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/ ºC
- 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

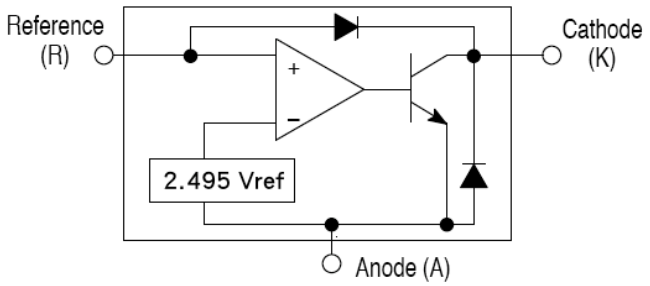
| Part No. | Package | Packing |
|---|---|---|
| TS431**x**IT B0 | TO-92 | 1Kpcs / Bulk |
| TS431**x**IT A3 | TO-92 | 2Kpcs / Ammo |
| TS431**x**IX RF | SOT-23 | 3Kpcs / 7” Reel |
| TS431**x**IY RM | SOT-89 | 1Kpcs / 7” Reel |
| TS431**x**IS RL | SOP-8 | 2.5Kpcs / 2.5” Reel |

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.

# TS431I

## Adjustable Precision Shunt Regulator

### Recommend Operating Condition

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

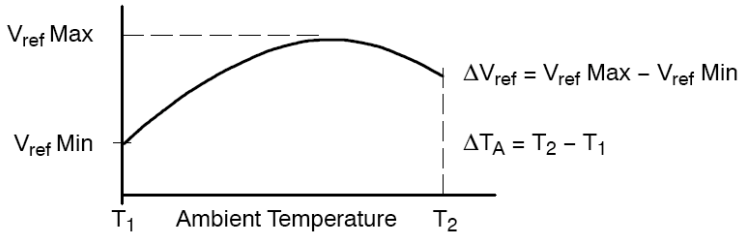
### Recommend Operating Condition

| 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<br>Vka = 36V to 10V (Figure 2) | --<br>-- | -1.4<br>-1.0 | -2.7<br>-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:

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




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

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

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

* The dynamic impedance ZKA 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

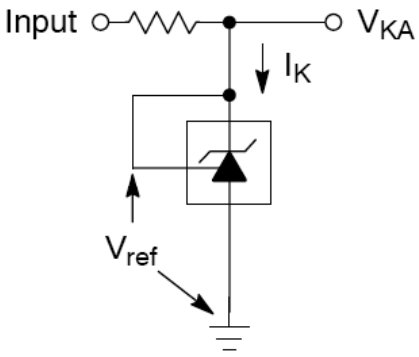



**Figure 1: Vka = Vref**

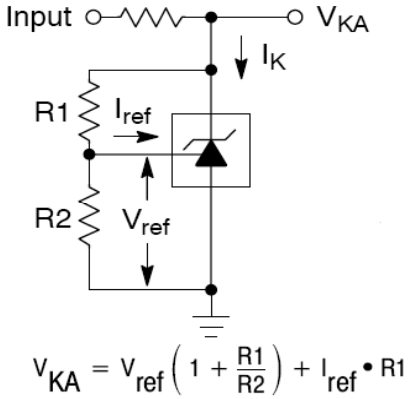



**Figure 2: Vka > Vref**

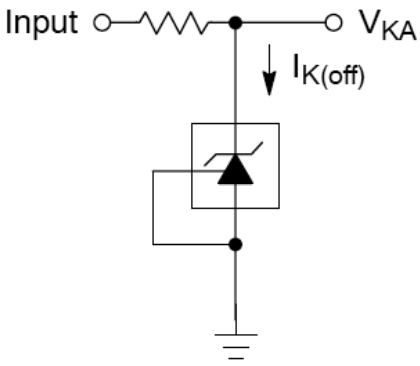



**Figure 3: Off-State Current**

## 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:

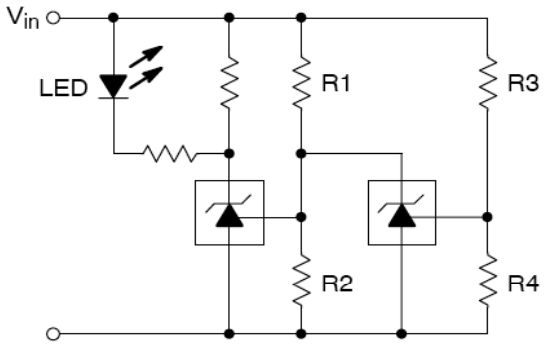
A) No load capacitance across the device, decouple at the load.

