

## 2.495V Programmable Shunt Voltage Reference

### GENERAL DESCRIPTION

TS431 series 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 0.22Ω.

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 2.5V reference makes it convenient to obtain a stable reference from 5.0V logic supplies, and since The TS431 series operates as a shunt regulator, it can be used as either a positive or negative stage reference.

### FEATURES

- Precision Reference Voltage  
TS431 – 2.495V ±2%  
TS431A – 2.495V ±1%  
TS431B – 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

### APPLICATION

- SMPS
- Lighting
- Telecommunication
- Home appliance



#### TO-92



#### Pin Definition:

1. Reference
2. Anode
3. Cathode

#### SOT-23



#### Pin Definition:

1. Reference
2. Cathode
3. Anode

#### SOP-8



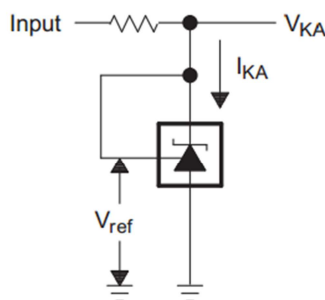
#### Pin Definition

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

#### Notes:

1. Moisture sensitivity level: level 3. Per J-STD-020 (SOP-8)
2. Moisture sensitivity level: level 1. Per J-STD-020 (SOT-23)

### TYPICAL APPLICATION CIRCUIT



<b>ABSOLUTE MAXIMUM RATINGS</b>			
<b>PARAMETER</b>	<b>SYMBOL</b>	<b>LIMIT</b>	<b>UNIT</b>
Cathode Voltage <sup>(Note 1)</sup>	$V_{KA}$	37	V
Continuous Cathode Current Range	$I_K$	-100 ~ +150	mA
Reference Input Current Range	$I_{REF}$	-0.05 ~ +10	mA
Power Dissipation	TO-92	0.625	W
	SOT-23	0.30	
	SOP-8	0.50	
Junction Temperature	$T_J$	+150	°C
Operating Temperature Range	$T_{OPER}$	0 ~ +70	°C
Storage Temperature Range	$T_{STG}$	-65 ~ +150	°C

<b>RECOMMEND OPERATING CONDITION</b>			
<b>PARAMETER</b>	<b>SYMBOL</b>	<b>LIMIT</b>	<b>UNIT</b>
Cathode Voltage	$V_{KA}$	Ref ~ 36	V
Continuous Cathode Current Range	$I_K$	1 ~ 100	mA

<b>ELECTRICAL CHARACTERISTICS</b>						
<b>PARAMETER</b>	<b>CONDITIONS</b>	<b>SYMBOL</b>	<b>MIN</b>	<b>TYP</b>	<b>MAX</b>	<b>UNIT</b>
Reference voltage	TS431A	$V_{REF}$	2.470	2.495	2.520	V
	TS431B		2.483		2.507	
Deviation of reference input voltage	$V_{KA} = V_{REF}$ , $I_K = 10\text{mA}$ $T_a = \text{full range}$	$\Delta V_{REF}$	--	3	17	mV
Ratio of change in Vref to change in cathode Voltage	$I_{KA} = 10\text{mA}$ , $V_{KA} = 10\text{V to } V_{REF}$ $V_{KA} = 36\text{V to } 10\text{V}$	$\frac{\Delta V_{REF}}{\Delta V_{KA}}$	--	-1.4	-2.7	mV/V
			--	-1.0	-2.0	
Reference Input current	$R1=10\text{K}\Omega$ , $R2=\infty$ , $I_{KA} = 10\text{mA}$ $T_a = \text{full range}$	$I_{REF}$	--	0.7	4.0	$\mu\text{A}$
Deviation of reference input current, over temp.	$R1=10\text{K}\Omega$ , $R2=\infty$ , $I_{KA} = 10\text{mA}$ $T_a = \text{full range}$	$\Delta I_{REF}$	--	0.4	1.2	$\mu\text{A}$
Off-state Cathode Current	$V_{REF} = 0\text{V}$ , $V_{KA} = 36\text{V}$	$I_{KA} (\text{off})$	--	--	1.0	$\mu\text{A}$
	$V_{REF} = 0\text{V}$ , $V_{KA} = 36\text{V}$ $T_J = -25^\circ\text{C} \sim 125^\circ\text{C}$ (Value is defined by design)		--	--	30	
Dynamic Output Impedance	$f < 1\text{KHz}$ , $V_{KA} = V_{REF}$ $I_{KA} = 1\text{mA to } 100\text{mA}$	$ Z_{KA} $	--	0.22	0.5	$\Omega$
Minimum operating cathode current	$V_{KA} = V_{REF}$	$I_{KA} (\text{min})$	--	0.4	0.6	mA

