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TAIWAN SEMICONDUCTOR

RoHS COMPLIANCE

TS431I

Adjustable Precision Shunt Regulator

TO-92

SOT-89

Pin Definition:
1. Reference
2. Anode
3. Cathode

SOT-23

Pin Definition:
1. Reference
2. Cathode
3. Anode

SOP-8

Pin Definition:

1. Cathode	8. Reference
2. Anode	7. Anode
3. Anode	6. Anode
4. N/C	5. N/C

General Description

The TS431I/431AI/431BI integrated circuits are three-terminal programmable shunt regulator diodes. These monolithic IC voltage references operate as a low temperature coefficient zener which is programmable from Vref to 36 volts with two external resistors. These devices exhibit a wide operating current range of 1.0 to 100mA with a typical dynamic impedance of 0.22Ω. The characteristics of these references make them excellent replacements for zener diodes in many applications such as digital voltmeters, power supplies, and op amp circuitry. The 2.5volt reference makes it convenient to obtain a stable reference from 5.0volt logic supplies, and since The TS431I/431AI/431BI operates as a shunt regulator, it can be used as either a positive or negative stage reference.

Features

- Precision Reference Voltage
  TS431I – 2.495V±2%
  TS431AI – 2.495V±1%
  TS431BI – 2.495V±0.5%
- Equivalent Full Range Temp. Coefficient: 50ppm/ °C
- Programmable Output Voltage up to 36V
- Fast Turn-On Response
- Sink Current Capability of 1~100mA
- Low Dynamic Output Impedance: 0.2Ω
- Low Output Noise

Ordering Information

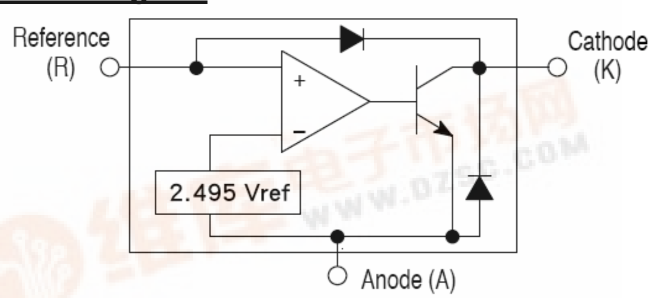
Part No.	Package	Packing
TS431**x**IT B0	TO-92	1Kpcs / Bulk
TS431**x**IT A3	TO-92	2Kpcs / Ammo
TS431**x**IX RF	SOT-23	3Kpcs / 7" Reel
TS431**x**IY RM	SOT-89	1Kpcs / 7" Reel
TS431**x**IS RL	SOP-8	2.5Kpcs / 2.5" Reel

Note: Where **xx** denotes voltage tolerance
Blank: ±2%
A: ±1%
B: ±0.5%

Application

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

Block Diagram



Absolute Maximum Rating (Ta = 25 °C unless otherwise noted)

Parameter	Symbol	Limit	Unit
Cathode Voltage (Note 1)	Vka	37	V
Continuous Cathode Current Range	Ik	-100 ~ +150	mA
Reference Input Current Range	Iref	-0.05 ~ +10	mA
Power Dissipation TO-92	Pd	0.625	W
SOT-23		0.30	
SOT-89 / SOP-8		0.50	
Junction Temperature	Tj	+150	°C
Operating Temperature Range	Toper	-40 ~ +85	°C
Storage Temperature Range	Tstg	-65 ~ +150	°C

Note 1: Voltage values are with respect to the anode terminal unless otherwise noted.

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Recommend Operating Condition

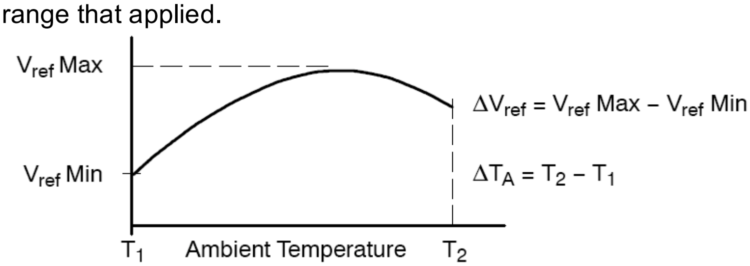
Parameter	Symbol	Limit	Unit
Cathode Voltage (Note 1)	Vka	Ref ~ 36	V
Continuous Cathode Current Range	Ik	1 ~ 100	mA

Recommend Operating Condition

Parameter		Symbo	Test Conditions	Min	Typ	Max	Unit
Reference voltage	TS431I	Vref	Vka =Vref, Ik=10mA (Figure 1) Ta=25 °C	2.450	2.495	2.550	V
	TS431AI			2.475		2.525	
	TS431BI			2.487		2.513	
Deviation of reference input voltage		ΔVref	Vka =Vref, Ik=10mA (Figure 1) Ta= full range	--	3	17	mV
Radio of change in Vref to change in cathode Voltage		ΔVref/ΔVka	Ika=10mA, Vka = 10V to Vref Vka = 36V to 10V (Figure 2)	-- --	-1.4 -1.0	-2.7 -2.0	mV/V
Reference Input current		Iref	R1=10KΩ, R2=∞, Ika=10mA Ta= full range (Figure 2)	--	0.7	4.0	uA
Deviation of reference input current, over temp.		ΔIref	R1=10KΩ, R2=∞, Ika=10mA Ta= full range (Figure 2)	--	0.4	1.2	uA
Off-state Cathode Current		Ika(off)	Vref=0V (Figure 3), Vka=36V	--	--	1.0	uA
Dynamic Output Impedance		|Zka|	f<1KHz, Vka=Vref Ika=1mA to 100mA (Figure 1)	--	0.22	0.5	Ω
Minimum operating cathode current		Ika(min)	Vka=Vref (Figure 1)	--	0.4	0.6	mA

* The deviation parameters ΔVref and ΔIref are defined as difference between the maximum value and minimum value obtained over the full operating ambient temperature range that applied.
* The average temperature coefficient of the reference input voltage, αVref is defined as:

$$\alpha V_{ref}\left(\frac{ppm}{^\circ C}\right) = \frac{\left(\frac{(\Delta V_{ref})}{V_{ref}\ (T_A = 25^\circ C)} \times 10^6\right)}{\Delta T_A}$$



Where: **T2-T1** = full temperature change.