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

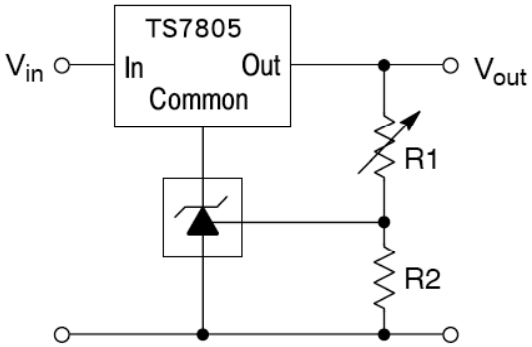



L.E.D. indicator is 'ON' when $V_{in}$ is between the upper and lower limits,

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

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

**Figure 4: Voltage Monitor**




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

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

**Figure 5: Output Control for Three Terminal Fixed Regulator**

## Applications Examples (Continue)

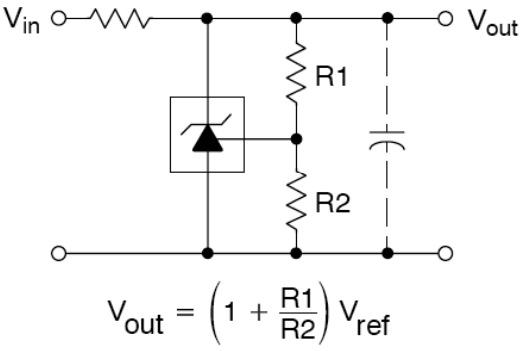