**Note :**

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

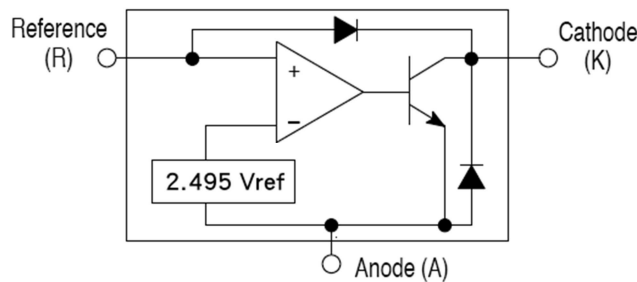
**ORDERING INFORMATION**

PART NO.	PACKAGE	PACKING
TS431ACT B0G	TO-92	1,000pcs / Bulk
TS431BCT B0G	TO-92	1,000pcs / Bulk
TS431ACT A3G	TO-92	2,000pcs / Ammo
TS431BCT A3G	TO-92	2,000pcs / Ammo
TS431ACX RFG	SOT-23	3,000pcs / 7" Reel
TS431BCX RFG	SOT-23	3,000pcs / 7" Reel
TS431ACS RLG	SOP-8	2,500pcs / 13" Reel
TS431BCS RLG	SOP-8	2,500pcs / 13" Reel
TS431CS RLG	SOP-8	2,500pcs / 13" Reel

**Note:**

1. Compliant to RoHS Directive 2011/65/EU and in accordance to WEEE 2002/96/EC.
2. Halogen-free according to IEC 61249-2-21 definition.

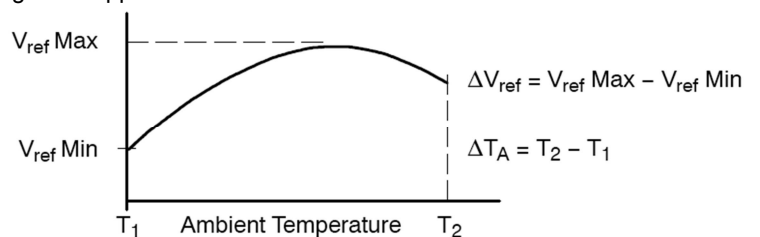
**BLOCK DIAGRAM**



\* The deviation parameters  $\Delta V_{REF}$  and  $\Delta I_{REF}$  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,  $\alpha V_{REF}$  is defined as:

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



Where:  $T_2 - T_1$  = full temperature change.

$\alpha V_{REF}$  can be positive or negative depending on whether the slope is positive or negative.

Example: Maximum  $V_{REF} = 2.496\text{V}$  at  $30^{\circ}\text{C}$ , minimum  $V_{REF} = 2.492\text{V}$  at  $0^{\circ}\text{C}$ ,  $V_{REF} = 2.495\text{V}$  at  $25^{\circ}\text{C}$ ,  $\Delta T = 70^{\circ}\text{C}$

$$\alpha V_{REF} = [4\text{mV} / 2495\text{mV}] * 10^6 / 70^{\circ}\text{C} \approx 23\text{ppm}/^{\circ}\text{C}$$

Because minimum  $V_{REF}$  occurs at the lower temperature, the coefficient is positive.

\* The dynamic impedance  $Z_{KA}$  is defined as:

$$|Z_{KA}| = \Delta V_{KA} / \Delta I_{KA}$$

\* When the device operating with two external resistors,  $R_1$  and  $R_2$ , (refer to Figure 2) the total dynamic impedance of the circuit is given by:

$$|Z_{KA}| = \Delta v / \Delta i \approx Z_{KA} * (1 + R_1 / R_2)$$

**ADDITIONAL INFORMATION – STABILITY**

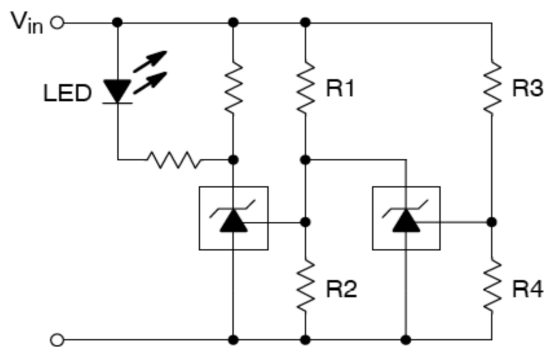
When The TS431/431A/431B is used as a shunt regulator, there are two options for selection of  $C_L$ , are recommended for optional stability:

