

## 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 TS4311/431AI/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  $V_{ref}$  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  $0.22\Omega$ . 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 TS4311/431AI/431BI operates as a shunt regulator, it can be used as either a positive or negative stage reference.

### Features

- Precision Reference Voltage  
TS431I –  $2.495V \pm 2\%$   
TS431AI –  $2.495V \pm 1\%$   
TS431BI –  $2.495V \pm 0.5\%$
- Equivalent Full Range Temp. Coefficient:  $50\text{ppm}/^\circ\text{C}$
- Programmable Output Voltage up to 36V
- Fast Turn-On Response
- Sink Current Capability of 1~100mA
- Low Dynamic Output Impedance:  $0.2\Omega$
- Low Output Noise

### Ordering Information

Part No.	Package	Packing
TS431x T B0	TO-92	1Kpcs / Bulk
TS431x T A3	TO-92	2Kpcs / Ammo
TS431x X RF	SOT-23	3Kpcs / 7" Reel
TS431x Y RM	SOT-89	1Kpcs / 7" Reel
TS431x S RL	SOP-8	2.5Kpcs / 2.5" Reel

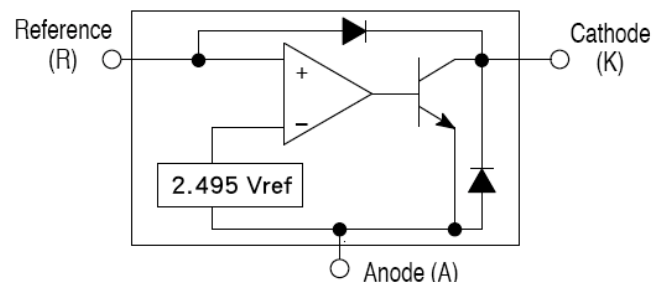
Note: Where **xx** denotes voltage tolerance

- Blank:  $\pm 2\%$
- A:  $\pm 1\%$
- B:  $\pm 0.5\%$

### 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	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.

### Recommend Operating Condition

Parameter	Symbol	Limit	Unit
Cathode Voltage (Note 1)	Vka	Ref ~ 36	V
Continuous Cathode Current Range	I <sub>k</sub>	1 ~ 100	mA

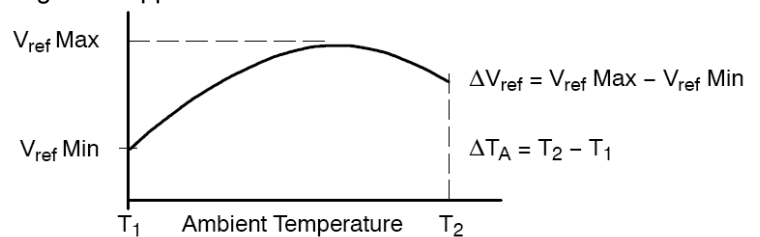
### Recommend Operating Condition

Parameter	Symbo	Test Conditions	Min	Typ	Max	Unit
Reference voltage	V <sub>ref</sub>	V <sub>ka</sub> = V <sub>ref</sub> , I <sub>k</sub> = 10mA (Figure 1) T <sub>a</sub> = 25 °C	2.450	2.495	2.550	V
			2.475		2.525	
			2.487		2.513	
Deviation of reference input voltage	ΔV <sub>ref</sub>	V <sub>ka</sub> = V <sub>ref</sub> , I <sub>k</sub> = 10mA (Figure 1) T <sub>a</sub> = full range	--	3	17	mV
Radio of change in V <sub>ref</sub> to change in cathode Voltage	ΔV <sub>ref</sub> /ΔV <sub>ka</sub>	I <sub>ka</sub> = 10mA, V <sub>ka</sub> = 10V to V <sub>ref</sub> V <sub>ka</sub> = 36V to 10V (Figure 2)	--	-1.4 -1.0	-2.7 -2.0	mV/V
Reference Input current	I <sub>ref</sub>	R1=10KΩ, R2=∞, I <sub>ka</sub> =10mA T <sub>a</sub> = full range (Figure 2)	--	0.7	4.0	uA
Deviation of reference input current, over temp.	ΔI <sub>ref</sub>	R1=10KΩ, R2=∞, I <sub>ka</sub> =10mA T <sub>a</sub> = full range (Figure 2)	--	0.4	1.2	uA
Off-state Cathode Current	I <sub>ka(off)</sub>	V <sub>ref</sub> =0V (Figure 3), V <sub>ka</sub> =36V	--	--	1.0	uA
Dynamic Output Impedance	Z <sub>ka</sub>	f<1KHz, V <sub>ka</sub> =V <sub>ref</sub> I <sub>ka</sub> =1mA to 100mA (Figure 1)	--	0.22	0.5	Ω
Minimum operating cathode current	I <sub>ka(min)</sub>	V <sub>ka</sub> =V <sub>ref</sub> (Figure 1)	--	0.4	0.6	mA

\* The deviation parameters ΔV<sub>ref</sub> and ΔI<sub>ref</sub> 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, αV<sub>ref</sub> is defined as:

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



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

αV<sub>ref</sub> can be positive or negative depending on whether the slope is positive or negative.

