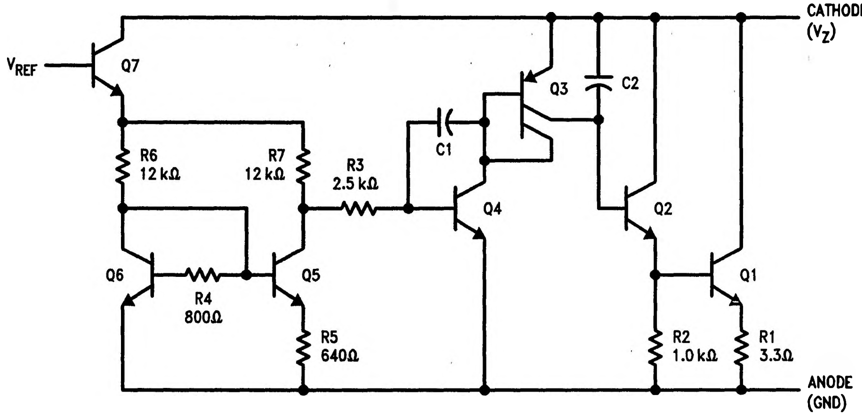
Note 4: The dynamic output impedance, r_Z, is defined as:

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

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:

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

Equivalent Circuit



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DC Test Circuits

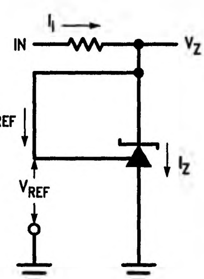

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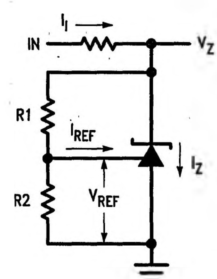
FIGURE 1. Test Circuit for $V_Z = V_{REF}$



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

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

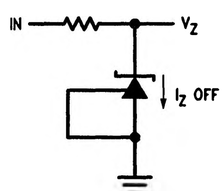

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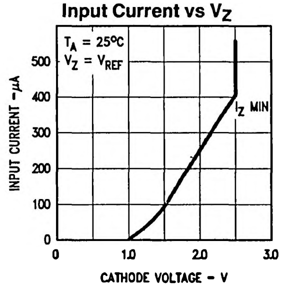
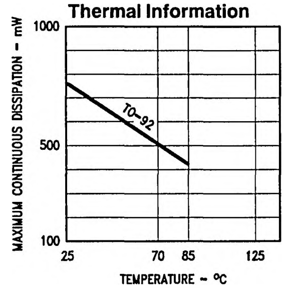
FIGURE 3. Test Circuit for Off-State Current

Typical Performance Characteristics

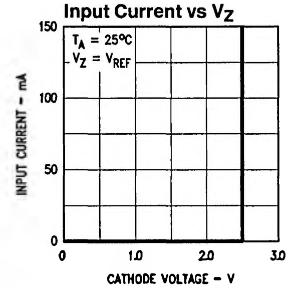
Input Current vs V_Z



Thermal Information



Input Current vs V_Z



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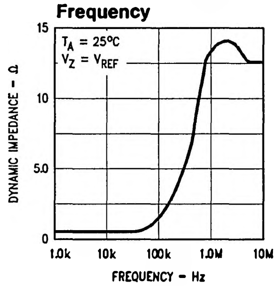
Dynamic Impedance vs Frequency



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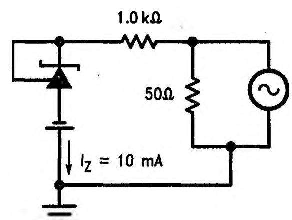

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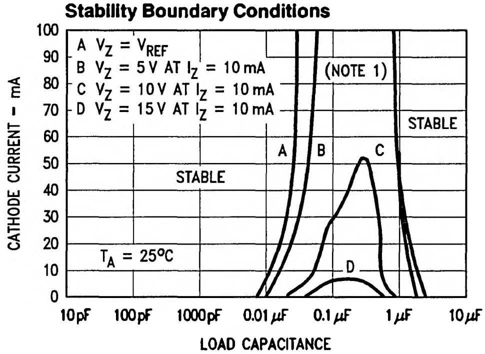
Stability Boundary Conditions



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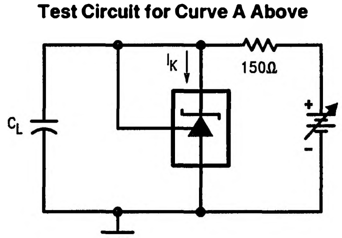
Note 1: The areas under the curves represent conditions that may cause the device to oscillate. For curves B, C, and D, R2 and V^+ were adjusted to establish the initial V_Z and I_Z conditions with $C_L = 0$. V^+ and C_L were then adjusted to determine the ranges of stability.