**Figure 6: Shunt Regulator**

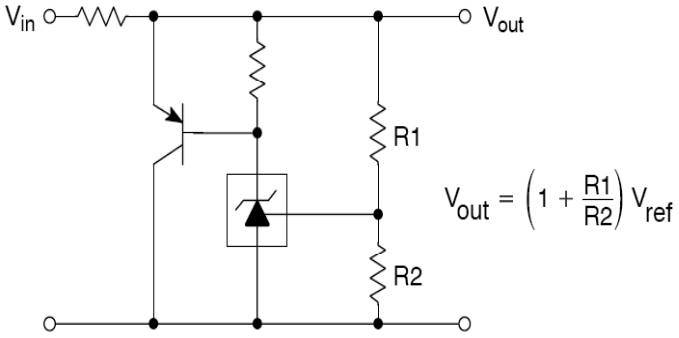



**Figure 7: High Current Shunt Regulator**

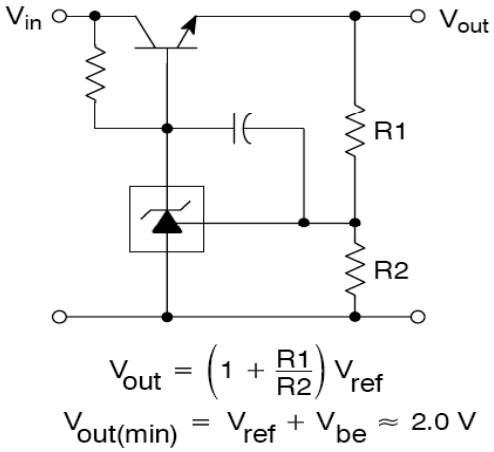



**Figure 8: Series Pass Regulator**

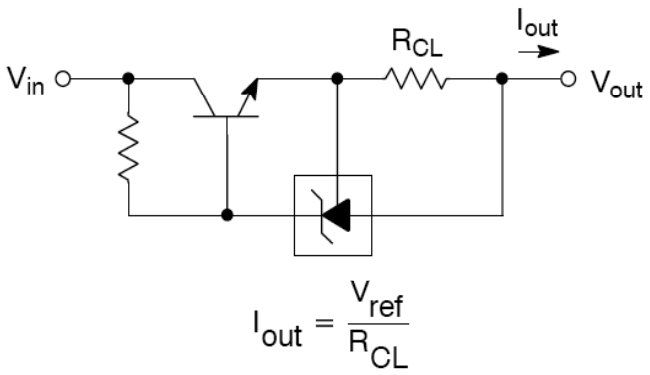



**Figure 9: Constant Current Source**

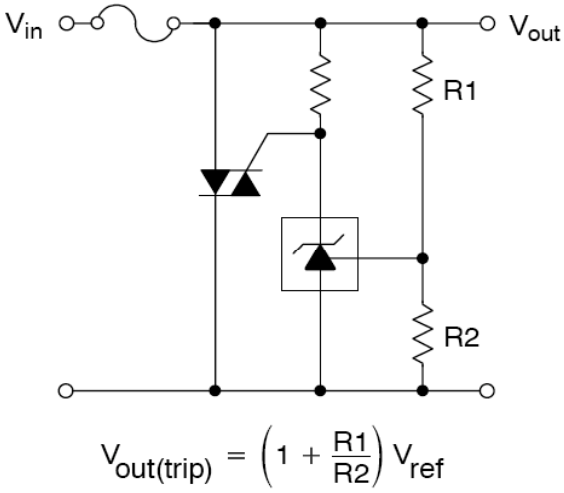



**Figure 10: TRIAC Crowbar**

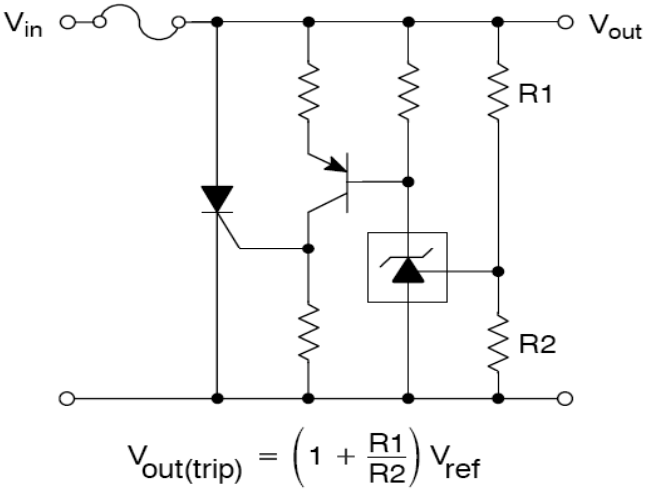
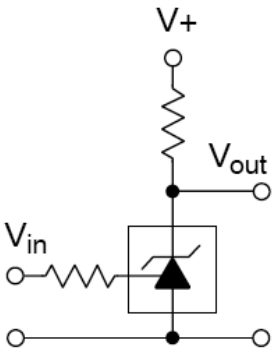