Example: Maximum V<sub>ref</sub>=2.496V at 30°C, minimum V<sub>ref</sub>=2.492V at 0°C, V<sub>ref</sub>=2.495V at 25°C, ΔT=70 °C

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

Because minimum V<sub>ref</sub> occurs at the lower temperature, the coefficient is positive

\* The dynamic impedance Z<sub>KA</sub> is defined as:

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

\* 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:

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

### Test Circuits

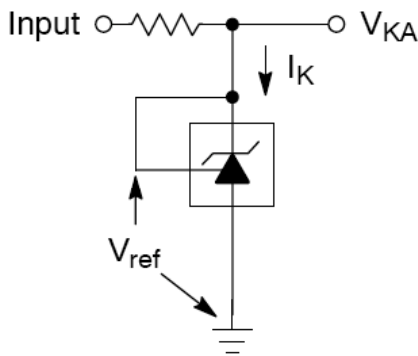


Figure 1:  $V_{KA} = V_{ref}$

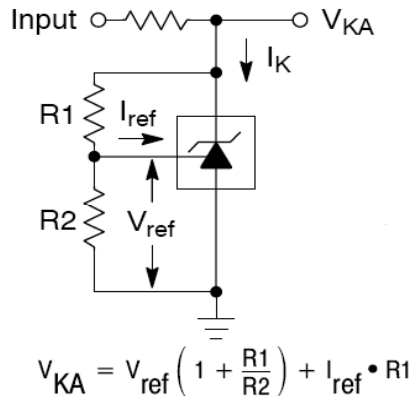


Figure 2:  $V_{KA} > V_{ref}$

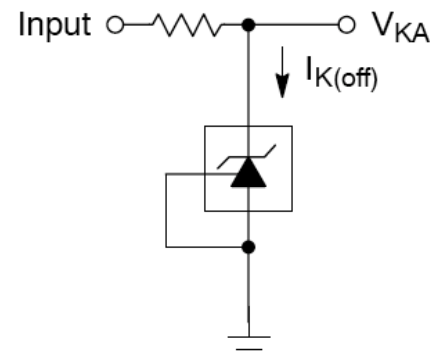


Figure 3: Off-State Current

### Additional Information – Stability

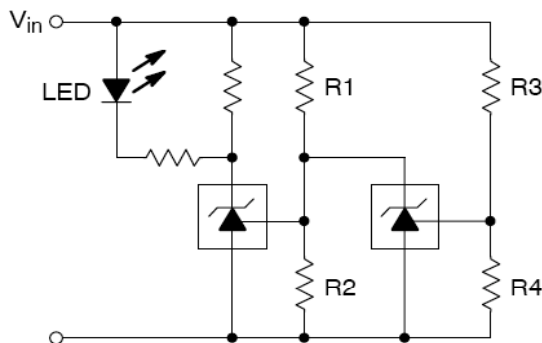
When The TS431I/431AI/431BI is used as a shunt regulator, there are two options for selection of  $C_L$ , are recommended for optional stability:

- 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  $\leq 1nF$  or  $\geq 10uF$ .