- 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 TS431/431A/431B 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 TS431/431A/431B 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**

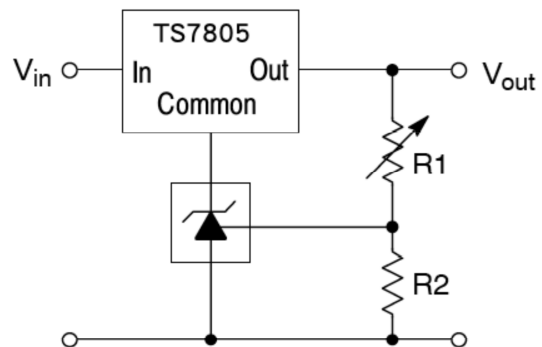


L.E.D. indicator is 'ON' when  $V_{in}$  is between the upper and lower limits,

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

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

**Figure 1. Voltage Monitor**

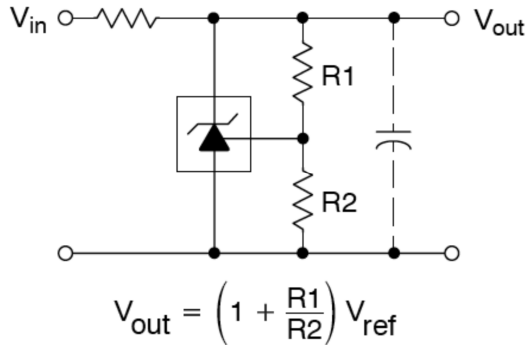


$$V_{out} = \left(1 + \frac{R1}{R2}\right) V_{ref}$$

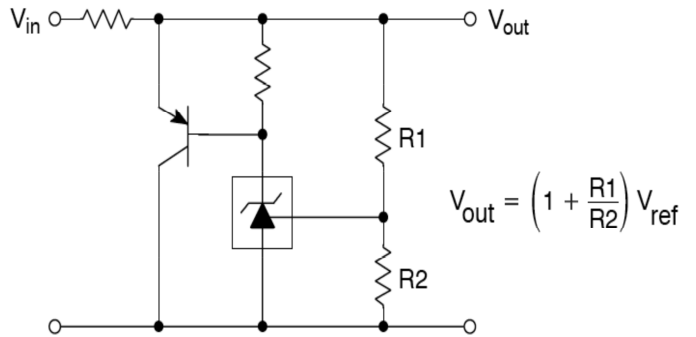
$$V_{out(min)} = V_{ref} + 5.0 V$$

**Figure 2. Output Control for Three Terminal Fixed Regulator**

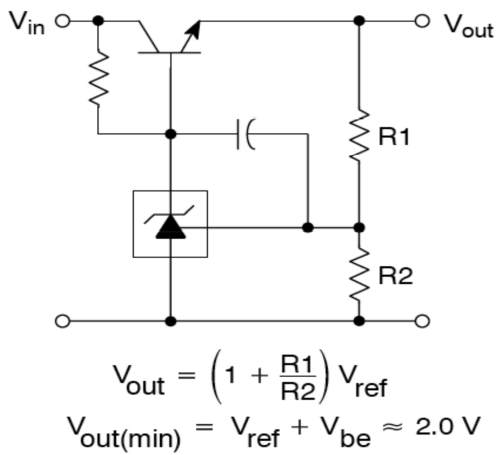
**APPLICATIONS EXAMPLES (CONTINUE)**



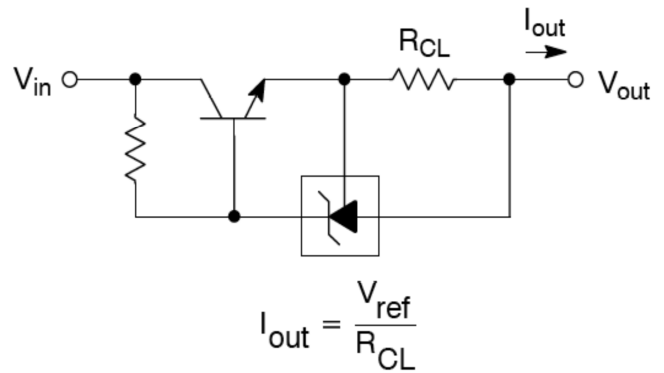
**Figure 3. Shunt Regulator**



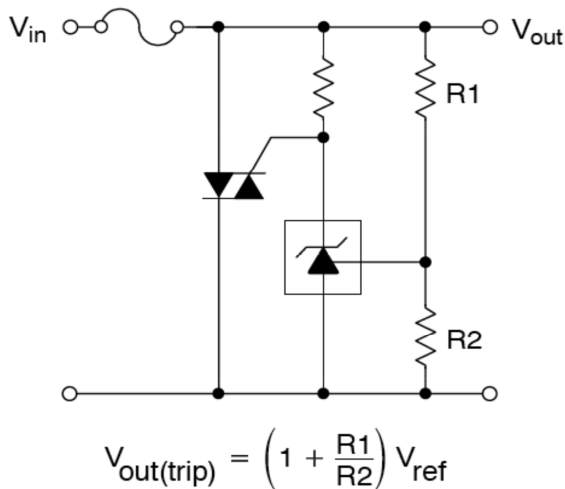
**Figure 4. High Current Shunt Regulator**



