VISHAY

Adjustable Precision Shunt Regulators
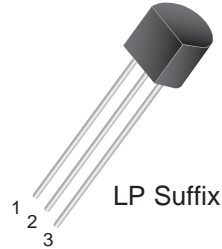
SO-8

SOT-23

SOT-89

TO-92

S Suffix

U Suffix

X Suffix

LP Suffix

Features

- Programmable Output Voltage to 30V
- Precision Reference Voltage
  GS431B: 2.495V ±0.5%
  TL431A: 2.495V ±1.0%
  TL431:   2.495V ±1.6%
- Sink Current Capability: 200mA.
- Minimum Cathode Current for Regulation: 250μA
- Equivalent Full-Range Temperature Coefficient:
  50 ppm/°C
- Fast Turn-On Response
- Low Dynamic Output Impedance: 0.08Ω
- Low Output Noise

Symbol

CATHODE (C)

REF (R)

ANODE (A)

Block Diagram

REF (R)

CATHODE (C)

2.495V

ANODE (A)

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 0.08Ω. Active output circuitry provides very sharp turn-on characteristics, making these devices excellent improved replacements for zener diodes in many applications.

The precise ±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.
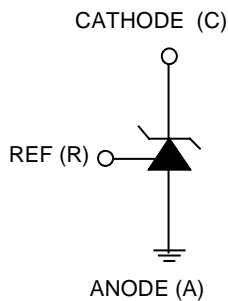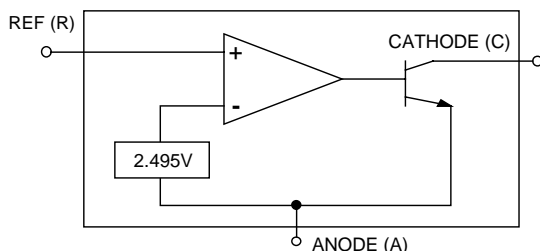
Applications

- 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°C/10 seconds at terminals

Case outlines are on the back pages

GS431B/TL431A/TL431

Vishay
formerly General Semiconductor

Ordering Information

GS431BIxx

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_{ref}
      Pin 3, Anode

U-2: Pin 1, V_{ref}
      Pin 2, Cathode
      Pin 3, Anode

TL431xIxx

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

SO-8 — Top View
Cathode 1, Anode 2, Anode 3, NC 4, 5 NC, 6 Anode, 7 Anode, 8 Ref

SOT-23 (U-1) — Top View
1. Cathode
2. V_{ref}
3. Anode

SOT-23 (U-2) — Top View
1. V_{ref}
2. Cathode
3. Anode

SOT-89 — Top View
1. V_{ref}
2. Anode (tab)
3. Cathode

TO-92 — Top View
1. V_{ref}
2. Anode
3. Cathode

Absolute Maximum Ratings $T_A = 25°C$ 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	°C
Junction Temperature		T_J	150	°C
Lead Temperature		T_L	260	°C
Storage Temperature		T_{stg}	−65 to 150	°C
Thermal Resistance	TO-92 Package SOT-23 Package SO-8 Package SOT-89 Package	$R_{\theta JA}$	115 310 163 120	°C/W

Electrical Characteristics $T_A = 25°C$ unless otherwise noted.