### Applications Examples

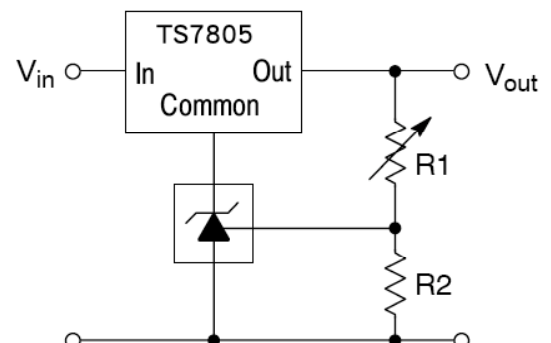


L.E.D. indicator is 'ON' when  $V_{in}$  is between the upper and lower limits,

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

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

Figure 4: Voltage Monitor

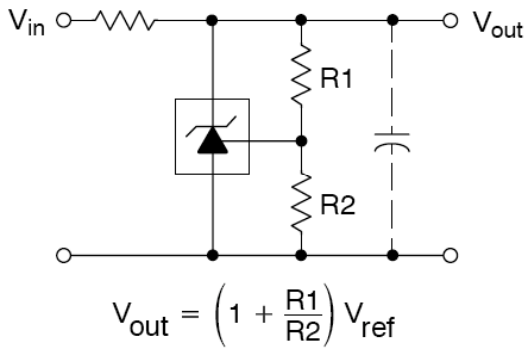


$$V_{out} = \left(1 + \frac{R1}{R2}\right) V_{ref}$$

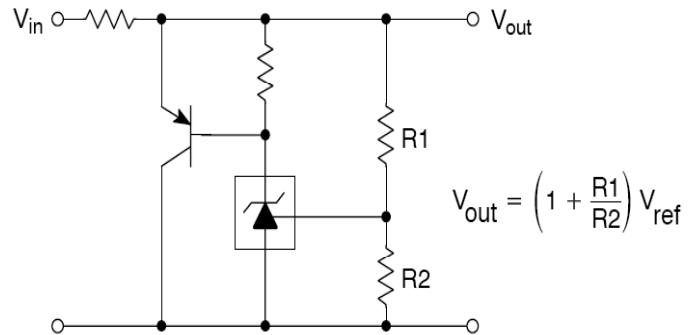
$$V_{out(min)} = V_{ref} + 5.0 V$$

Figure 5: Output Control for Three Terminal Fixed Regulator

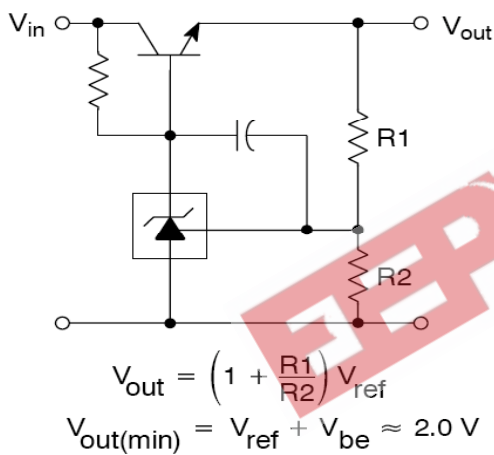
**Applications Examples (Continue)**



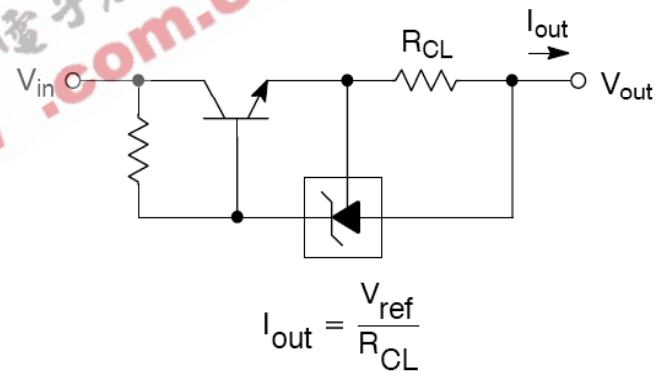
**Figure 6: Shunt Regulator**



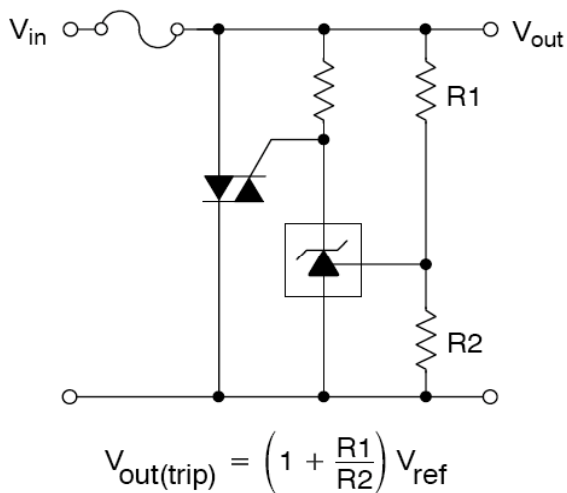
**Figure 7: High Current Shunt Regulator**