αVref can be positive or negative depending on whether the slope is positive or negative.

Example: Maximum Vref=2.496V at 30°C, minimum Vref=2.492V at 0°C, Vref=2.495V at 25°C, ΔT=70 °C

$$\left|\alpha_{V_{ref}}\right| = \frac{\left(\frac{4\ mV}{2495\ mV}\right) \times 10^6}{70^\circ C} \approx \frac{23\ ppm}{^\circ C}$$

Because minimum Vref occurs at the lower temperature, the coefficient is possitive

* The dynamic impedance ZKA is defined as:

$$\left|Z_{KA}\right| = \frac{\Delta V_{KA}}{\Delta I_K}$$

* When the device operating with two external resistors, R1 and R2, (refer to Figure 2) the total dynamic impedance of the circuit is given by:

$$\left|Z_{KA}'\right| = \left|Z_{KA}\right| \times \left(1 + \frac{R1}{R2}\right)$$

Test Circuits

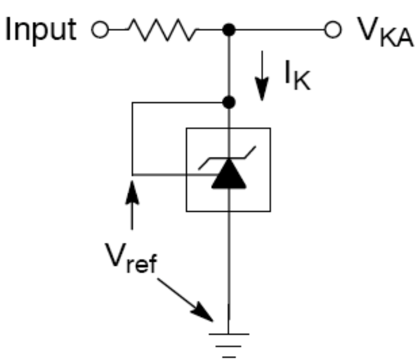


Figure 1: Vka = Vref

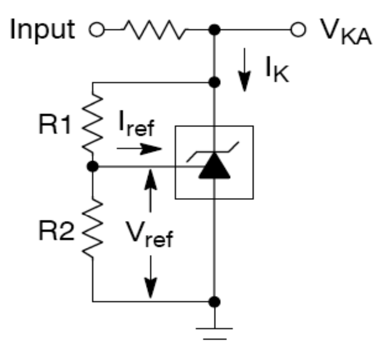


Figure 2: Vka > Vref

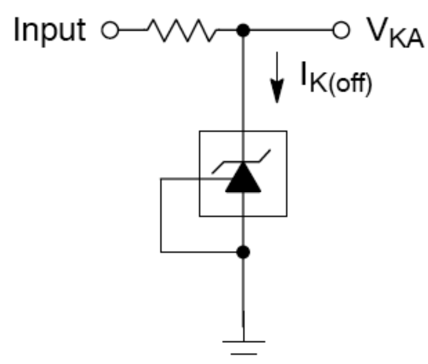


Figure 3: Off-State Current

Additional Information – Stability

When The TS431I/431AI/431BI is used as a shunt regulator, there are two options for selection of C_L, are recommended for optional stability:

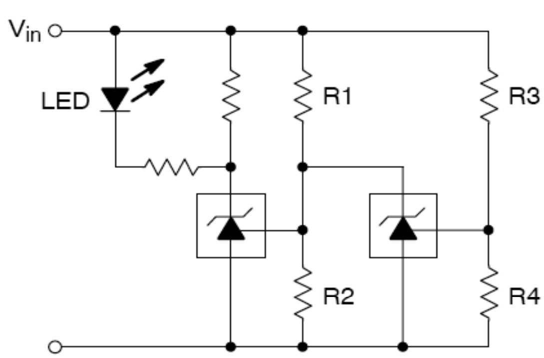
A) No load capacitance across the device, decouple at the load.

B) Large capacitance across the device, optional decoupling at the load.

The reason for this is that TS431I/431AI/431BI exhibits instability with capacitances in the range of 10nF to 1uF (approx.) at light cathode current up to 3mA (typ). The device is less stable the lower the cathode voltage has been set for. Therefore while the device will be perfectly stable operating at a cathode current of 10mA (approx.) with a 0.1uF capacitor across it, it will oscillate transiently during start up as the cathode current passes through the instability region. Select a very low capacitance, or alternatively a high capacitance (10uF) will avoid this issue altogether. Since the user will probably wish to have local decoupling at the load anyway, the most cost effective method is to use no capacitance at all directly across the device. PCB trace/via resistance and inductance prevent the local load decoupling from causing the oscillation during the transient start up phase.

Note: if the TS431I/431AI/431BI is located right at the load, so the load decoupling capacitor is directly across it, then this capacitor will have to be ≤1nF or ≥10uF.