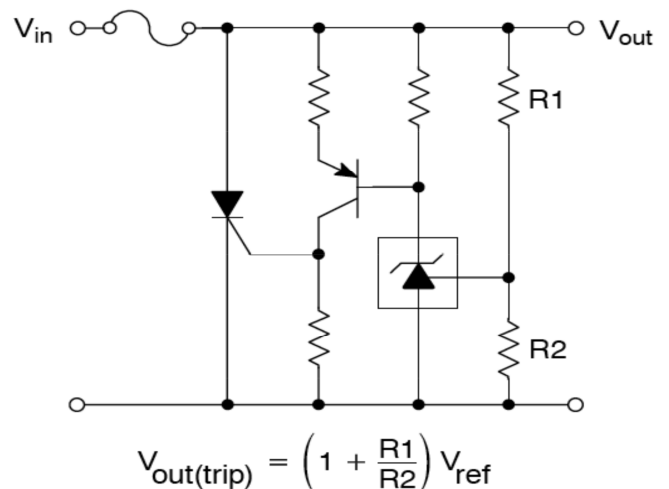
**Figure 5. Series Pass Regulator**



**Figure 6. Constant Current Source**

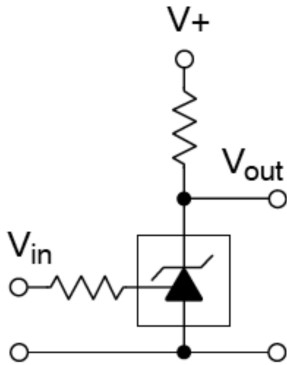


**Figure 7. TRIAC Crowbar**



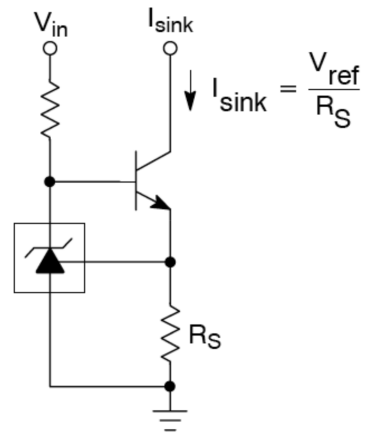
**Figure 8. SCR Crowbar**

**APPLICATIONS EXAMPLES (CONTINUE)**

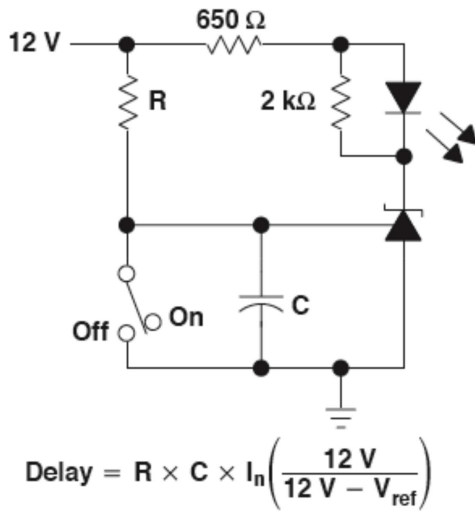


V <sub>in</sub>	V <sub>out</sub>
<V <sub>ref</sub>	V <sub>+</sub>
>V <sub>ref</sub>	≈0.74V

