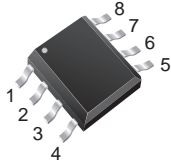
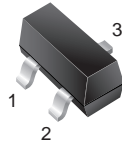


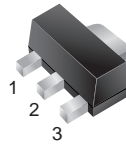
## Adjustable Precision Shunt Regulators

**SO-8**


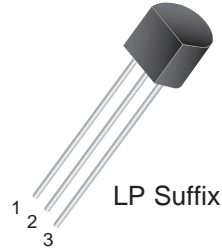
S Suffix

**SOT-23**


U Suffix

**SOT-89**


X Suffix

**TO-92**


LP Suffix

### Features

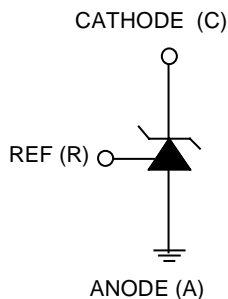
- Programmable Output Voltage to 30V
- Precision Reference Voltage  
 GS431B: 2.495V  $\pm$ 0.5%  
 TL431A: 2.495V  $\pm$ 1.0%  
 TL431: 2.495V  $\pm$ 1.6%
- Sink Current Capability: 200mA.
- Minimum Cathode Current for Regulation: 250 $\mu$ A
- Equivalent Full-Range Temperature Coefficient: 50 ppm/ $^{\circ}$ C
- Fast Turn-On Response
- Low Dynamic Output Impedance: 0.08 $\Omega$
- Low Output Noise

### Description

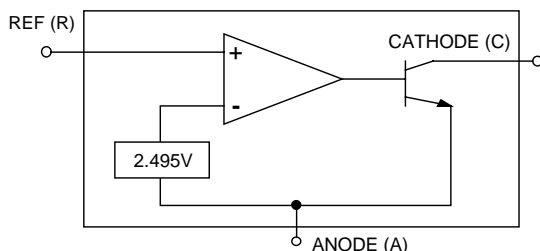
The GS431B/TL431A/TL431 are 3-terminal adjustable precision shunt regulators with guaranteed temperature stability over the applicable extended commercial temperature range. The output voltage may be set at any level greater than 2.495V ( $V_{REF}$ ) up to 30V merely by selecting two external resistors that act as a voltage divider network. These devices have a typical output impedance of 0.08 $\Omega$ . Active output circuitry provides very sharp turn-on characteristics, making these devices excellent improved replacements for zener diodes in many applications.

The precise  $\pm$ 0.5% reference voltage tolerance of the GS431B makes it possible in many applications to avoid the use of a variable resistor, consequently saving cost and eliminating drift and reliability problems associated with it.

### Symbol



### Block Diagram



### Applications

- Voltage Monitor
- Delay Timer
- Constant-Current Source/Sink
- High-Current Shunt Regulator
- Crow Bar
- Over-Voltage/Under-Voltage Protection

### Mechanical Data

**Case:** SO-8, SOT-23, SOT-89, TO-92

**High temperature soldering guaranteed:**

260 $^{\circ}$ C/10 seconds at terminals

*Case outlines are on the back pages*

Vishay  
formerly General Semiconductor

## Ordering Information

### GS431B<sub>lxx</sub>

Package code

SO-8: S  
TO-92: LP  
SOT-89: X  
SOT-23: U-1/U-2

U-1: Pin 1, Cathode  
Pin 2, V<sub>ref</sub>  
Pin 3, Anode

U-2: Pin 1, V<sub>ref</sub>  
Pin 2, Cathode  
Pin 3, Anode

### TL431<sub>xlxx</sub>

Tolerance

Default: 1.6%  
A: 1.0%

Package code

SO-8: S  
TO-92: LP  
SOT-89: X  
SOT-23: U-1/U-2

## Marking Information

### SOT-23

GS431B,	(U-1)	DAxxxx*
TL431A,	(U-1)	DBxxxx
TL431,	(U-1)	DCxxxx
GS431B,	(U-2)	DDxxxx
TL431A,	(U-2)	DExxxx
TL431,	(U-2)	DGxxxx