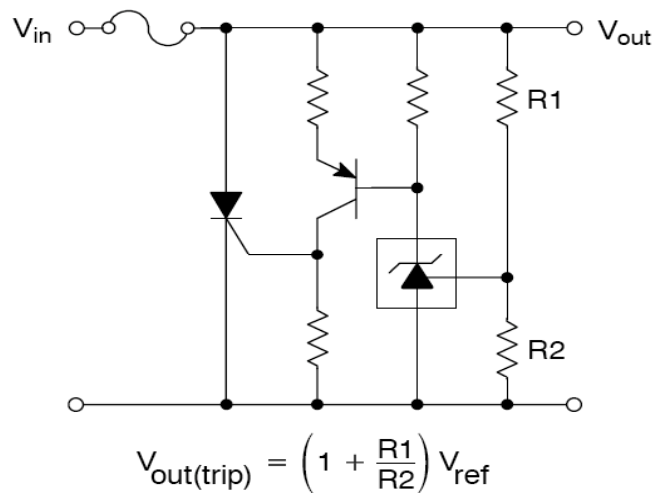
**Figure 8: Series Pass Regulator**



**Figure 9: Constant Current Source**

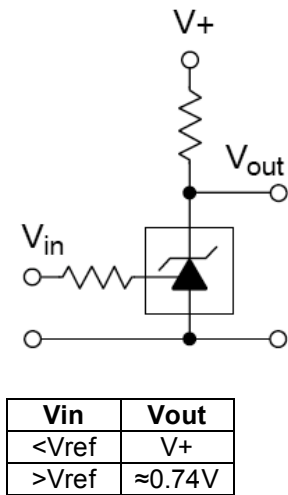


**Figure 10: TRIAC Crowbar**

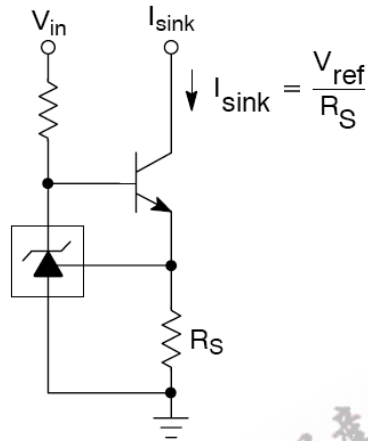


**Figure 11: SCR Crowbar**

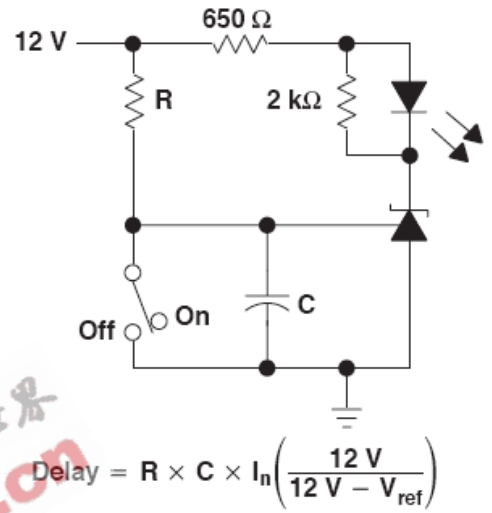
### Applications Examples (Continue)



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



**Figure 13: Constant Current Sink**



**Figure 14: Delay Timer**

### Typical Performance Characteristics

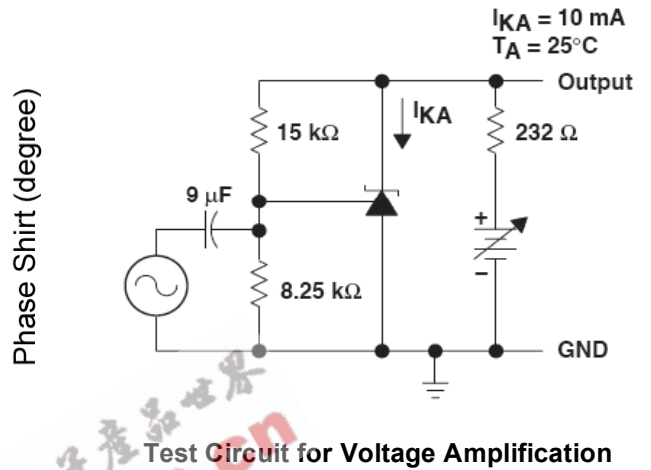
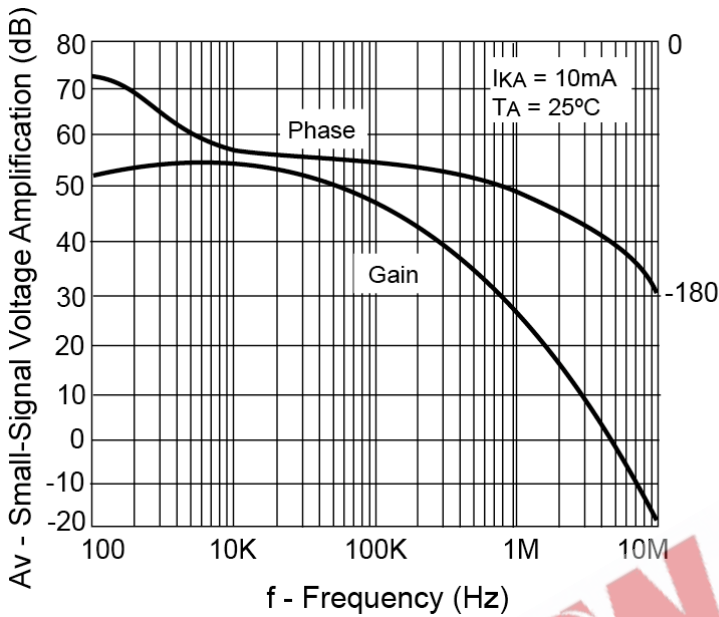
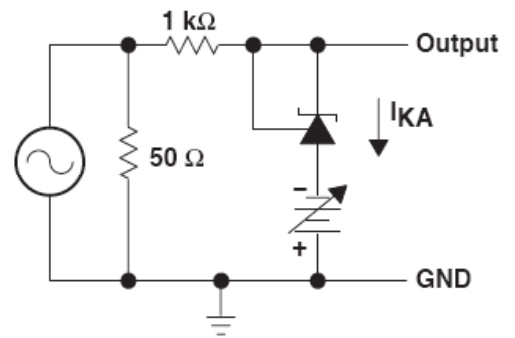
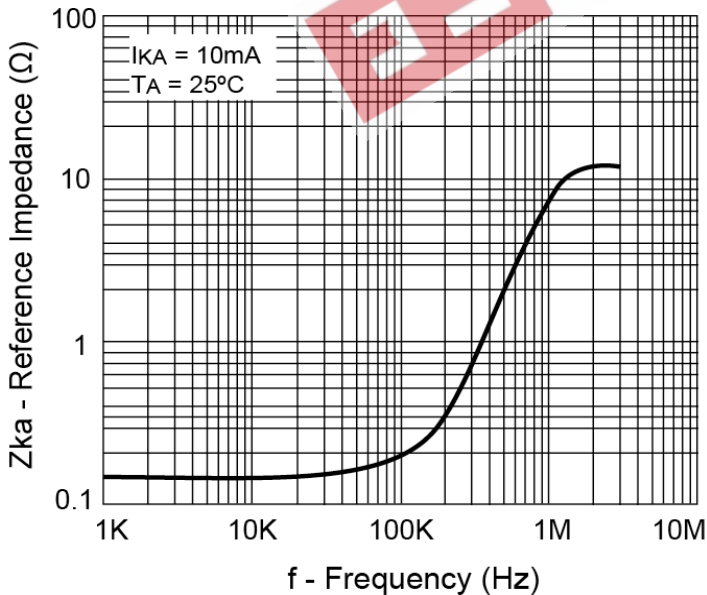