**Figure 9. Single-Supply Comparator with Temperature-Compensated Threshold**

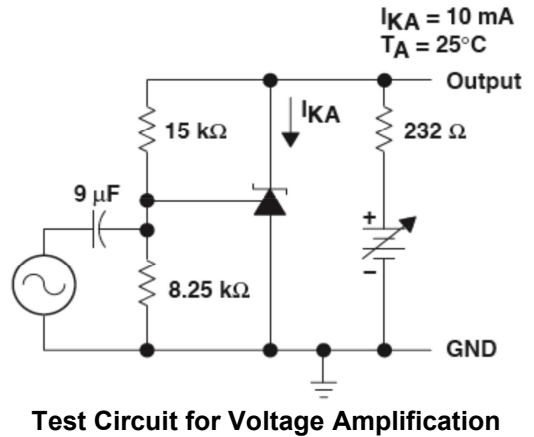
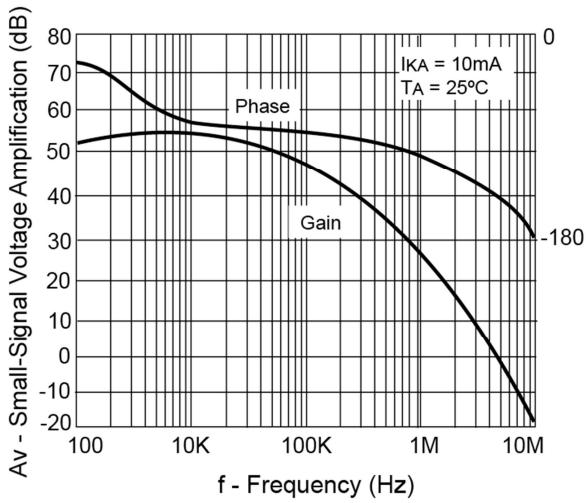


**Figure 10. Constant Current Sink**

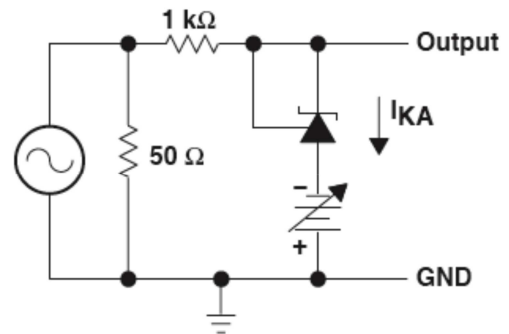
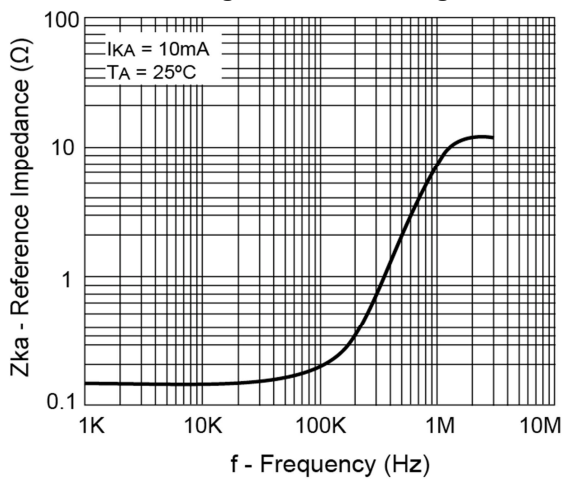


**Figure 11. Delay Timer**

**TYPICAL PERFORMANCE CHARACTERISTICS**

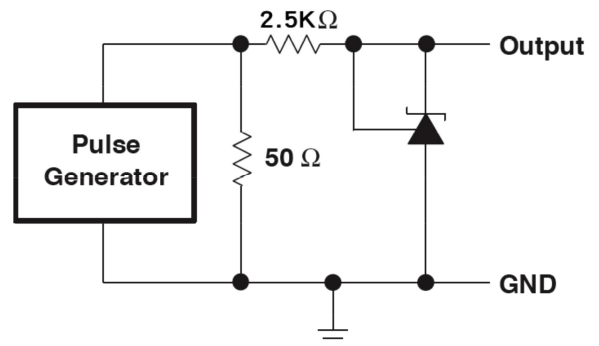
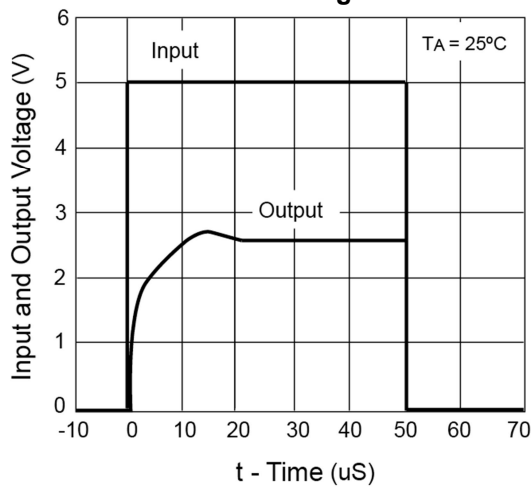