\*Last two digits denote datecode

<b>SO-8</b>	<p>Top View</p> <p>Cathode 1      8 Ref Anode 2      7 Anode Anode 3      6 Anode NC 4      5 NC</p>
<b>SOT-23 (U-1)</b>	<p>Top View</p> <p>1. Cathode 2. V<sub>ref</sub> 3. Anode</p>
<b>SOT-23 (U-2)</b>	<p>Top View</p> <p>1. V<sub>ref</sub> 2. Cathode 3. Anode</p>
<b>SOT-89</b>	<p>Top View</p> <p>1. V<sub>ref</sub> 2. Anode (tab) 3. Cathode</p>
<b>TO-92</b>	<p>Top View</p> <p>1. V<sub>ref</sub> 2. Anode 3. Cathode</p>



**Absolute Maximum Ratings**  $T_A = 25^\circ\text{C}$  unless otherwise noted.

Parameter	Symbol	Value	Unit
Cathode voltage	$V_Z$	30	V
Continuous cathode current	$I_Z$	-10 to 250	mA
Reference Input Current Range	$I_{REF}$	-0.05 to 10	mA
Operating Temperature Range	$T_{oper}$	-40 to 85	$^\circ\text{C}$
Junction Temperature	$T_J$	150	$^\circ\text{C}$
Lead Temperature	$T_L$	260	$^\circ\text{C}$
Storage Temperature	$T_{stg}$	-65 to 150	$^\circ\text{C}$
Thermal Resistance	$R_{\theta JA}$	TO-92 Package 115 SOT-23 Package 310 SO-8 Package 163 SOT-89 Package 120	$^\circ\text{C/W}$

**Electrical Characteristics**  $T_A = 25^\circ\text{C}$  unless otherwise noted.

Parameter	Symbol	Test Conditions	Min	Typ	Max	Unit	
Reference Voltage	$V_{REF}$	$V_Z = V_{REF}$ $I_L = 10\text{mA}$ (Fig. 1) $T_A = 25^\circ\text{C}$	GS431B	2.482	2.495	2.508	V
			TL431A	2.470	2.495	2.520	
			TL431	2.455	2.495	2.535	
		$V_Z = V_{REF}$ $I_L = 10\text{mA}$ (Fig. 1) $T_A = -40^\circ\text{C}$ to $+85^\circ\text{C}$	GS431B	2.475	-	2.520	
			TL431A	2.445	-	2.545	
			TL431	2.43	-	2.56	
Deviation of reference Input voltage over temperature <sup>(1)</sup>	$\Delta V_{REF}$	$V_Z = V_{REF}$ $I_L = 10\text{mA}$	$T_A = 0^\circ\text{C}$ to $70^\circ\text{C}$	-	9.0	20	mV
			$T_A = -40^\circ\text{C}$ to $+85^\circ\text{C}$ (Fig. 1)	-	15.0	50	
Ratio of the change in reference voltage to the change in cathode voltage	$\frac{\Delta V_{REF}}{\Delta V_Z}$	$I_Z = 10\text{mA}$ (Fig. 2)	$V_Z = V_{REF} \sim 10\text{V}$	-	0.5	2.0	mV/V
			$V_Z = 10\text{V} \sim 30\text{V}$	-	0.35	1.5	
Reference input current	$I_{REF}$	$R_1 = 10\text{K}\Omega$ , $R_2 = \infty$ $I_L = 10\text{mA}$ (Fig. 2)	$T_A = 25^\circ\text{C}$	-	0.8	3.5	$\mu\text{A}$
			$T_A = -40^\circ\text{C}$ to $+85^\circ\text{C}$	-	-	4.5	
Deviation of reference input current over temperature	$\alpha I_{REF}$	$R_1 = 10\text{K}\Omega$ , $R_2 = \infty$ $I_L = 10\text{mA}$ $T_A = -40^\circ\text{C}$ to $+85^\circ\text{C}$ (Fig. 2)	-	0.3	1.2	$\mu\text{A}$	
Minimum cathode current for regulation	$I_{Z(MIN)}$	$V_Z = V_{REF}$ (Fig. 1)	-	0.25	0.5	mA	
Off-state current	$I_{Z(OFF)}$	$V_Z = 30\text{V}$ , $V_{REF} = 0\text{V}$ (Fig 3)	-	0.1	1.0	$\mu\text{A}$	
Dynamic output impedance <sup>(2)</sup>	$R_Z$	$V_Z = V_{REF}$ , $f = 1.0\text{KHz}$ $\Delta I_Z = 1.0\text{mA}$ to $50\text{mA}$	-	0.08	0.3	$\Omega$	