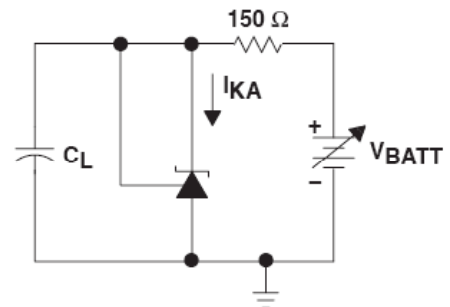
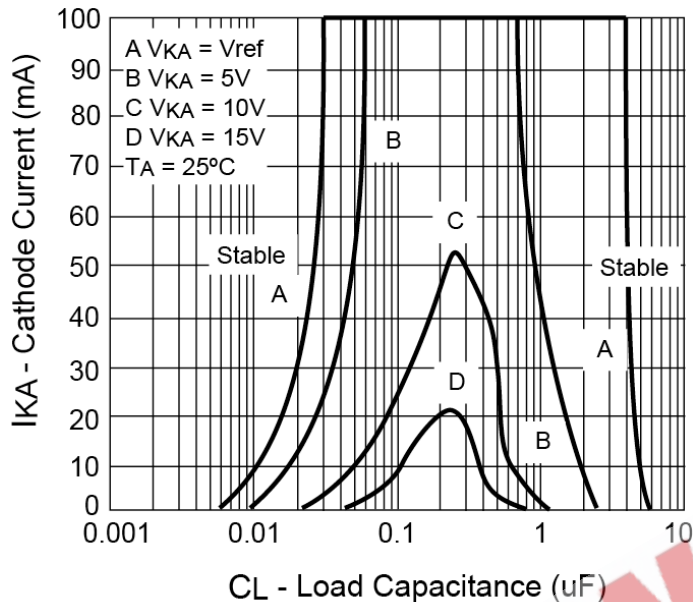
Figure 14: Small-Signal Voltage Gain and Phase Shift vs. Frequency



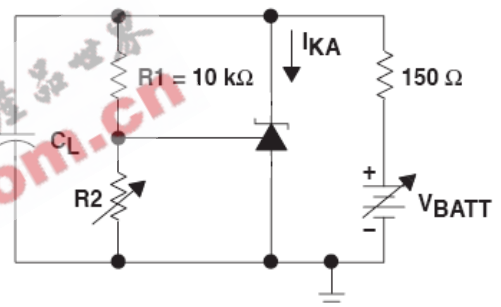
Test Circuit for Reference Impedance

Figure 15: Reference Impedance vs. Frequency

### Typical Performance Characteristics (Continue)



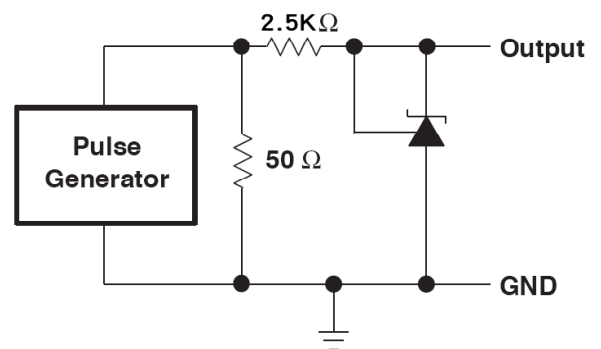
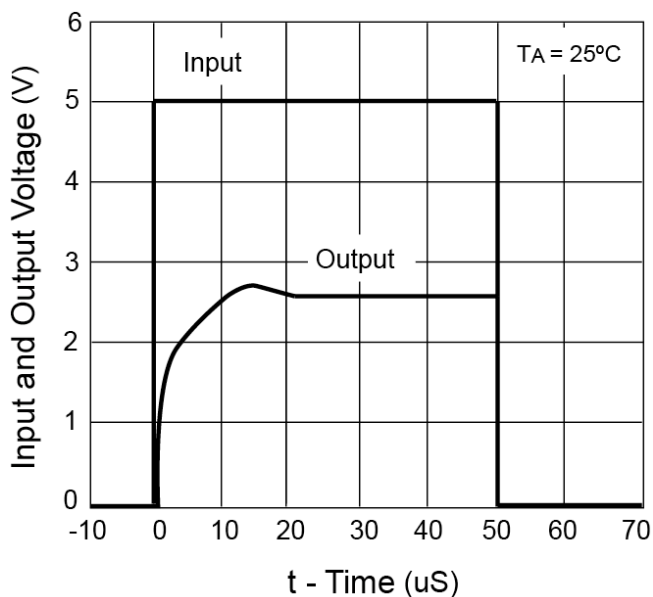
Test Circuit for Curve A