**Figure 12. Small-Signal Voltage Gain and Phase Shift vs. Frequency**



**Test Circuit for Reference Impedance**

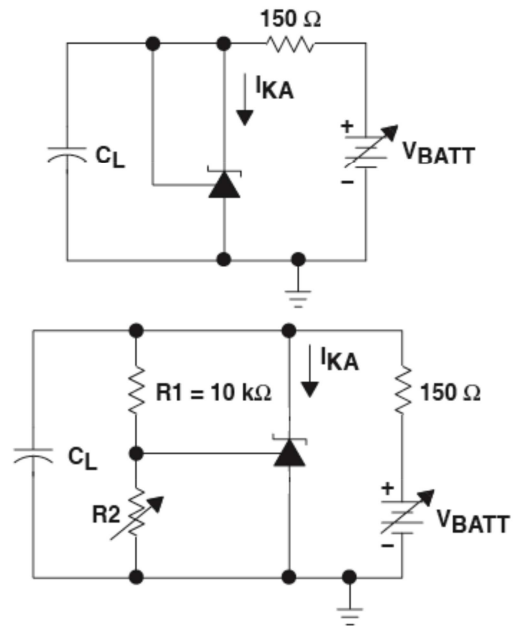
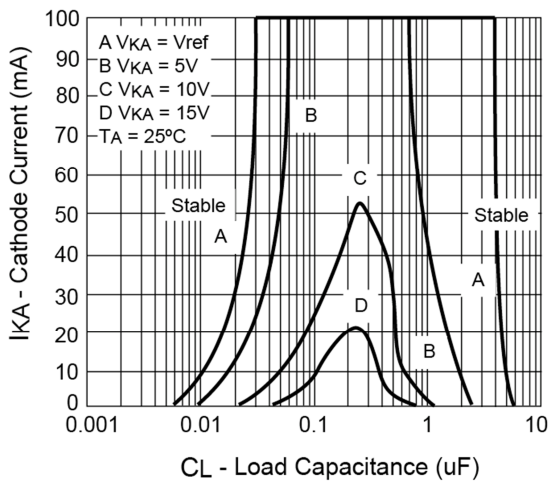
**Figure 13. Reference Impedance vs. Frequency**



**Test Circuit for Pulse Response,  $I_k=1\text{mA}$**

**Figure 14. Pulse Response**

**TYPICAL PERFORMANCE CHARACTERISTICS (CONTINUE)**



**Test Circuit for Curve B, C and D**

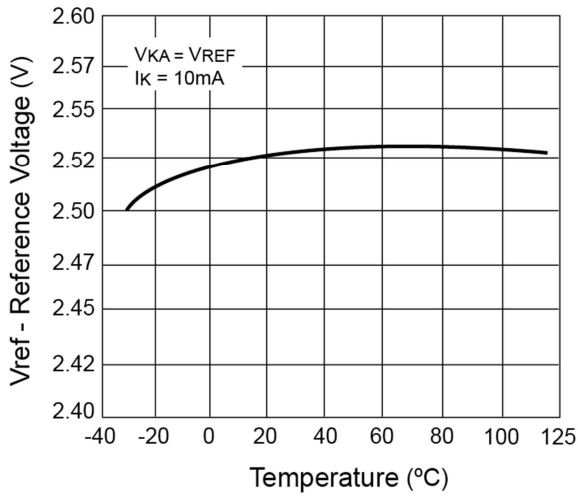
The areas under the curves represent conditions that may cause the device to oscillate. For curves B, C, and D, R2 and V+ were adjusted to establish the initial  $V_{KA}$  and  $I_{KA}$  conditions with  $C_L=0$ .  $V_{BATT}$  and  $C_L$  then were adjusted to determine the ranges of stability.