**Figure 11: SCR Crowbar**

## Applications Examples (Continue)




| Vin | Vout |
|---|---|
| <Vref | V+ |
| >Vref | ≈0.74V |

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

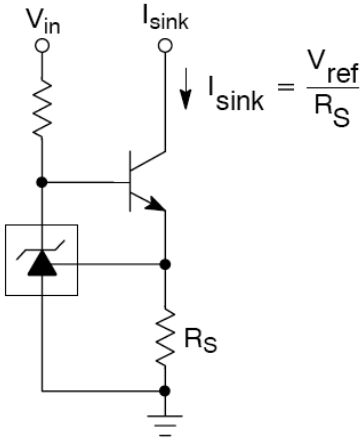



**Figure 13: Constant Current Sink**

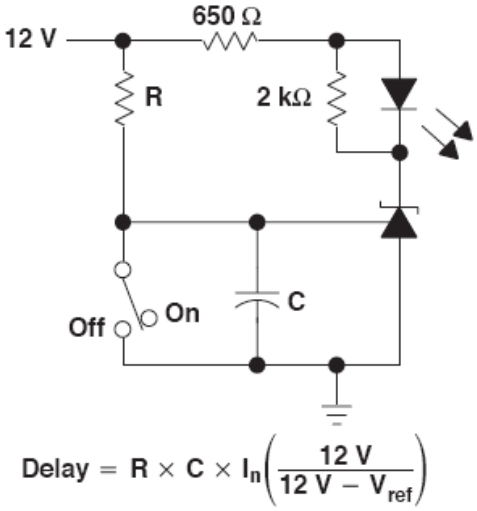
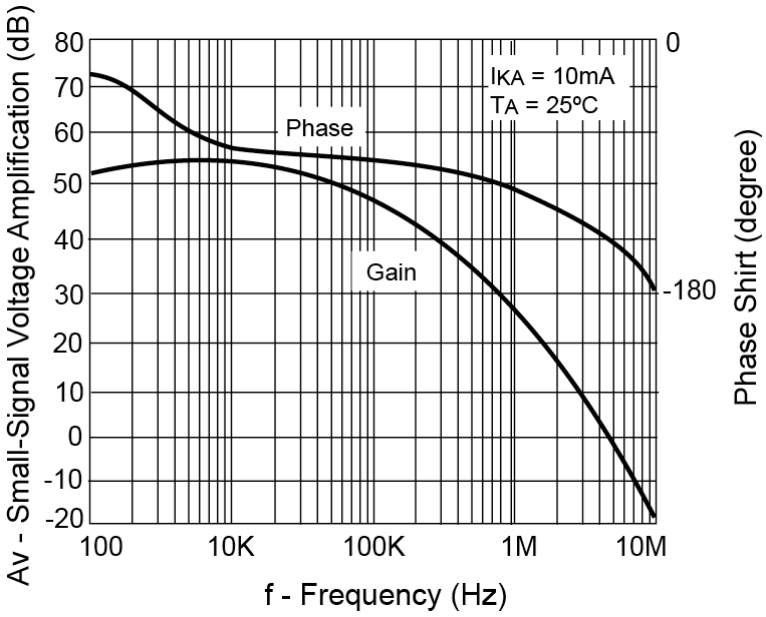
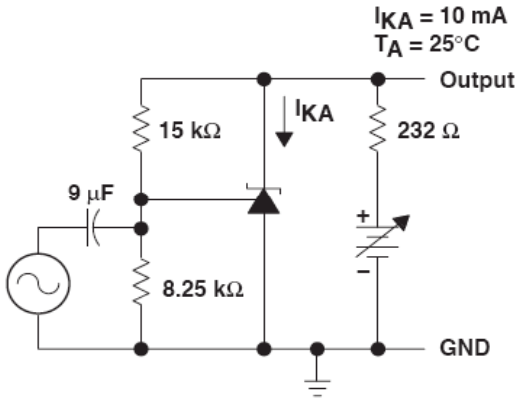