Applications Examples

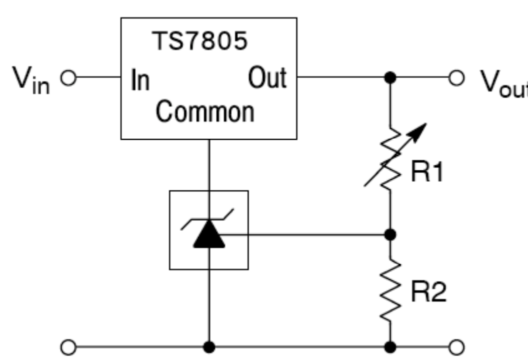


L.E.D. indicator is 'ON' when V_{in} is between the upper and lower limits,

$$\text{Lower limit} = \left(1 + \frac{R1}{R2}\right) V_{ref}$$

$$\text{Upper limit} = \left(1 + \frac{R3}{R4}\right) V_{ref}$$

Figure 4: Voltage Monitor

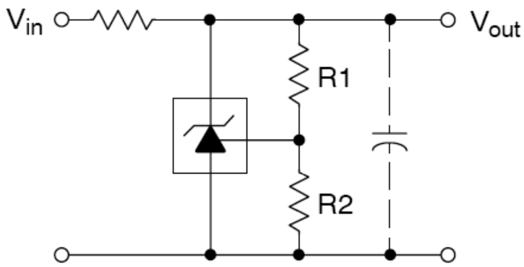


$$V_{out} = \left(1 + \frac{R1}{R2}\right) V_{ref}$$

$$V_{out(min)} = V_{ref} + 5.0\text{ V}$$

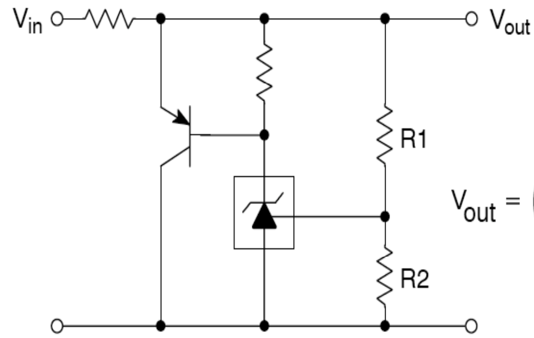
Figure 5: Output Control for Three Terminal Fixed Regulator

Applications Examples (Continue)



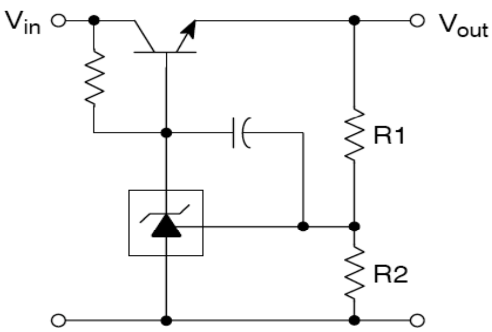
$$V_{out} = \left(1 + \frac{R1}{R2}\right) V_{ref}$$

Figure 6: Shunt Regulator



$$V_{out} = \left(1 + \frac{R1}{R2}\right) V_{ref}$$

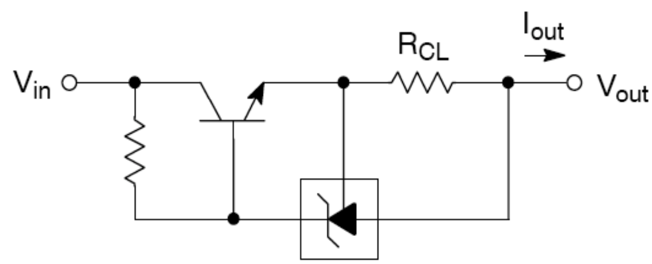
Figure 7: High Current Shunt Regulator



$$V_{out} = \left(1 + \frac{R1}{R2}\right) V_{ref}$$

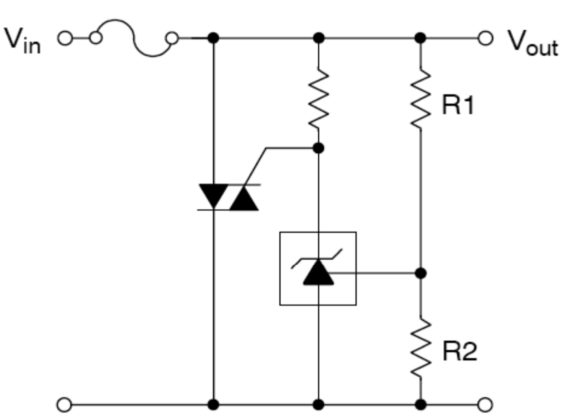
$$V_{out(min)} = V_{ref} + V_{be} \approx 2.0\text{ V}$$

Figure 8: Series Pass Regulator



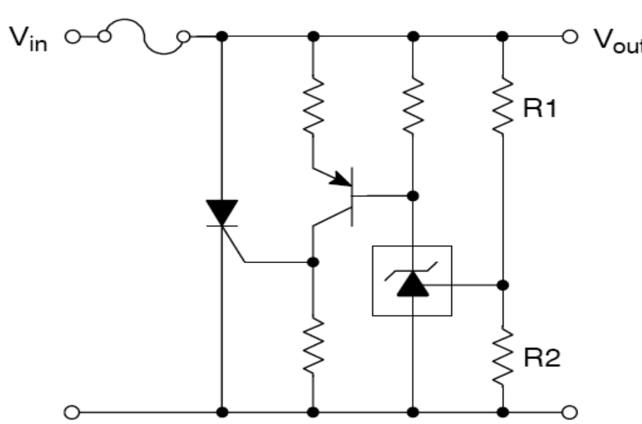
$$I_{out} = \frac{V_{ref}}{R_{CL}}$$

Figure 9: Constant Current Source



$$V_{out(trip)} = \left(1 + \frac{R1}{R2}\right) V_{ref}$$

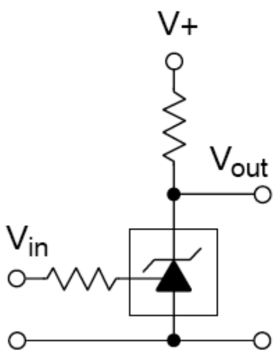
Figure 10: TRIAC Crowbar



$$V_{out(trip)} = \left(1 + \frac{R1}{R2}\right) V_{ref}$$

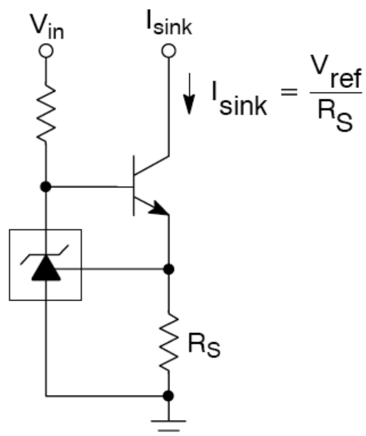
Figure 11: SCR Crowbar

Applications Examples (Continue)