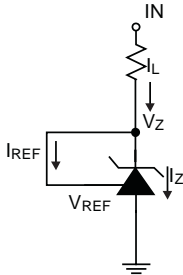
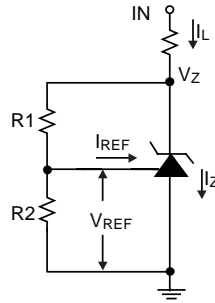


Fig. 1 Test Circuit for  $V_Z = V_{REF}$



Note:  $V_Z = V_{REF}(1 + R_1/R_2) + I_{REF}R_1$

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

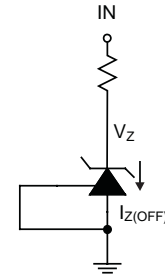
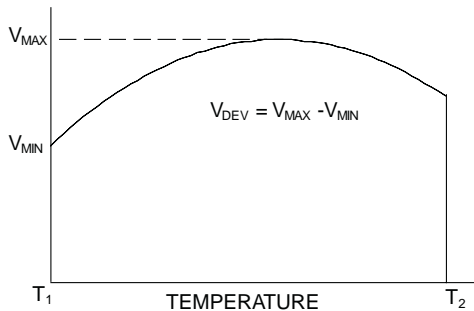


Fig. 3 Test Circuit for off-state current

**Note 1.** Deviation of reference input voltage,  $\Delta V_{REF}$ , 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,  $\alpha V_{REF}$  is defined as:

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

Where:

$T_2 - T_1$  = full temperature change.

The slope can be positive or negative depending on whether  $V_{MAX}$  or  $V_{MIN}$  occurs at the lower ambient temperature.

Example:  $\Delta V_{REF} = 9.0\text{mV}$ ,  $V_{REF} = 2495\text{mV}$ ,  
 $T_2 - T_1 = 70^\circ\text{C}$ , slope is positive.

$$\alpha V_{REF} = \frac{\left[ \frac{9.0\text{mV}}{2495\text{mV}} \right] 10^6}{70^\circ\text{C}} = 50\text{ppm}/^\circ\text{C}$$