**Figure 15. Reference Impedance vs. Frequency**

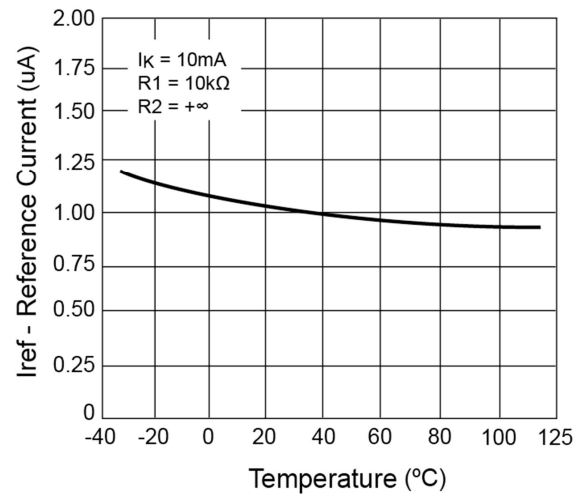


**CHARACTERISTICS CURVES**

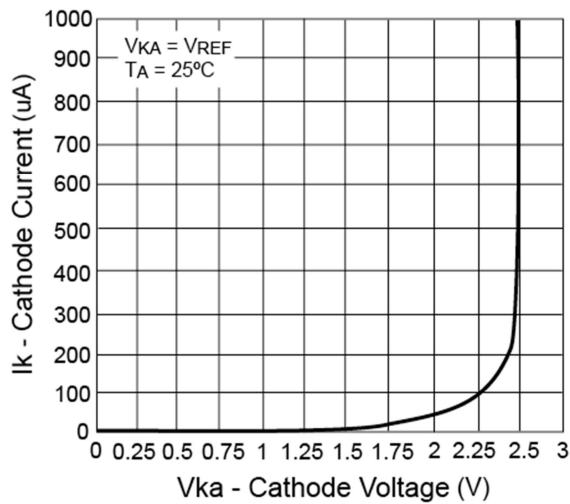
( $T_c = 25^\circ\text{C}$  unless otherwise noted)



**Figure 16. Reference Voltage vs. Temperature**



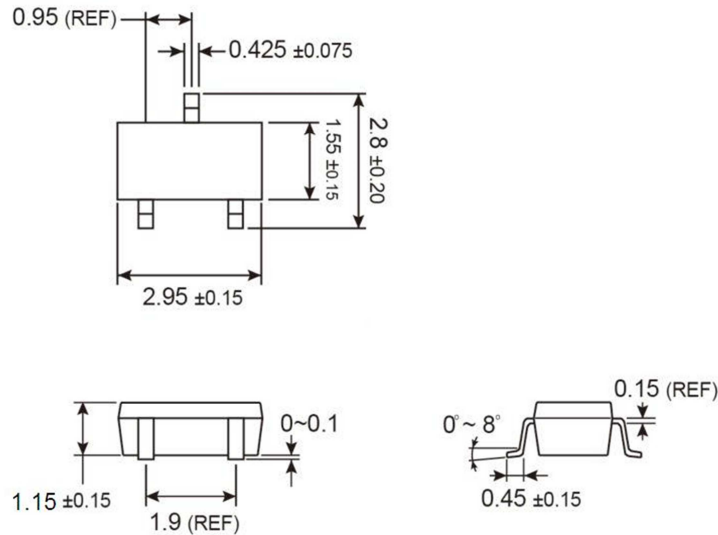
**Figure 17. Reference Current vs. Temperature**



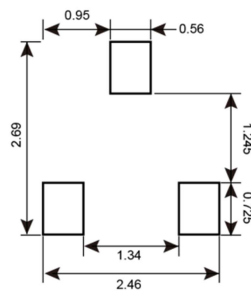
**Figure 18. Cathode Current vs. Cathode Voltage**

**PACKAGE OUTLINE DIMENSIONS** (Unit: Millimeters)

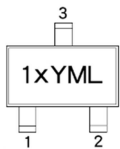
**SOT-23**



**SUGGESTED PAD LAYOUT** (Unit: Millimeters)



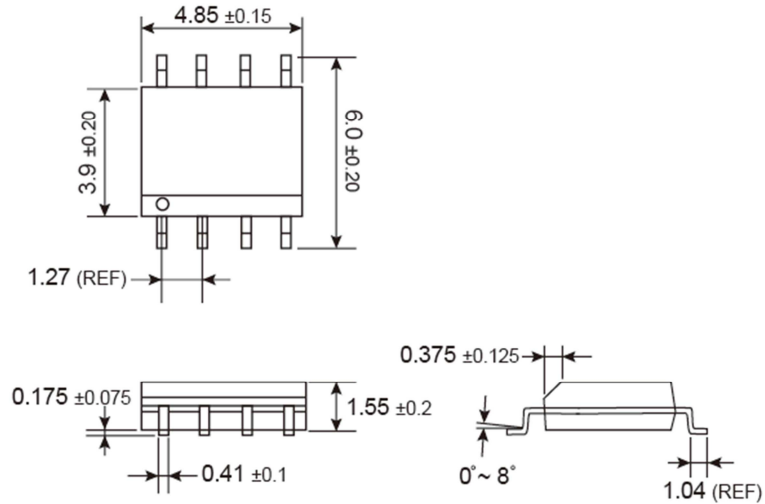
**MARKING DIAGRAM**



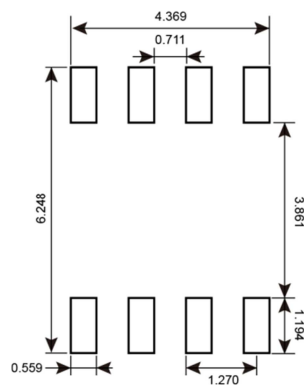
- 1** = Device Code
- X** = Tolerance Code  
(**A** =  $\pm 1\%$ , **B** =  $\pm 0.5\%$ , **Blank** =  $\pm 2\%$ )
- Y** = Year Code
- M** = Month Code for Halogen Free Product
  - O** =Jan    **P** =Feb    **Q** =Mar    **R** =Apr
  - S** =May    **T** =Jun    **U** =Jul    **V** =Aug
  - W** =Sep    **X** =Oct    **Y** =Nov    **Z** =Dec
- L** = Lot Code