**Figure 14: Delay Timer**

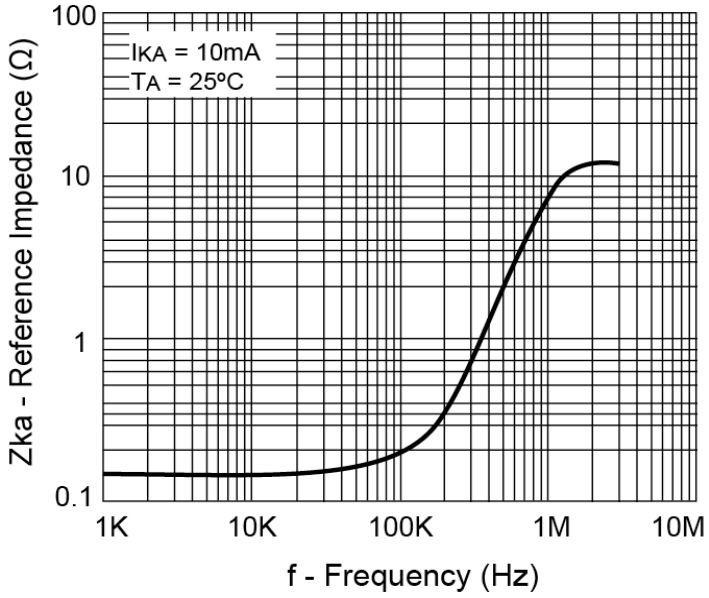
## Typical Performance Characteristics

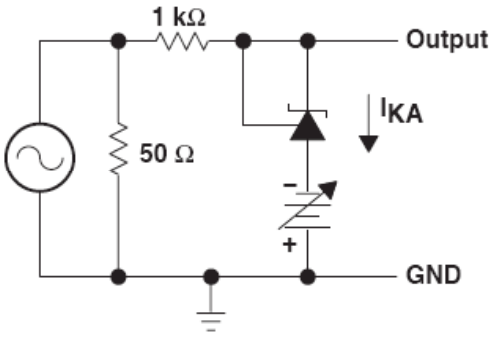



**Test Circuit for Voltage Amplification**

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

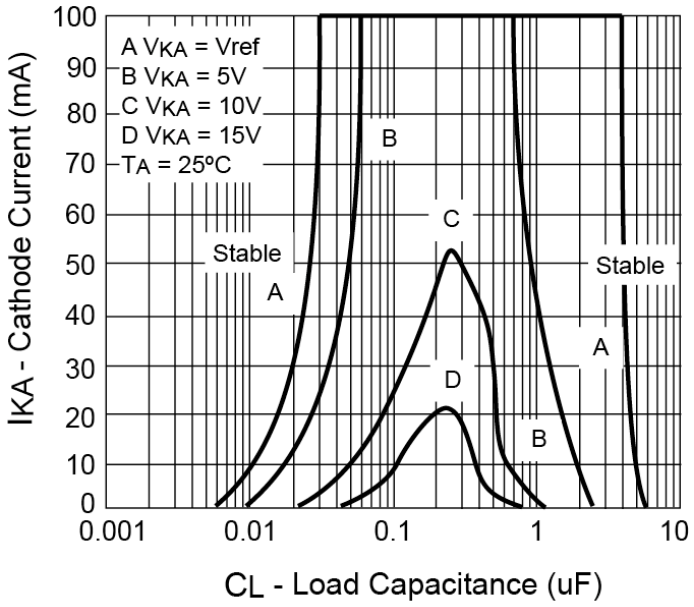


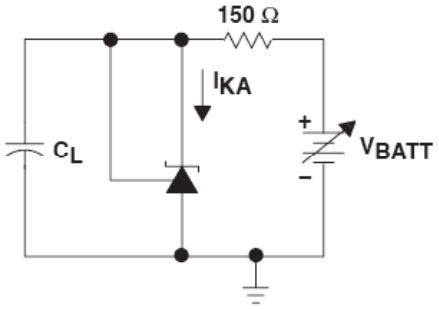




**Test Circuit for Reference Impedance**

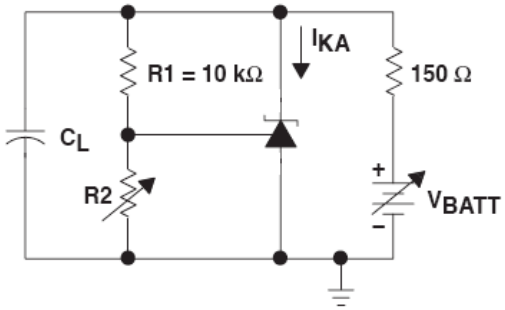
**Figure 15: Reference Impedance vs. Frequency**