| Parameter	Symbol	Test Conditions			Min	Typ	Max	Unit
Reference Voltage	V_{REF}	$V_Z = V_{REF}$ $I_L = 10mA$ (Fig. 1) $T_A = 25°C$		GS431B	2.482	2.495	2.508	V
				TL431A	2.470	2.495	2.520	
				TL431	2.455	2.495	2.535	
		$V_Z = V_{REF}$ $I_L = 10mA$ (Fig. 1) $T_A = −40°C$ to $+85°C$		GS431B	2.475	–	2.520	
				TL431A	2.445	–	2.545	
				TL431	2.43	–	2.56	
Deviation of reference Input voltage over temperature[1]	ΔV_{REF}	$V_Z = V_{REF}$ $I_L = 10mA$	$T_A = 0°C$ to 70°C		–	9.0	20	mV
			$T_A = −40°C$ to $+85°C$ (Fig. 1)		–	15.0	50	
Ratio of the change in reference voltage to the change in cathode voltage	$\dfrac{\Delta V_{REF}}{\Delta V_Z}$	$I_Z = 10mA$ (Fig. 2)	$V_Z = V_{REF} \sim 10V$		–	0.5	2.0	mV/V
			$V_Z = 10V \sim 30V$		–	0.35	1.5	
Reference input current	I_{REF}	$R1 = 10K\Omega$, $R2 = \infty$ $I_L = 10mA$ (Fig. 2)	$T_A = 25°C$		–	0.8	3.5	µA
			$T_A = −40°C$ to $+85°C$		–	–	4.5	
Deviation of reference input current over temperature	αI_{REF}	$R1 = 10K\Omega$, $R2 = \infty$ $I_L = 10mA$ $T_A = −40°C$ to $+85°C$ (Fig. 2)			–	0.3	1.2	µA
Minimum cathode current for regulation	$I_{Z(MIN)}$	$V_Z = V_{REF}$ (Fig. 1)			–	0.25	0.5	mA
Off-state current	$I_{Z(OFF)}$	$V_Z = 30V$, $V_{REF} = 0V$ (Fig 3)			–	0.1	1.0	µA
Dynamic output impedance[2]	R_Z	$V_Z = V_{REF}$, $f = 1.0KH_Z$ $\Delta I_Z = 1.0mA$ to 50mA			–	0.08	0.3	Ω
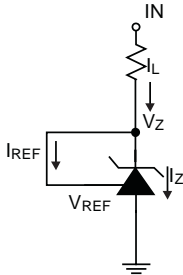
Fig. 1 Test Circuit for V$_Z$=V$_{REF}$
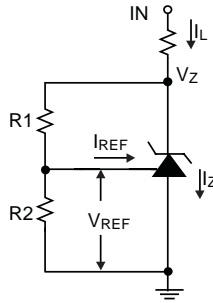
Note: V$_Z$=V$_{REF}$(1+R1/R2)+I$_{REF}$xR1
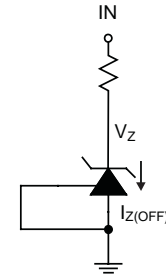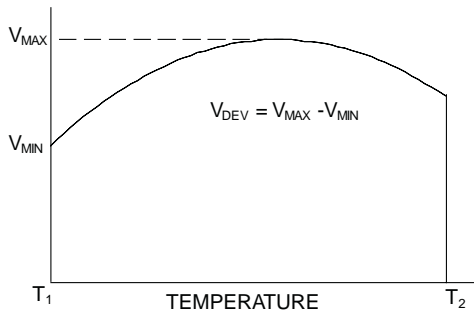
Fig. 2 Test Circuit for V$_Z$>V$_{REF}$

Fig. 3 Test Circuit for off-state current

Note 1. Deviation of reference input voltage, ΔV$_{REF}$, 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, αV$_{REF}$ is defined as:

$$\alpha V_{REF}\frac{ppm}{°C} = \frac{\pm\left[\frac{V_{MAX}-V_{MIN}}{V_{REF}(at\ 25°C)}\right]10^6}{T2-T1} = \frac{\pm\left[\frac{V_{DEV}}{V_{REF}(at\ 25°C)}\right]10^6}{T2-T1}$$

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: ΔV$_{REF}$ = 9.0mV, V$_{REF}$ = 2495mV,
T$_2$ - T$_1$ = 70°C, slope is positive.