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,  $R_2$  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,  $I_K=1mA$

Figure 17: Pulse Response

### Electrical Characteristics

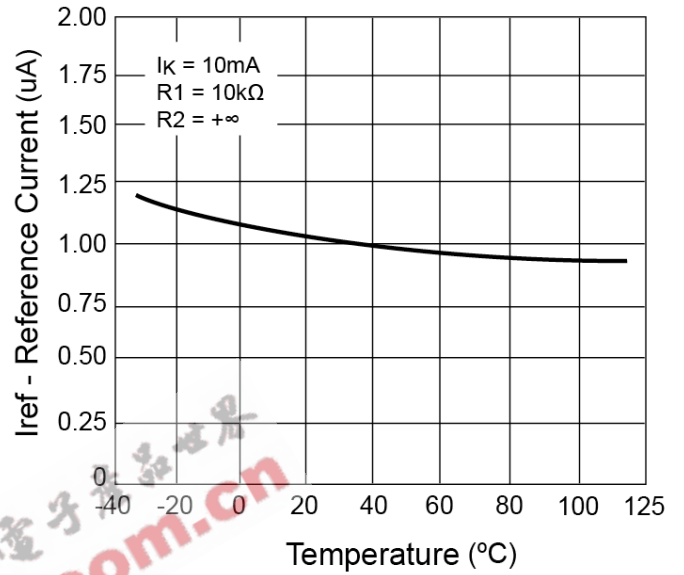
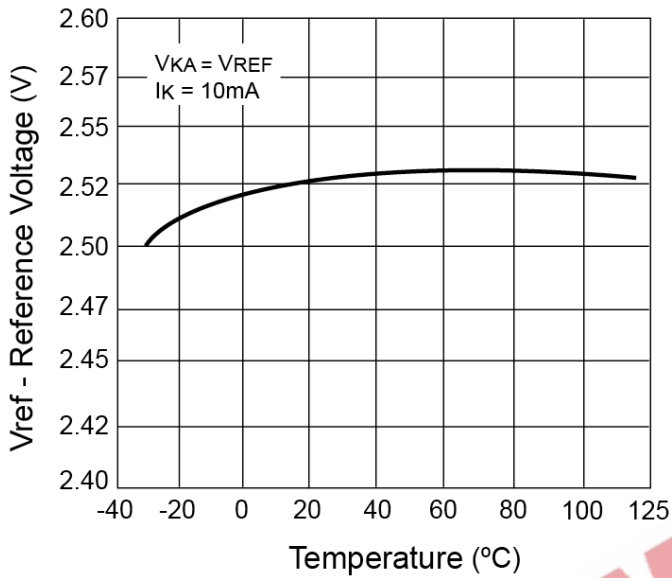


Figure 18: Reference Voltage vs. Temperature

Figure 19: Reference Current vs. Temperature

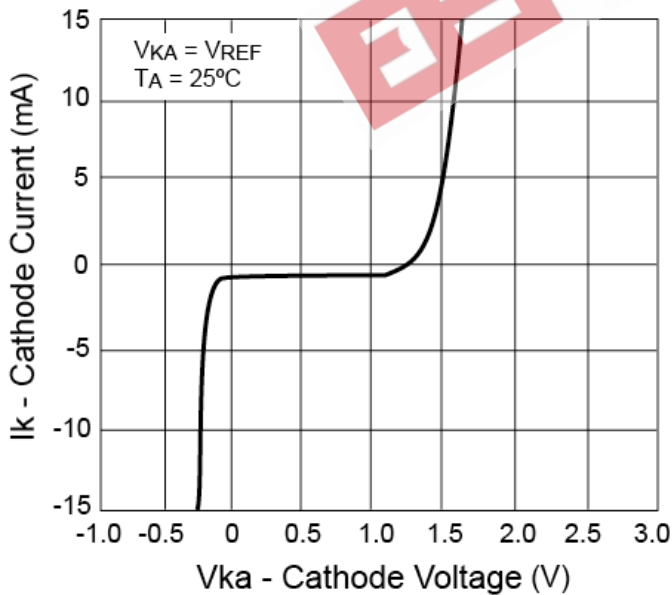
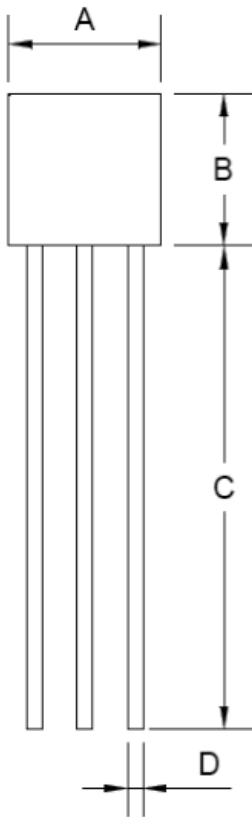