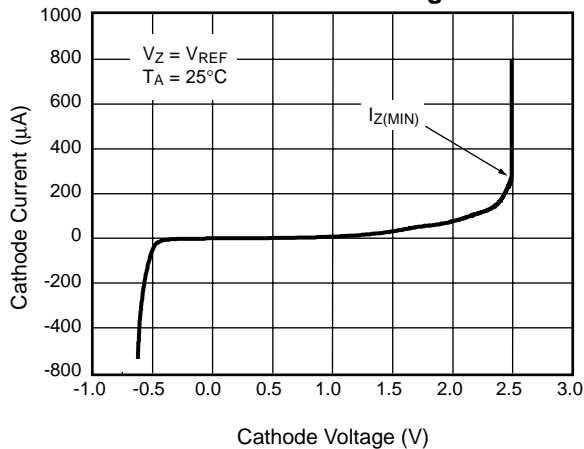
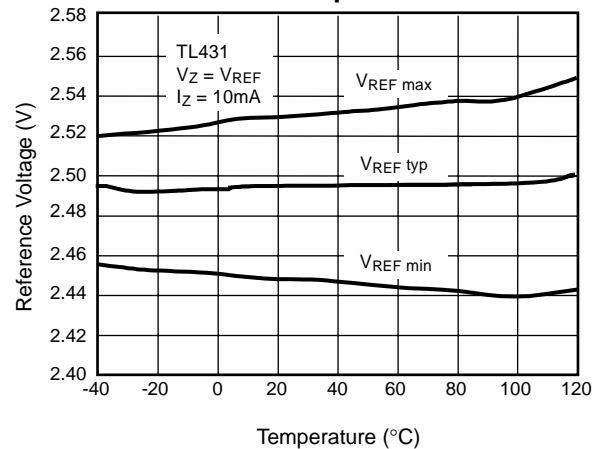
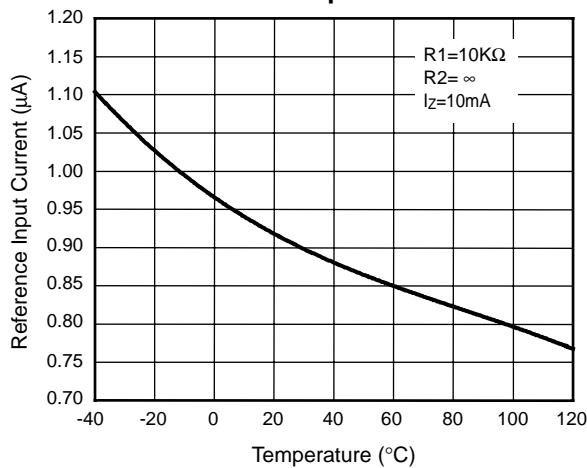
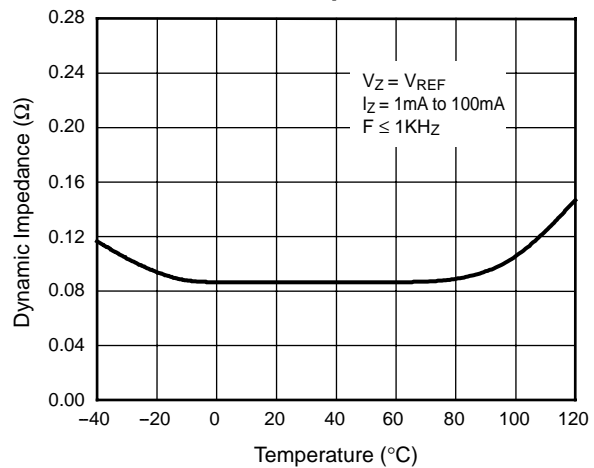
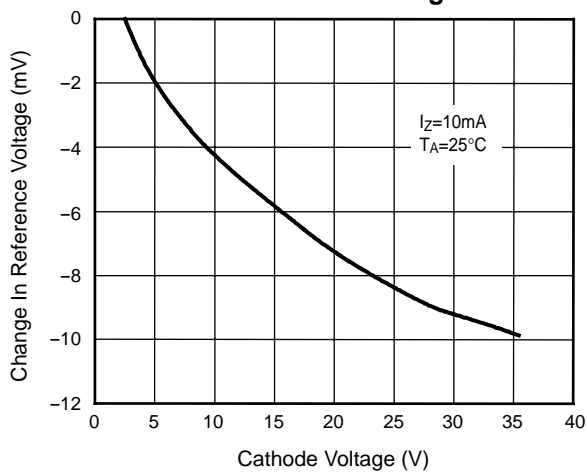
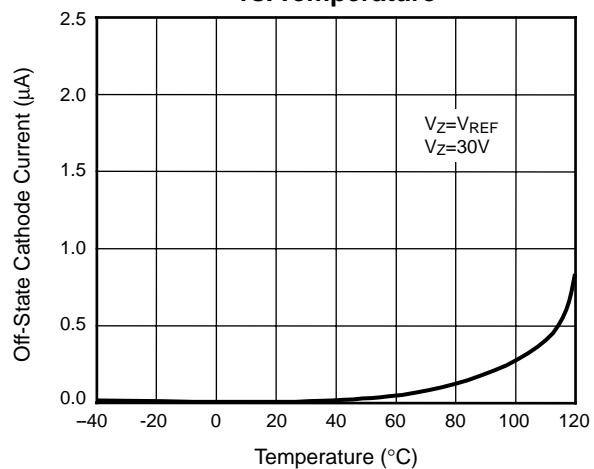
**Note 2.** The dynamic output impedance,  $R_Z$ , is defined as:

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

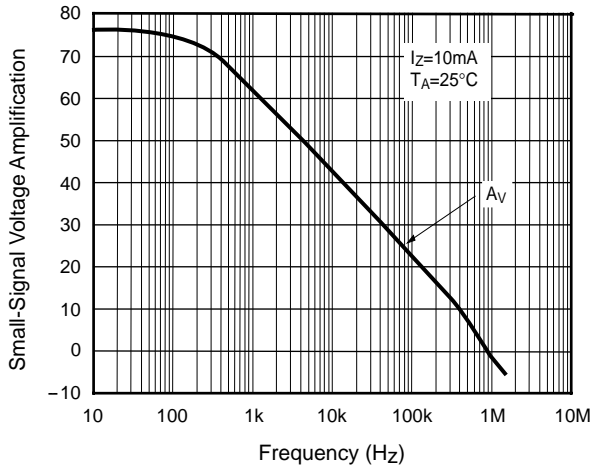
When the device is programmed with two external resistors,  $R_1$  and  $R_2$ , (see Fig. 2), the dynamic output impedance of the overall circuit, is defined as:

$$r_Z = \frac{\Delta V_Z}{\Delta I_Z} \approx R_Z \left[ 1 + \frac{R_1}{R_2} \right]$$

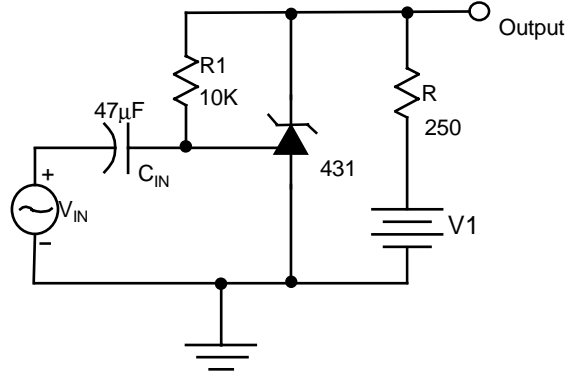
## Typical Performance Characteristics

**Fig. 4 – Cathode Current vs. Cathode Voltage**

**Fig. 5 – Reference Voltage vs. Temperature**

**Fig. 6 – Reference Input Current vs. Temperature**

**Fig. 7 – Dynamic Impedance vs. Temperature**

**Fig. 8 – Change in Reference Voltage vs. Cathode Voltage**

**Fig. 9 – Off-State Cathode Current vs. Temperature**


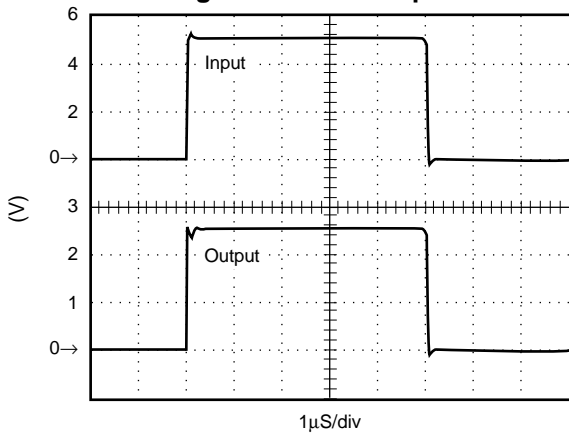
**Fig. 10 – Small Signal Voltage Amplification vs. Frequency**