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

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, R1 and R2, (see Fig. 2), the dynamic output impedance of the overall circuit, is defined as:

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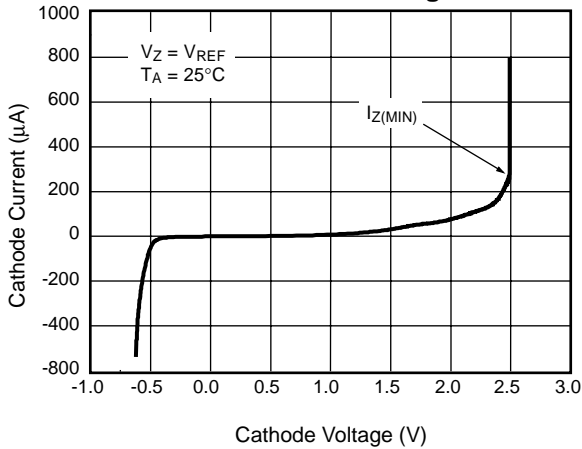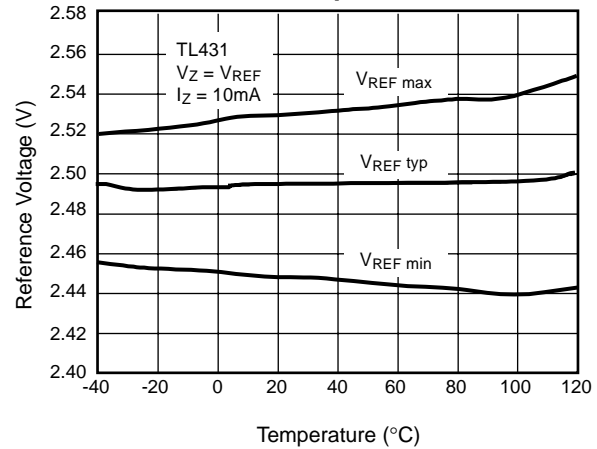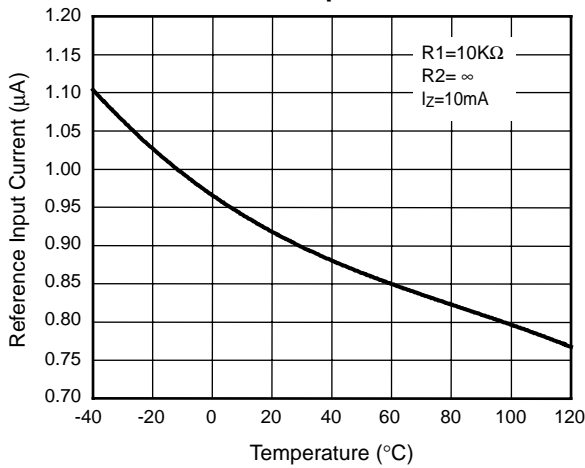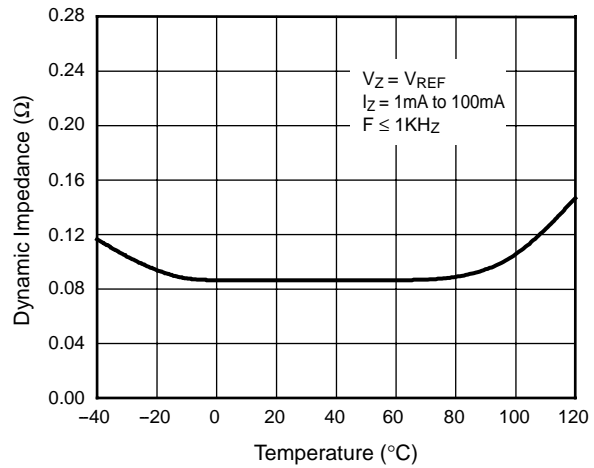
Typical Performance Characteristics