Figure 20: Cathode Current vs. Cathode Voltage

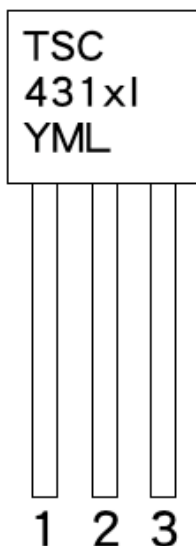


### TO-92 Mechanical Drawing



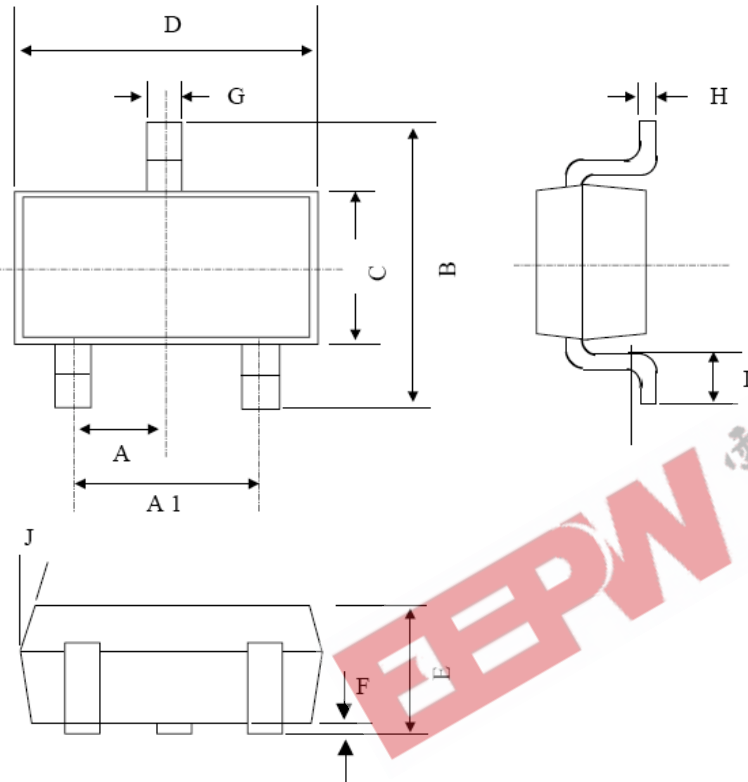
TO-92 DIMENSION				
DIM	MILLIMETERS		INCHES	
	MIN	MAX	MIN	MAX
A	4.30	4.70	0.169	0.185
B	4.30	4.70	0.169	0.185
C	14.30(typ)		0.563(typ)	
D	0.43	0.49	0.017	0.019
E	2.19	2.81	0.086	0.111
F	3.30	3.70	0.130	0.146
G	2.42	2.66	0.095	0.105
H	0.37	0.43	0.015	0.017

### Marking Diagram



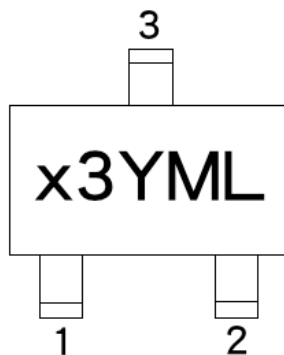
- X** = Tolerance Code  
(**A** = ±1%, **B** = ±0.5%, **Blank** = ±2%,)
- Y** = Year Code
- M** = Month Code  
(**A**=Jan, **B**=Feb, **C**=Mar, **D**=Apr, **E**=May, **F**=Jun, **G**=Jul, **H**=Aug, **I**=Sep, **J**=Oct, **K**=Nov, **L**=Dec)
- L** = Lot Code