## Typical Performance Characteristics (Continue)



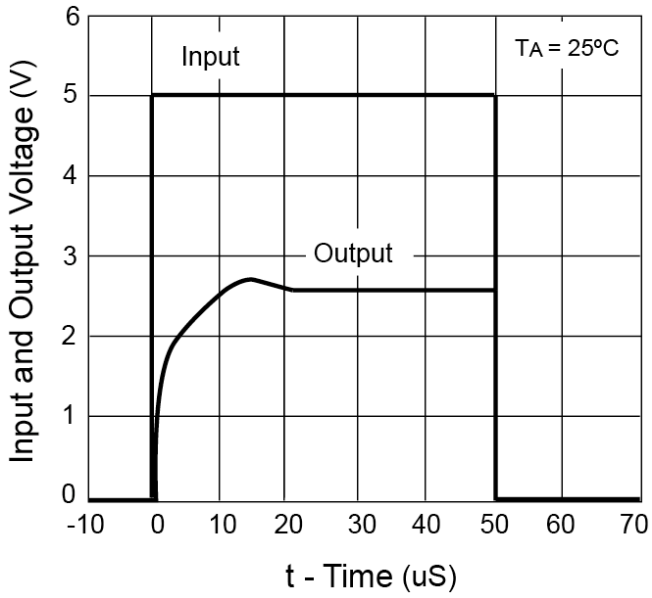

**Test Circuit for Curve A**

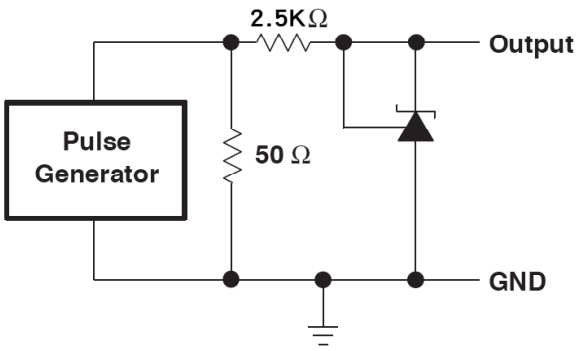



**Test Circuit for Curve B, C and D**

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