Fig. 4 – Cathode Current vs. Cathode Voltage

$V_Z = V_{REF}$
$T_A = 25°C$

$I_{Z(MIN)}$

Fig. 5 – Reference Voltage vs. Temperature

TL431
$V_Z = V_{REF}$
$I_Z = 10mA$

$V_{REF\ max}$

$V_{REF\ typ}$

$V_{REF\ min}$

Fig. 6 – Reference Input Current vs. Temperature

$R1=10K\Omega$
$R2= \infty$
$I_Z=10mA$

Fig. 7 – Dynamic Impedance vs. Temperature

$V_Z = V_{REF}$
$I_Z = 1mA\ to\ 100mA$
$F \leq 1KH_Z$

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

$I_Z=10mA$
$T_A=25°C$
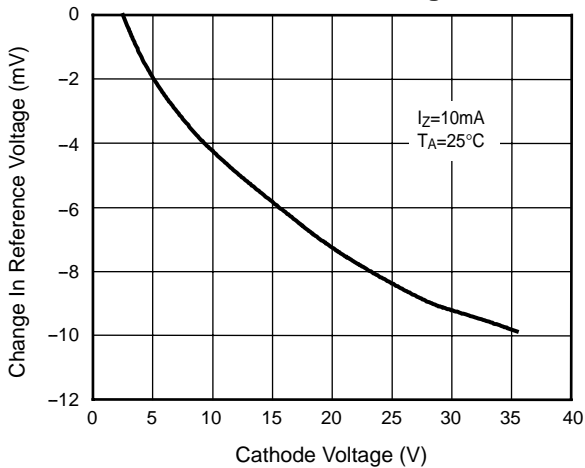
Fig. 9 – Off-State Cathode Current vs. Temperature

$V_Z=V_{REF}$
$V_Z=30V$
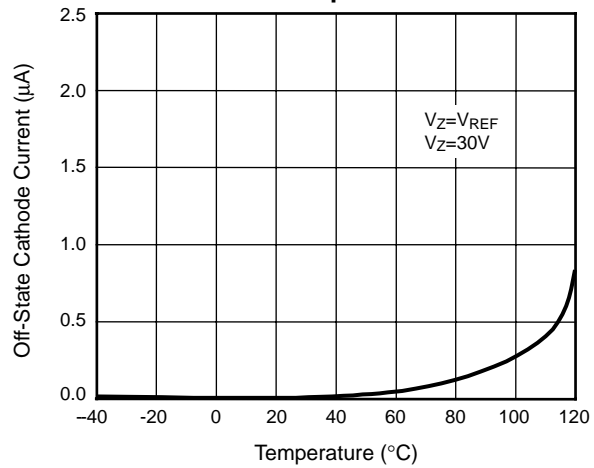
Fig. 10 – Small Signal Voltage Amplification vs. Frequency

I_Z=10mA
T_A=25°C

A_V

Small-Signal Voltage Amplification
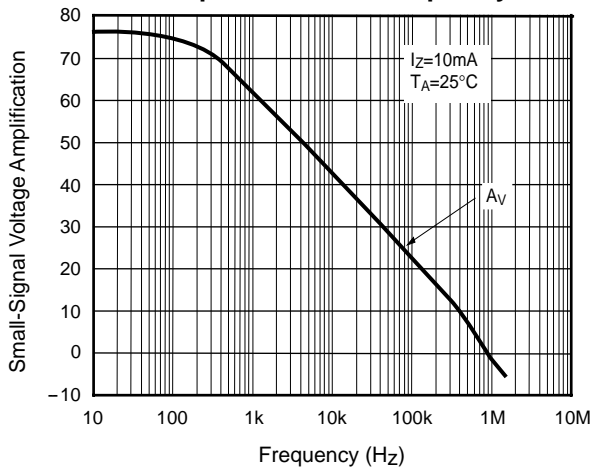
Frequency (H$_Z$)

Fig. 11 – Test Circuit Frequency Response

Output
R1
10K
47μF
C_{IN}
V_{IN}
431
R
250
V1
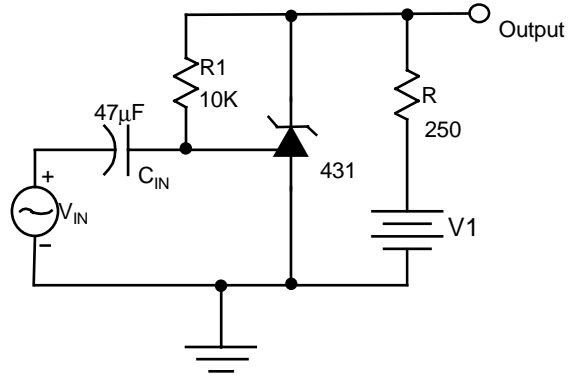
Fig. 12 – Pulse Response