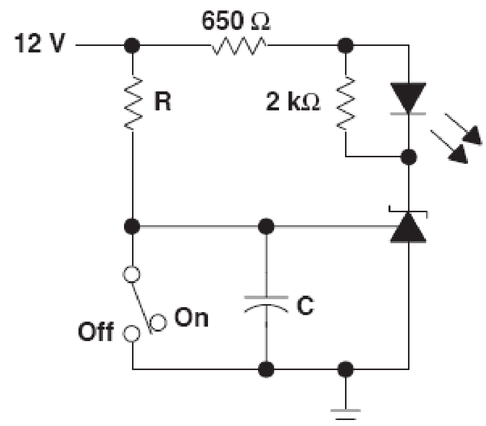
Vin	Vout
<Vref	V+
>Vref	≈0.74V

Figure 12: Single-Supply Comparator with Temperature-Compensated Threshold



$$I_{sink} = \frac{V_{ref}}{R_S}$$

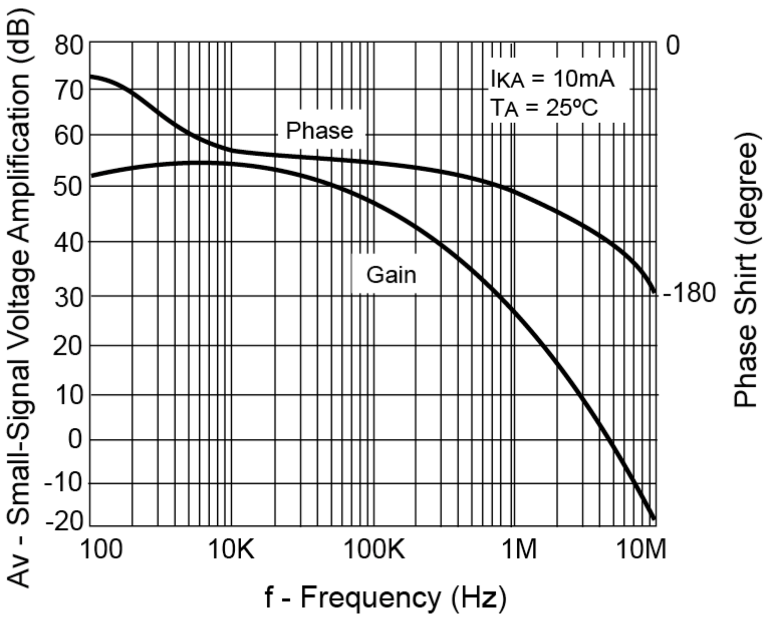
Figure 13: Constant Current Sink

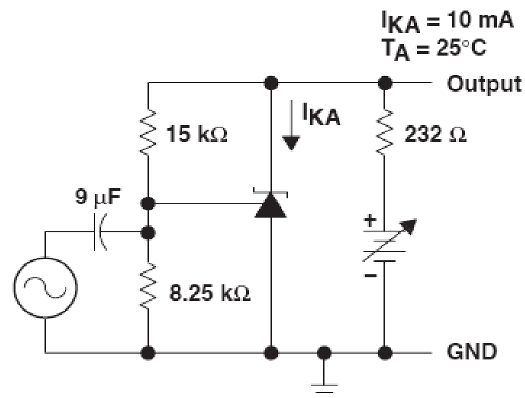


$$\text{Delay} = R \times C \times l_n\left(\frac{12\text{ V}}{12\text{ V} - V_{ref}}\right)$$