### SOT-23 Mechanical Drawing



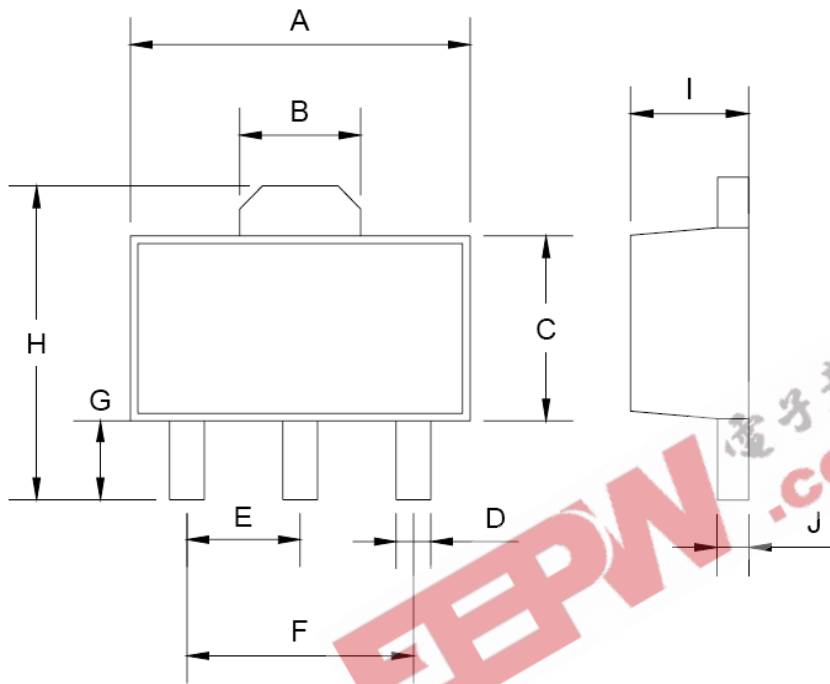
DIM	SOT-23 DIMENSION			
	MILLIMETERS		INCHES	
	MIN	MAX	MIN	MAX.
A	0.95 BSC		0.037 BSC	
A1	1.9 BSC		0.074 BSC	
B	2.60	3.00	0.102	0.118
C	1.40	1.70	0.055	0.067
D	2.80	3.10	0.110	0.122
E	1.00	1.30	0.039	0.051
F	0.00	0.10	0.000	0.004
G	0.35	0.50	0.014	0.020
H	0.10	0.20	0.004	0.008
I	0.30	0.60	0.012	0.024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

### Marking Diagram



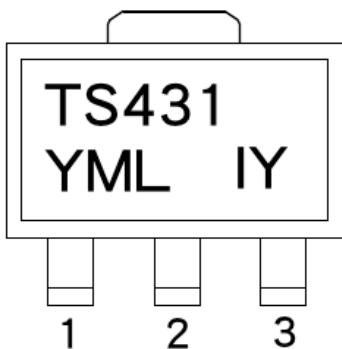
- X** = Device Code  
(**A** = TS431AI, **B** = TS431BI, **C** = TS431I,)
- 3** = SOT-23 package
- Y** = Year Code
- M** = Month Code  
(**A**=Jan, **B**=Feb, **C**=Mar, **D**=Apr, **E**=May, **F**=Jun, **G**=Jul, **H**=Aug, **I**=Sep, **J**=Oct, **K**=Nov, **L**=Dec)
- L** = Lot Code

### SOT-89 Mechanical Drawing



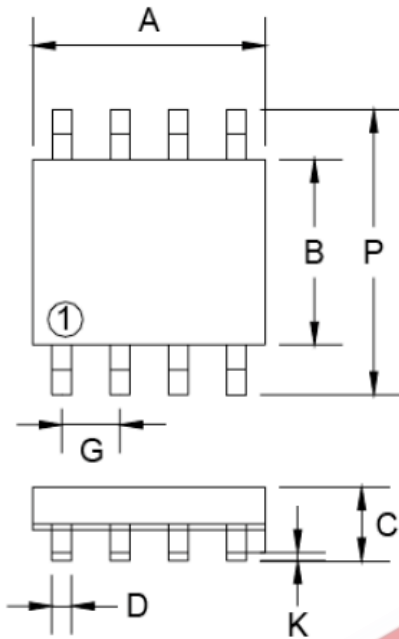
DIM	SOT-89 DIMENSION			
	MILLIMETERS		INCHES	
	MIN	MAX	MIN	MAX
A	4.40	4.60	0.173	0.181
B	1.50	1.7	0.059	0.070
C	2.30	2.60	0.090	0.102
D	0.40	0.52	0.016	0.020
E	1.50	1.50	0.059	0.059
F	3.00	3.00	0.118	0.118
G	0.89	1.20	0.035	0.047
H	4.05	4.25	0.159	0.167
I	1.4	1.6	0.055	0.068
J	0.35	0.44	0.014	0.017

### Marking Diagram



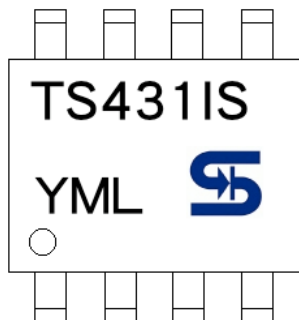
- Y** = Year Code
- M** = Month Code  
(A=Jan, B=Feb, C=Mar, D=Apl, E=May, F=Jun, G=Jul, H=Aug, I=Sep, J=Oct, K=Nov, L=Dec)
- L** = Lot Code
- IY** = Package Code

### SOP-8 Mechanical Drawing



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	0°	7°	0°	7°
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

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