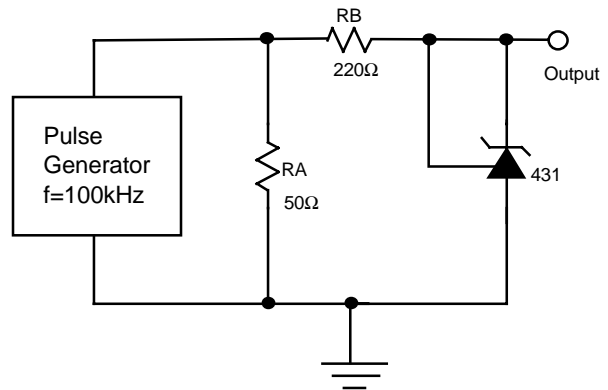
**Fig. 11 – Test Circuit Frequency Response**



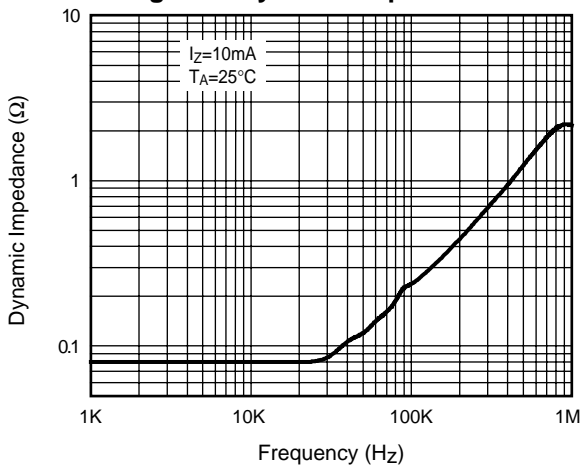
**Fig. 12 – Pulse Response**



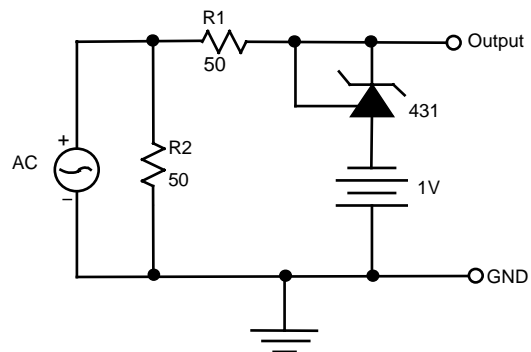
**Fig. 13 – Test Circuit For Pulse**



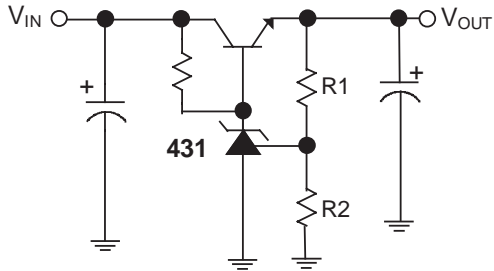
**Fig. 14 – Dynamic Impedance vs.**



**Fig. 15 – Test Circuit for Dynamic**

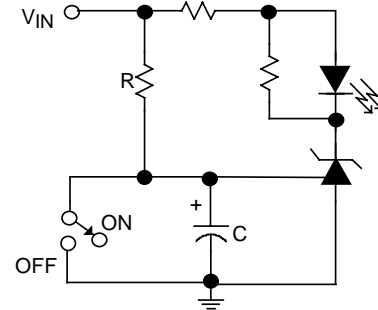


## Application Examples

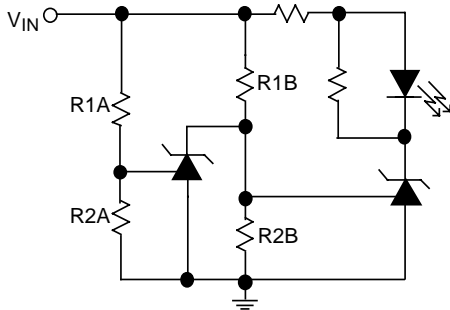
**Fig. 16 – Typical Application Circuit**