Figure 14: Delay Timer

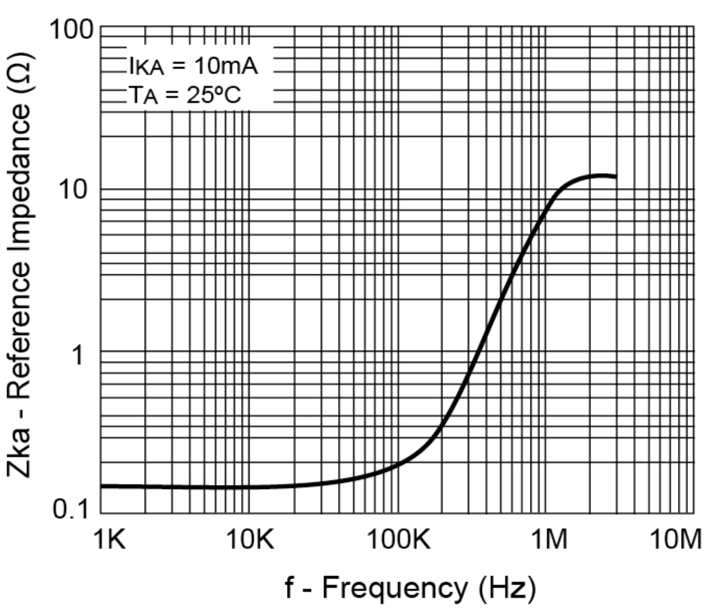
Typical Performance Characteristics

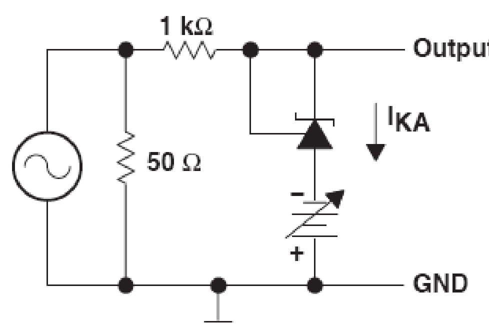




Test Circuit for Voltage Amplification

Figure 14: Small-Signal Voltage Gain and Phase Shirt vs. Frequency

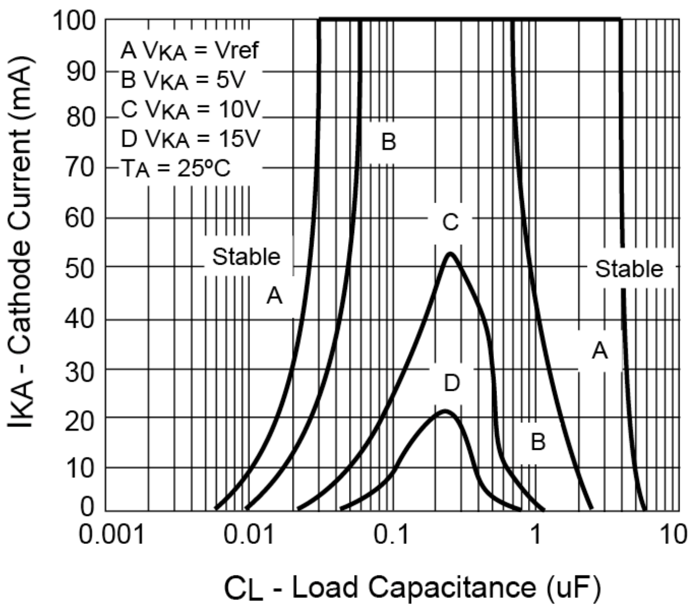


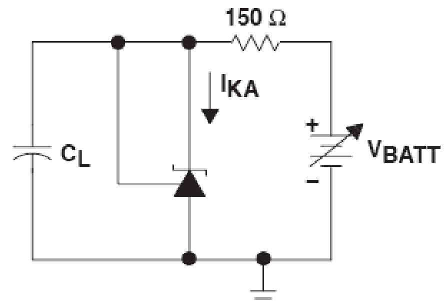


Test Circuit for Reference Impedance

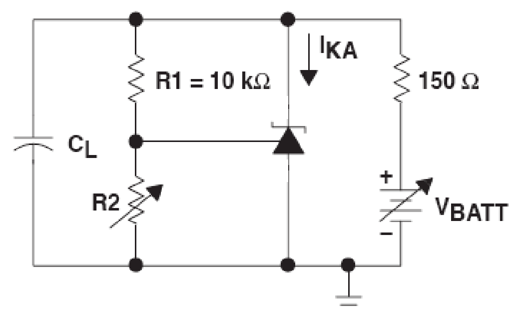
Figure 15: Reference Impedance vs. Frequency

Typical Performance Characteristics (Continue)





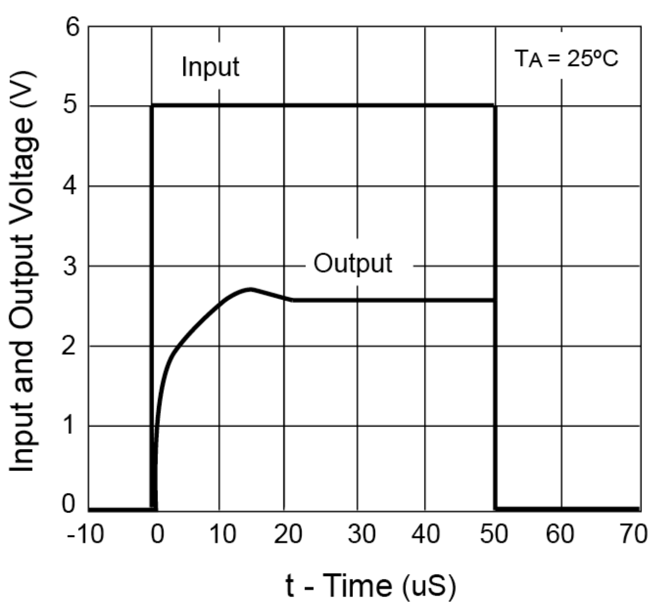
Test Circuit for Curve A

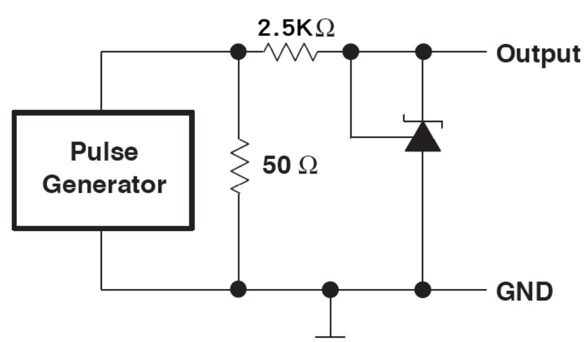


Test Circuit for Curve B, C and D

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_{KA} and I_{KA} conditions with C_L=0. V_{BATT} and C_L then were adjusted to determine the ranges of stability.