**PACKAGE OUTLINE DIMENSIONS** (Unit: Millimeters)

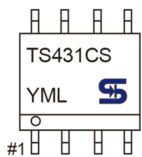
**SOP-8**



**SUGGESTED PAD LAYOUT** (Unit: Millimeters)



**MARKING DIAGRAM**



**Y** = Year Code

**M** = Month Code for Halogen Free Product

**O** =Jan    **P** =Feb    **Q** =Mar    **R** =Apr

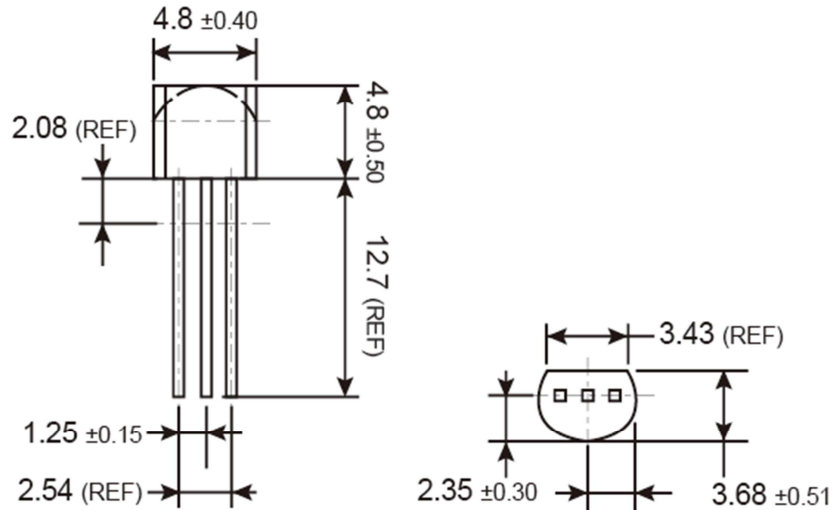
**S** =May    **T** =Jun    **U** =Jul    **V** =Aug

**W** =Sep    **X** =Oct    **Y** =Nov    **Z** =Dec

**L** = Lot Code

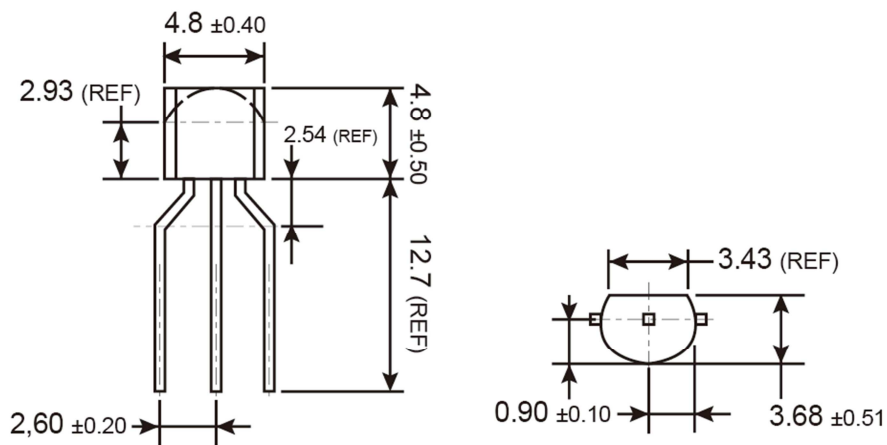
**PACKAGE OUTLINE DIMENSIONS** (Unit: Millimeters)

**TO-92**

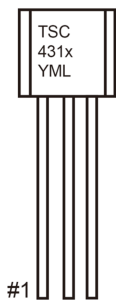


**PACKAGE OUTLINE DIMENSIONS** (Unit: Millimeters)

**TO-92 AMMO PACK**



**MARKING DIAGRAM**



- X** = Tolerance Code  
(**A** =  $\pm 1\%$ , **B** =  $\pm 0.5\%$ , **Blank** =  $\pm 2\%$ .)
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