Input

Output

(V)

1μS/div
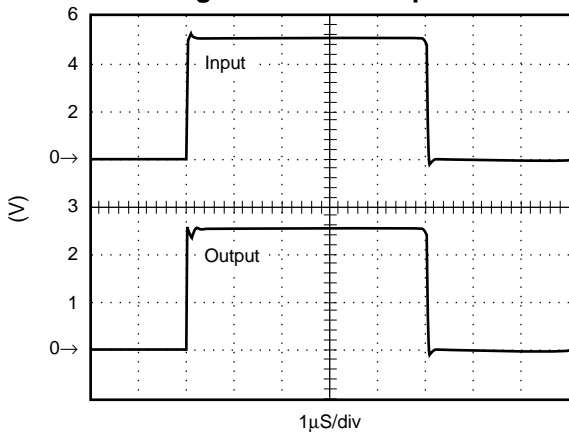
Fig. 13 – Test Circuit For Pulse

RB
220Ω
Output
Pulse Generator
f=100kHz
RA
50Ω
431

Fig. 14 – Dynamic Impedance vs.

I_Z=10mA
T_A=25°C

Dynamic Impedance (Ω)

Frequency (H$_Z$)
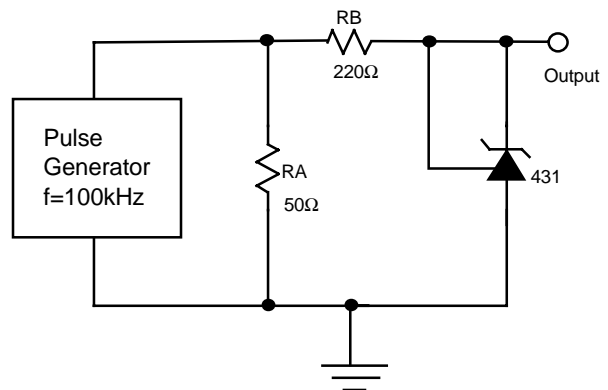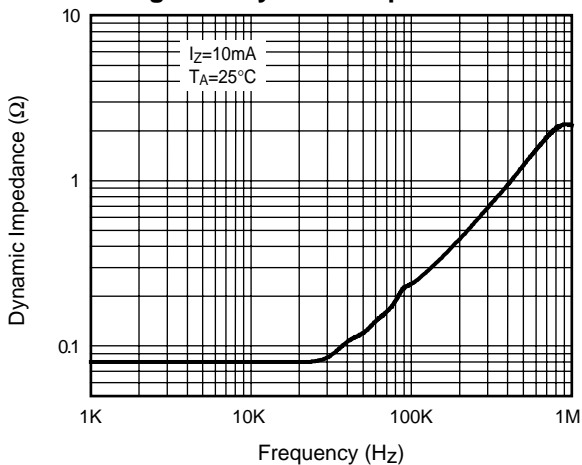
Fig. 15 – Test Circuit for Dynamic

R1
50
Output
AC
R2
50
431
1V
GND
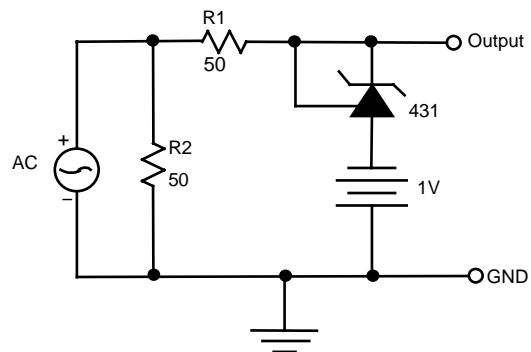
Application Examples