Figure 16: Stability Boundary Condition





Test Circuit for Pulse Response, Ik=1mA

Figure 17: Pulse Response

Electrical Characteristics

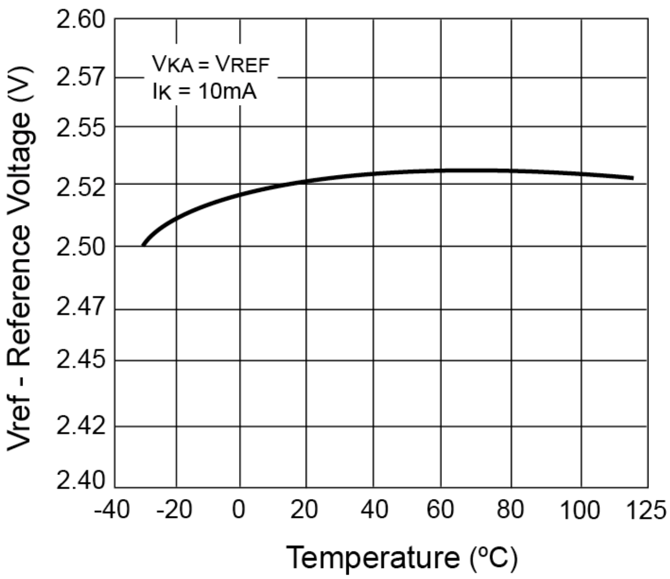


Figure 18: Reference Voltage vs. Temperature

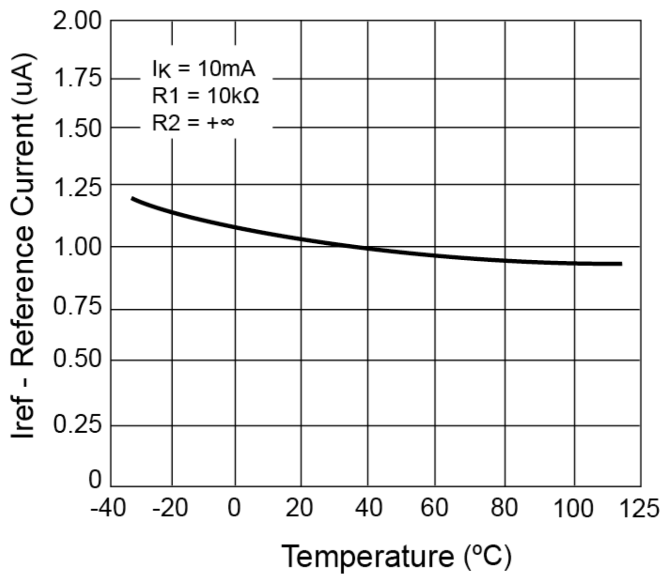


Figure 19: Reference Current vs. Temperature

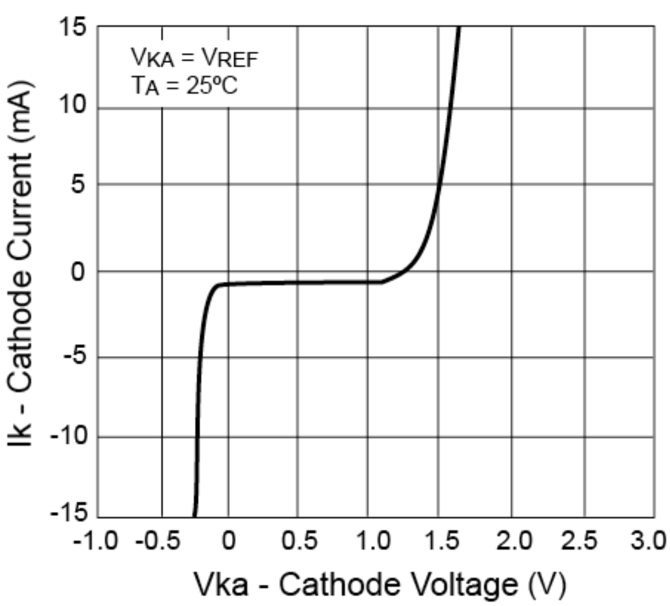
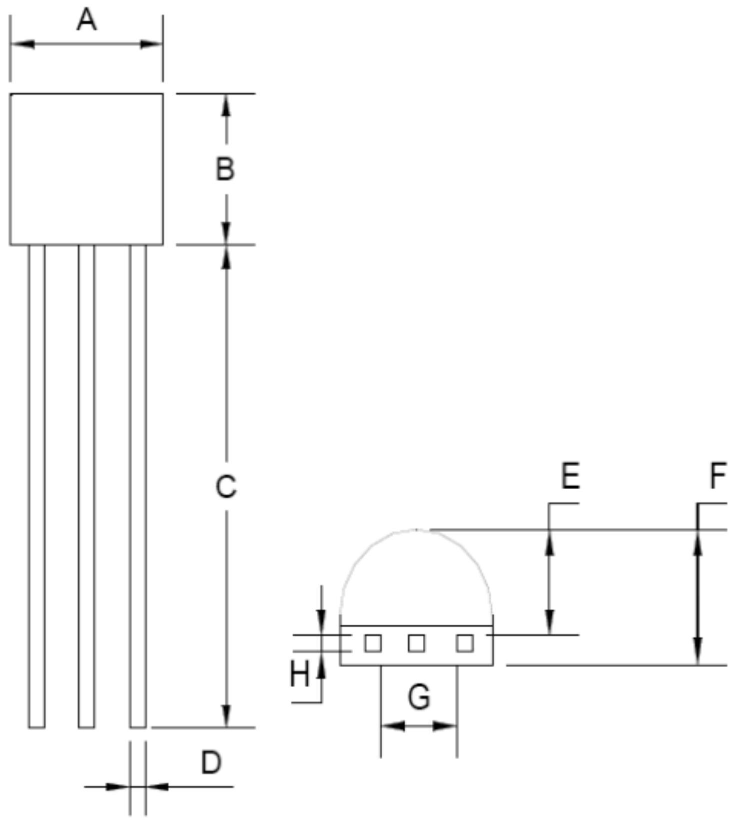