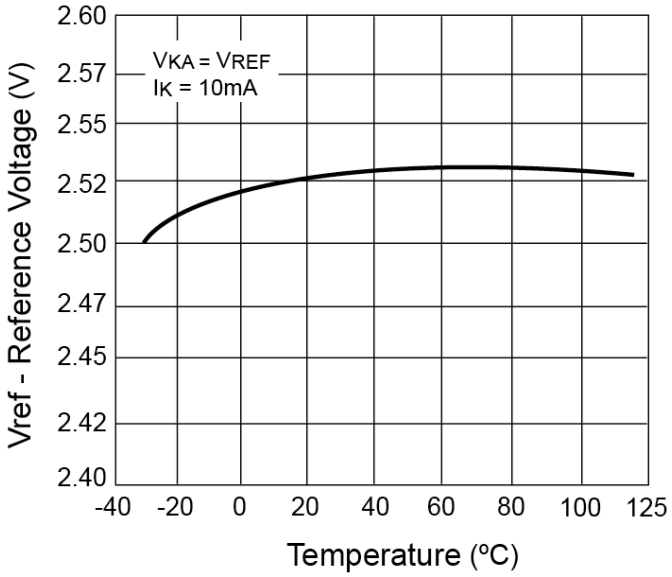



**Figure 18: Reference Voltage vs. Temperature**

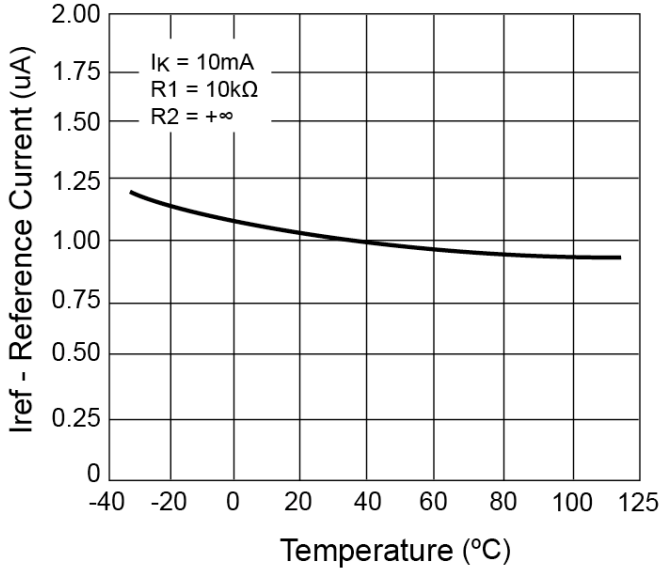



**Figure 19: Reference Current vs. Temperature**

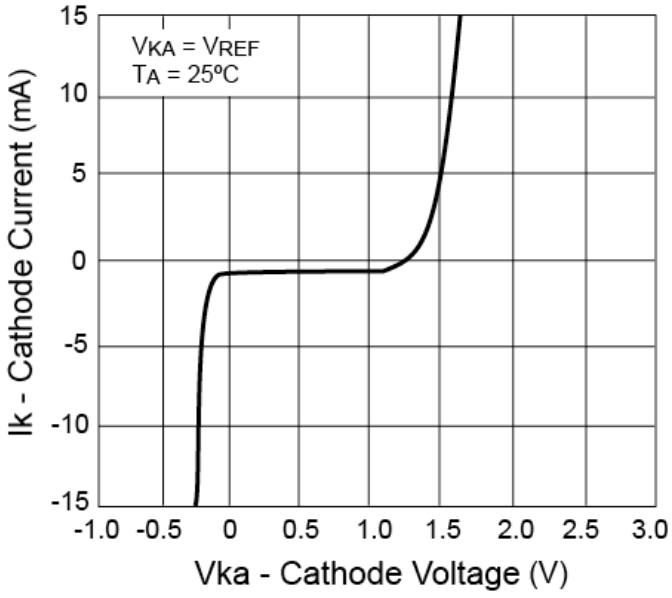
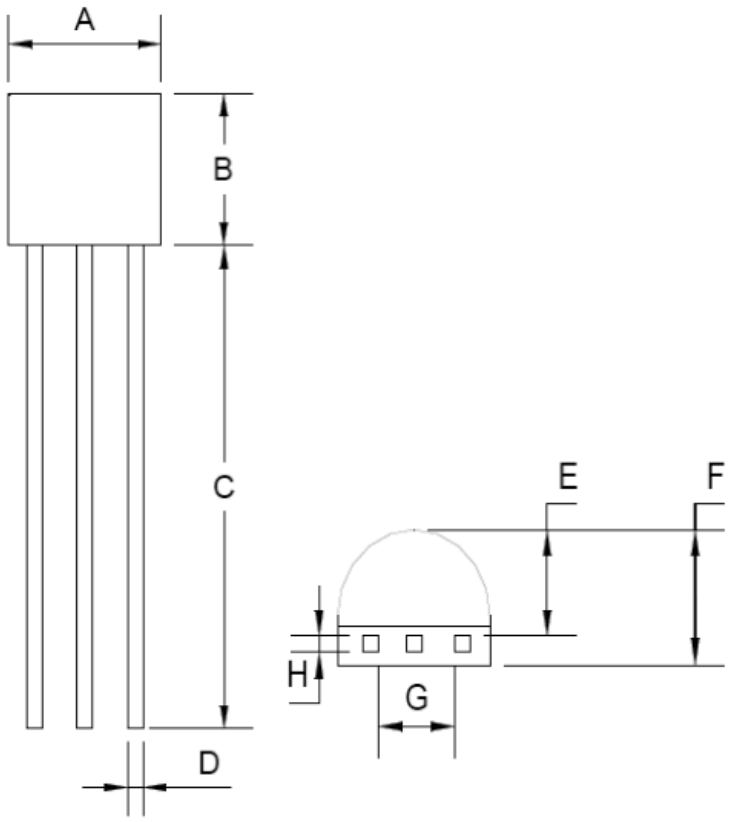