Fig. 16 – Typical Application Circuit
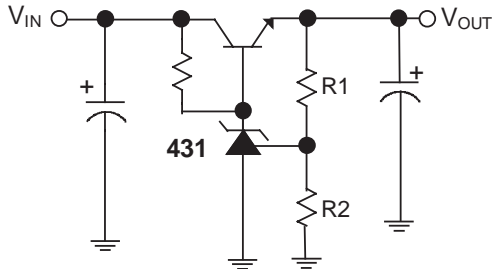
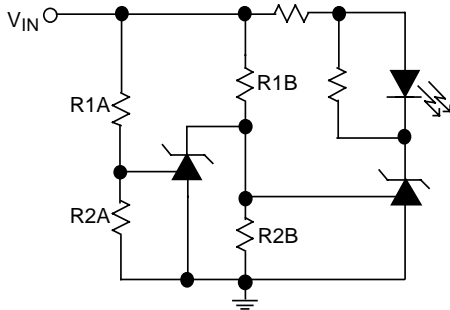

$V_{OUT} = (1+R1/R2) \times V_{REF}$

Precision Regulator

Fig. 17 – Delay Timer
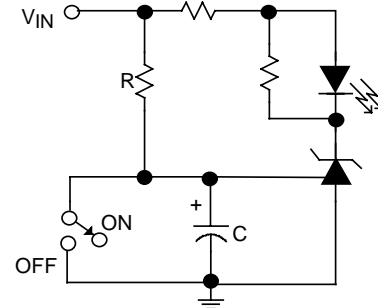
$\text{Delay} = R \times C \times n \left(\dfrac{V_{IN}}{V_{IN} - V_{REF}} \right)$
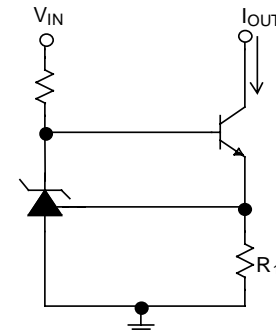
Fig. 18 – Voltage Monitor

LED on when Low Limit $< V_{IN} <$ High Limit
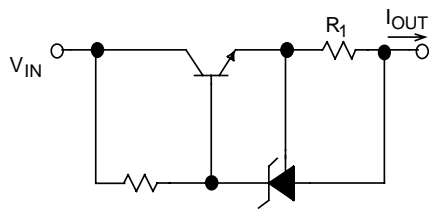
Low Limit $\cong V_{REF} (1+R1B/R2B)$

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

Fig. 19 – Constant-Current Sink

$I_{OUT} = V_{REF} / R_1$
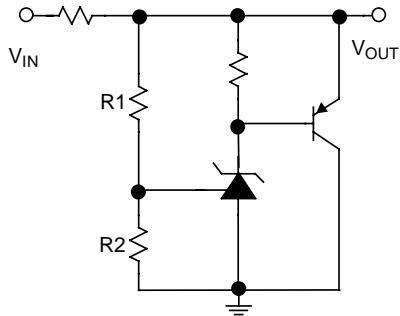
Fig. 20 – Current Limiter or Current Source

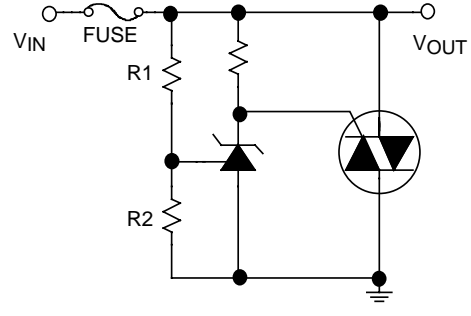$I_{OUT} = V_{REF} / R_1$

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formerly General Semiconductor

Application Examples
(continued)