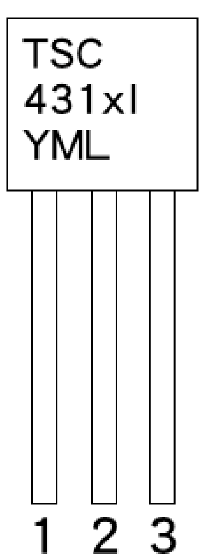
Figure 20: Cathode Current vs. Cathode Voltage

TO-92 Mechanical Drawing



TO-92 DIMENSION				
DIM	MILLIMETERS		INCHES	
	MIN	MAX	MIN	MAX
A	4.30	4.70	0.169	0.185
B	4.30	4.70	0.169	0.185
C	14.30(typ)		0.563(typ)	
D	0.43	0.49	0.017	0.019
E	2.19	2.81	0.086	0.111
F	3.30	3.70	0.130	0.146
G	2.42	2.66	0.095	0.105
H	0.37	0.43	0.015	0.017

Marking Diagram



X = Tolerance Code
(**A** = ±1%, **B** = ±0.5%, **Blank** = ±2%,)
Y = Year Code
M = Month Code
(**A**=Jan, **B**=Feb, **C**=Mar, **D**=Apl, **E**=May, **F**=Jun, **G**=Jul, **H**=Aug, **I**=Sep, **J**=Oct, **K**=Nov, **L**=Dec)
L = Lot Code

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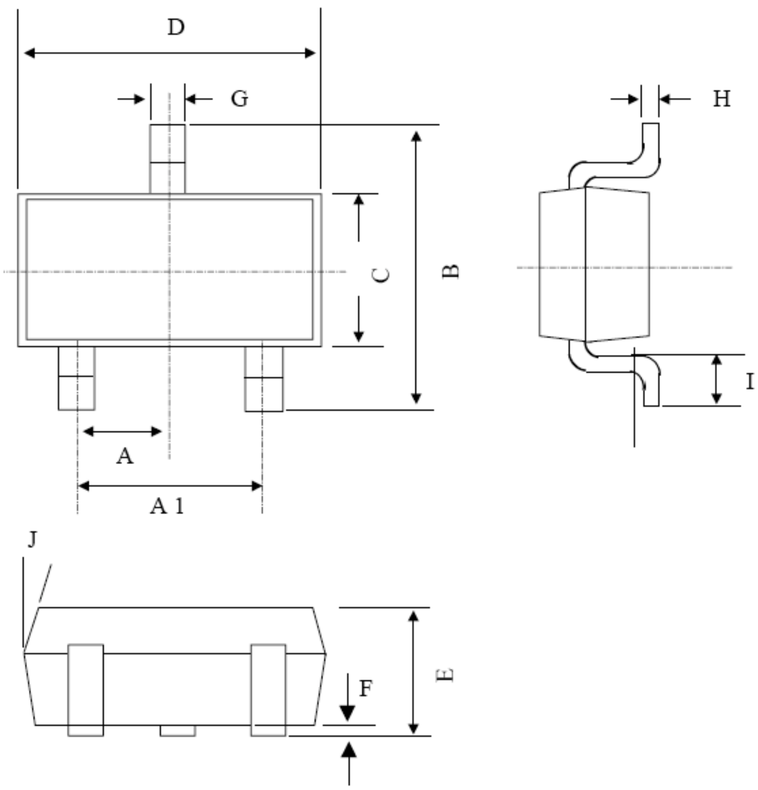
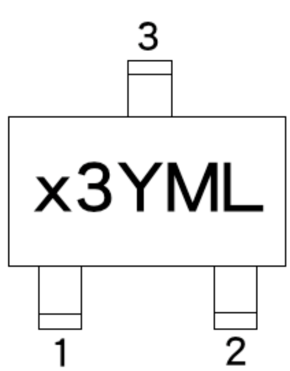
SOT-23 Mechanical Drawing



SOT-23 DIMENSION				
DIM	MILLIMETERS		INCHES	
	MIN	MAX	MIN	MAX.
A	0.95 BSC		0.037 BSC	
A1	1.9 BSC		0.074 BSC	
B	2.60	3.00	0.102	0.118
C	1.40	1.70	0.055	0.067
D	2.80	3.10	0.110	0.122
E	1.00	1.30	0.039	0.051
F	0.00	0.10	0.000	0.004
G	0.35	0.50	0.014	0.020
H	0.10	0.20	0.004	0.008
I	0.30	0.60	0.012	0.024
J	5º	10º	5º	10º