$$V_{OUT} = (1 + R1/R2) \times V_{REF}$$

### Precision Regulator

**Fig. 17 – Delay Timer**


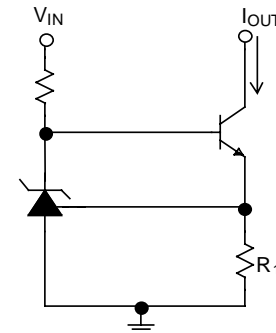
$$\text{Delay} = R \times C \times n \left( \frac{V_{IN}}{V_{IN} - V_{REF}} \right)$$

**Fig. 18 – Voltage Monitor**


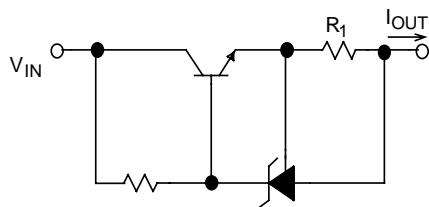
LED on when Low Limit <  $V_{IN}$  < High Limit

Low Limit  $\cong V_{REF} (1 + R1B/R2B)$

High Limit  $\cong V_{REF} (1 + R1A/R2A)$

**Fig. 19 – Constant-Current Sink**


$$I_{OUT} = V_{REF} / R_1$$

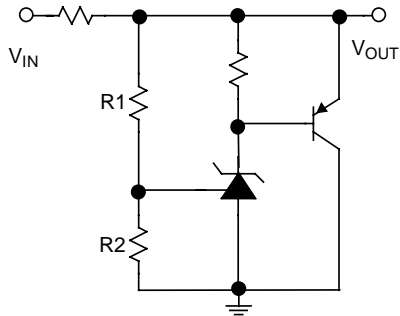
**Fig. 20 – Current Limiter or Current Source**


$$I_{OUT} = V_{REF} / R_1$$

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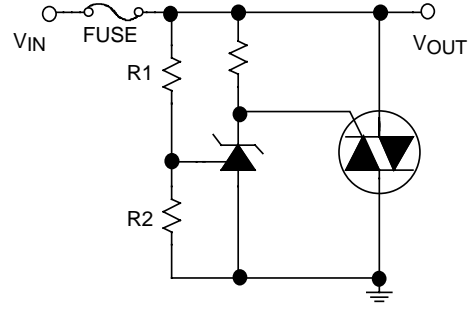
## Application Examples (continued)

**Fig. 21 – High-Current Shunt Regulator**



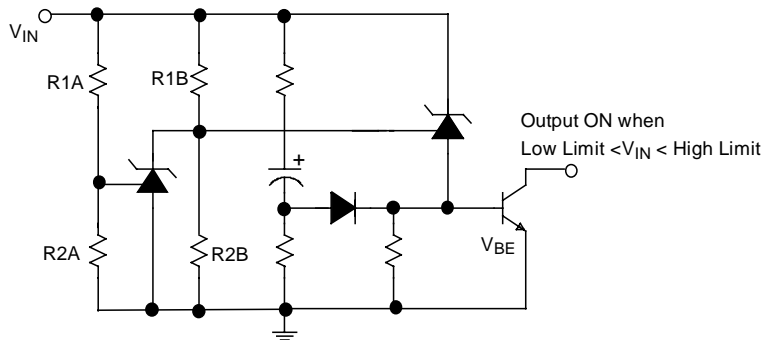
$$V_{OUT} = (1 + R1/R2) \times V_{REF}$$