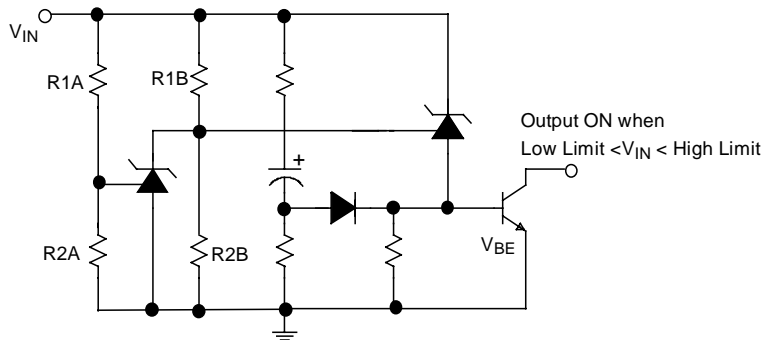**Fig. 21 – High-Current Shunt Regulator**

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

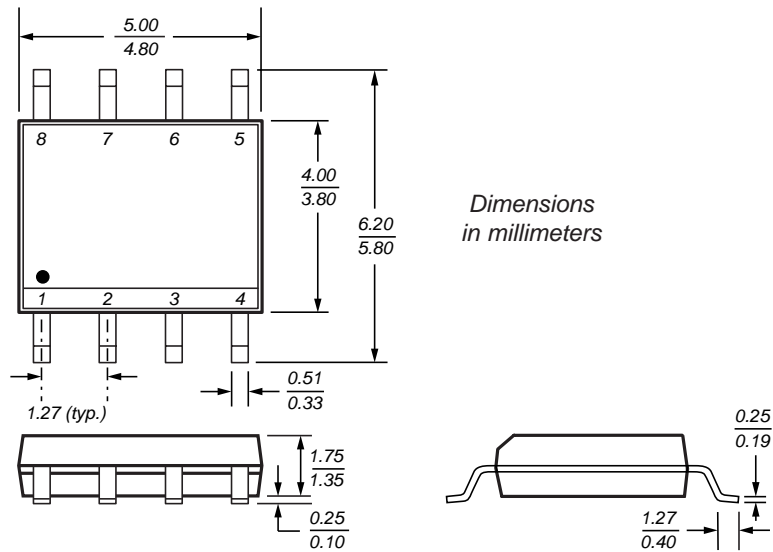**Fig. 22 – Crow Bar**

$$V_{LIMIT} = (1+R1/R2) \times V_{REF}$$
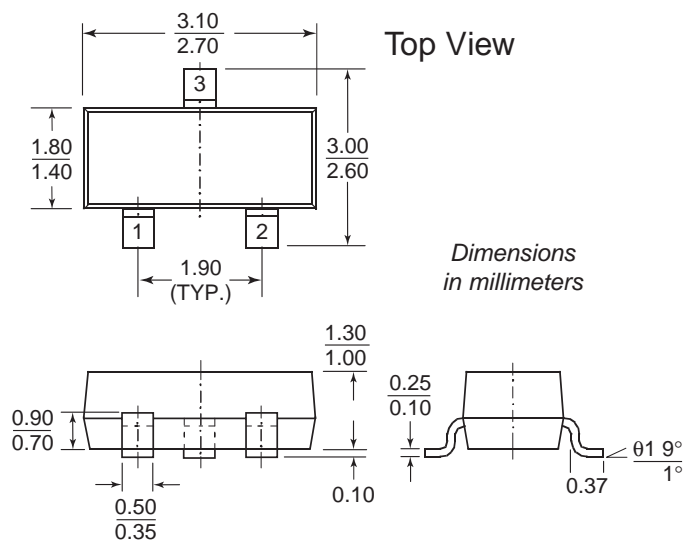
Fig. 23 – Over-Voltage / Under-Voltage Protection Circuit

Output ON when
Low Limit $<V_{IN}<$ High Limit

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

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

SO-8 Case Outline

Dimensions in millimeters

SOT-23 Case Outline

Top View

Dimensions in millimeters

SOT-89 Case Outline

TO-92 Case Outline