Test Circuit for Curve A Above



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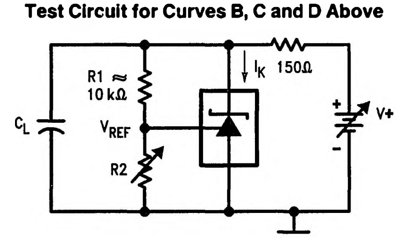
Test Circuit for Curves B, C and D Above



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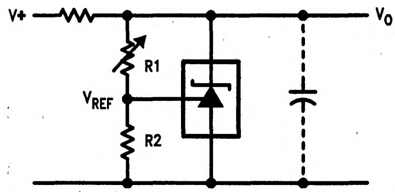
Typical Applications

Shunt Regulator



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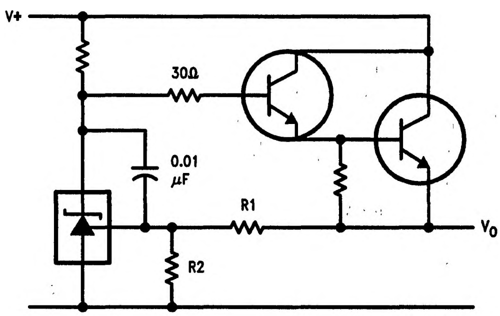
$$V_O \approx \left(1 + \frac{R1}{R2}\right) V_{REF}$$

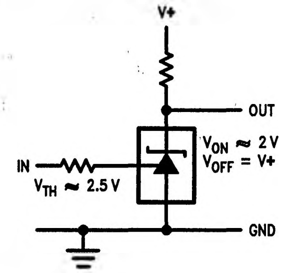
Series Regulator



TL/H/10055-16

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

Single Supply Comparator with Temperature Compensated Threshold



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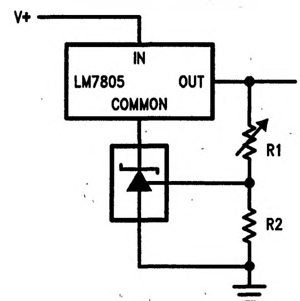
Output Control of a Three Terminal Fixed Regulator



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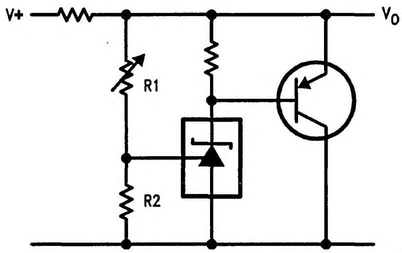
$$V_O = \left(1 + \frac{R1}{R2}\right) V_{REF}$$

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

Typical Applications (Continued)

Higher Current Shunt Regulator



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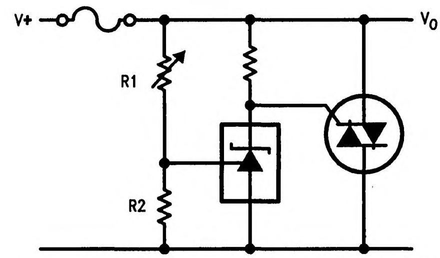
$$V_O = \left(1 + \frac{R1}{R2}\right)V_{REF}$$

Crow Bar



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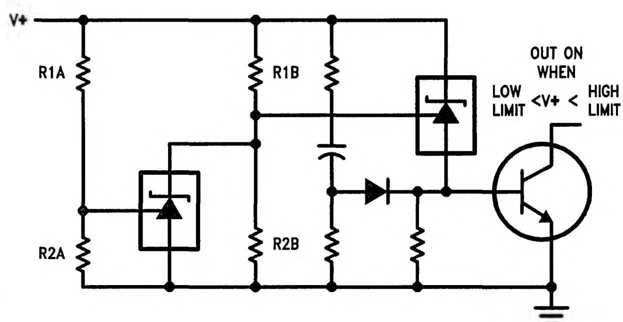
$$V_{LIMIT} \approx \left(1 + \frac{R1}{R2}\right)V_{REF}$$

Over Voltage/Under Voltage Protection Circuit



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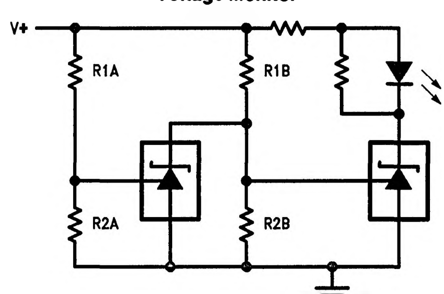
$$\text{LOW LIMIT} \approx V_{REF}\left(1 + \frac{R1B}{R2B}\right) + V_{BE}$$

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

Voltage Monitor



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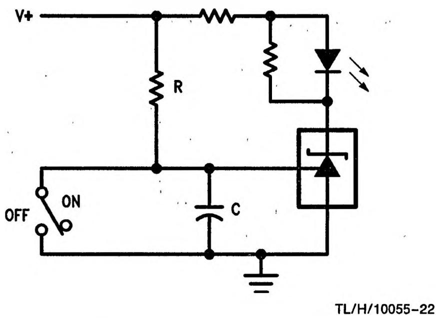
$$\text{LOW LIMIT} \approx V_{REF}\left(1 + \frac{R1B}{R2B}\right)$$

LED ON WHEN
LOW LIMIT < V^+ < HIGH LIMIT

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

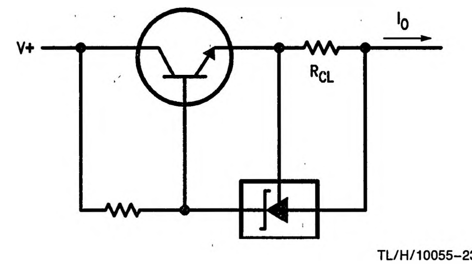
Typical Applications (Continued)

Delay Timer



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

Current Limiter or Current Source



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

Constant Current Sink