**Fig. 22 – Crow Bar**



$$V_{LIMIT} = (1 + R1/R2) \times V_{REF}$$

**Fig. 23 – Over-Voltage / Under-Voltage Protection Circuit**



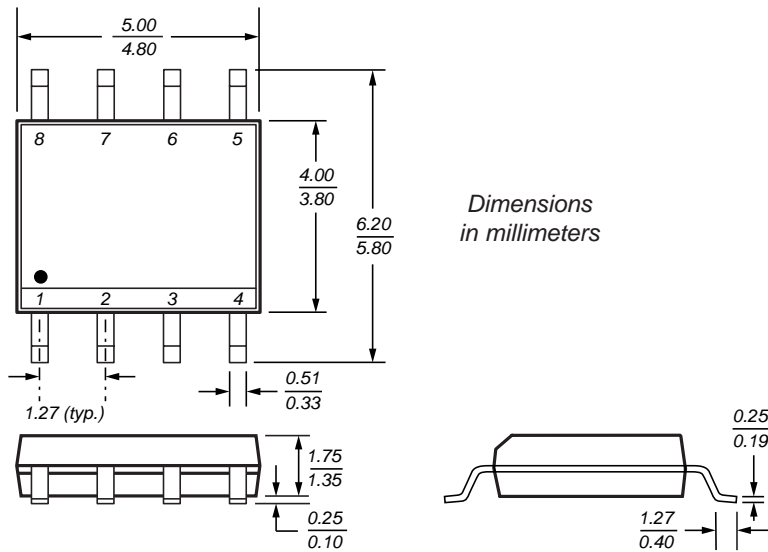
Output ON when  
Low Limit < V<sub>IN</sub> < High Limit

$$\text{Low Limit} \cong V_{REF} (1 + R1B/R2B) + V_{BE}$$

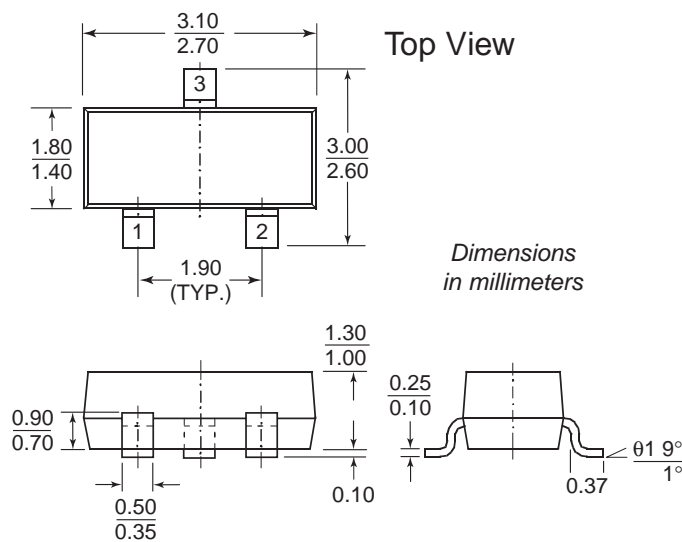
$$\text{High Limit} \cong V_{REF} (1 + R1A/R2A)$$



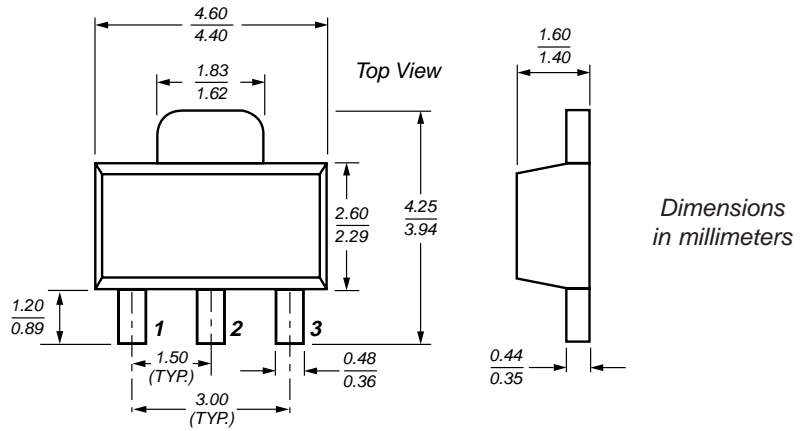
**SO-8 Case Outline**



**SOT-23 Case Outline**



**SOT-89 Case Outline**



**TO-92 Case Outline**