Marking Diagram



X = Device Code
(**A** = TS431AI, **B** = TS431BI, **C** = TS431I,)
3 = SOT-23 package
Y = Year Code
M = Month Code
(**A**=Jan, **B**=Feb, **C**=Mar, **D**=Apl, **E**=May, **F**=Jun, **G**=Jul, **H**=Aug, **I**=Sep, **J**=Oct, **K**=Nov, **L**=Dec)
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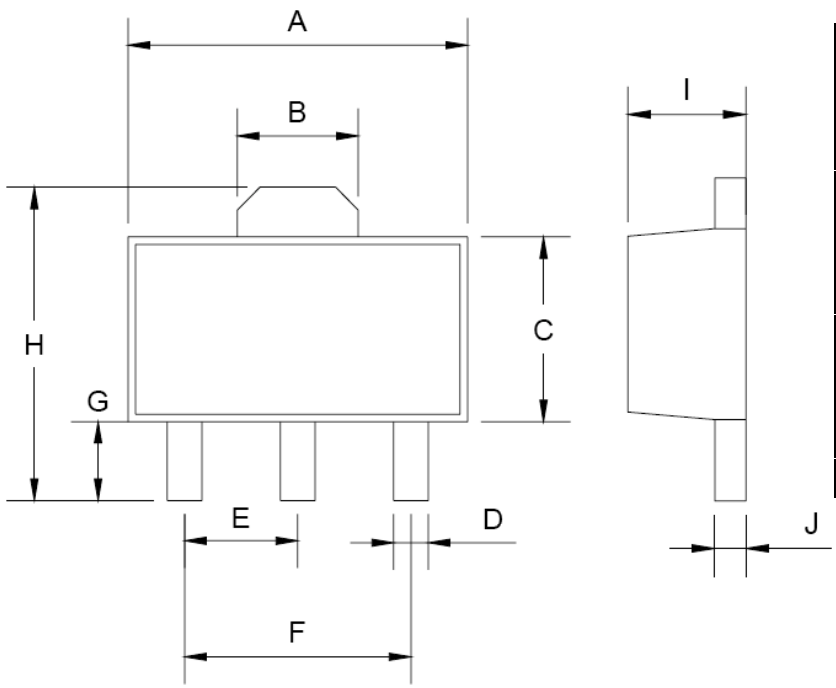
TS431I

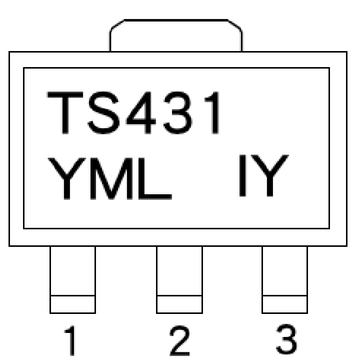
Adjustable Precision Shunt Regulator

SOT-89 Mechanical Drawing



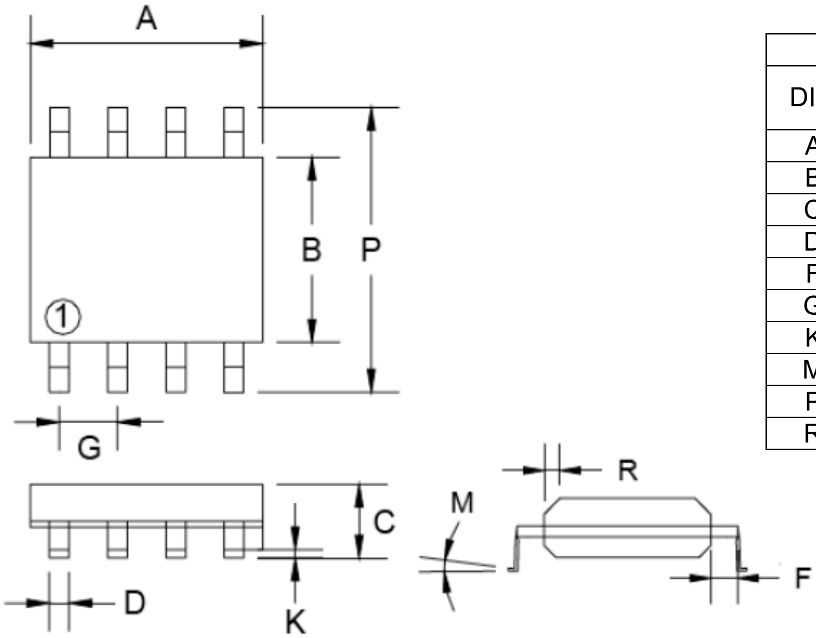
SOT-89 DIMENSION				
DIM	MILLIMETERS		INCHES	
	MIN	MAX	MIN	MAX
A	4.40	4.60	0.173	0.181
B	1.50	1.7	0.059	0.070
C	2.30	2.60	0.090	0.102
D	0.40	0.52	0.016	0.020
E	1.50	1.50	0.059	0.059
F	3.00	3.00	0.118	0.118
G	0.89	1.20	0.035	0.047
H	4.05	4.25	0.159	0.167
I	1.4	1.6	0.055	0.068
J	0.35	0.44	0.014	0.017

Marking Diagram



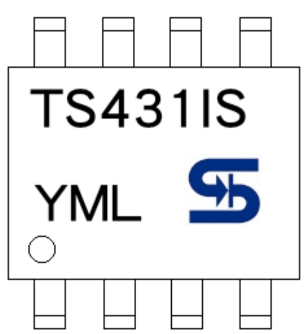
Y = Year Code
M = Month Code
(**A**=Jan, **B**=Feb, **C**=Mar, **D**=Apl, **E**=May, **F**=Jun, **G**=Jul, **H**=Aug, **I**=Sep, **J**=Oct, **K**=Nov, **L**=Dec)
L = Lot Code
IY = Package Code

SOP-8 Mechanical Drawing



SOP-8 DIMENSION				
DIM	MILLIMETERS		INCHES	
	MIN	MAX	MIN	MAX.
A	4.80	5.00	0.189	0.196
B	3.80	4.00	0.150	0.157
C	1.35	1.75	0.054	0.068
D	0.35	0.49	0.014	0.019
F	0.40	1.25	0.016	0.049
G	1.27BSC		0.05BSC	
K	0.10	0.25	0.004	0.009
M	0º	7º	0º	7º
P	5.80	6.20	0.229	0.244
R	0.25	0.50	0.010	0.019

Marking Diagram



Y = Year Code
M = Month Code
(**A**=Jan, **B**=Feb, **C**=Mar, **D**=Apl, **E**=May, **F**=Jun, **G**=Jul, **H**=Aug, **I**=Sep, **J**=Oct, **K**=Nov, **L**=Dec)
L = Lot Code

TS431I

Adjustable Precision Shunt Regulator

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