**Figure 20: Cathode Current vs. Cathode Voltage**

# TS431I

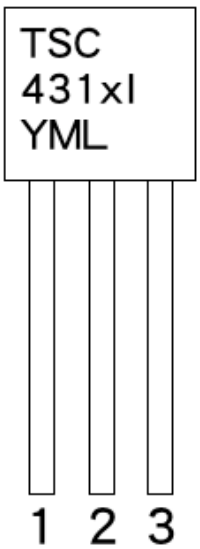
Adjustable Precision Shunt Regulator

## TO-92 Mechanical Drawing



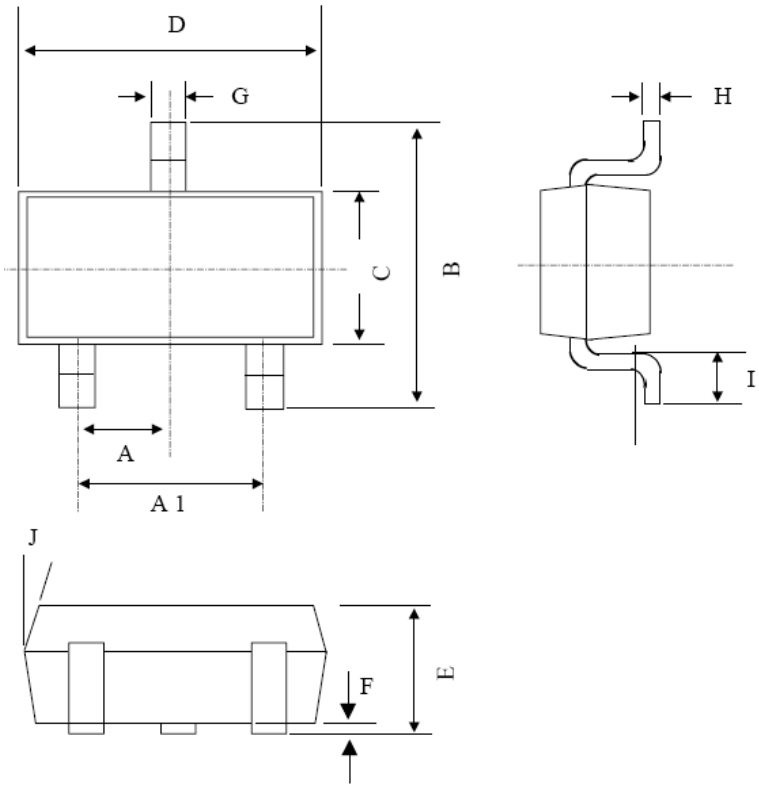

| TO-92 DIMENSION | | | | |
|---|---|---|---|---|
| DIM | MILLIMETERS | | INCHES | |
| | MIN | MAX | MIN | MAX |
| A | 4.30 | 4.70 | 0.169 | 0.185 |
| B | 4.30 | 4.70 | 0.169 | 0.185 |
| C | 14.30(typ) | | 0.563(typ) | |
| D | 0.43 | 0.49 | 0.017 | 0.019 |
| E | 2.19 | 2.81 | 0.086 | 0.111 |
| F | 3.30 | 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



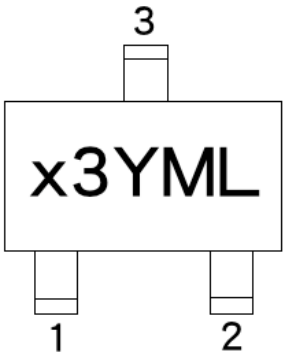

**X** = Tolerance Code
(**A** = ±1%, **B** = ±0.5%, **Blank** = ±2%,)
**Y** = Year Code
**M** = Month Code
(**A**=Jan, **B**=Feb, **C**=Mar, **D**=Apl, **E**=May, **F**=Jun, **G**=Jul, **H**=Aug, **I**=Sep, **J**=Oct, **K**=Nov, **L**=Dec)
**L** = Lot Code

## SOT-23 Mechanical Drawing



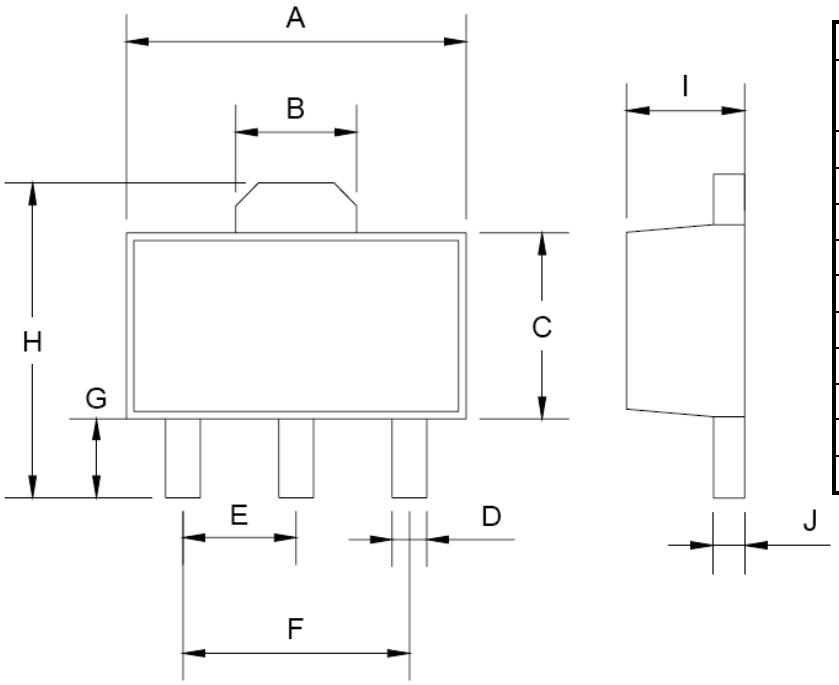

| SOT-23 DIMENSION | | | | |
|---|---|---|---|---|
| DIM | MILLIMETERS | | INCHES | |
| | MIN | MAX | MIN | MAX. |
| A | 0.95 BSC | | 0.037 BSC | |
| A1 | 1.9 BSC | | 0.074 BSC | |
| B | 2.60 | 3.00 | 0.102 | 0.118 |
| C | 1.40 | 1.70 | 0.055 | 0.067 |
| D | 2.80 | 3.10 | 0.110 | 0.122 |
| E | 1.00 | 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 | 5° | 10° | 5° | 10° |

## Marking Diagram



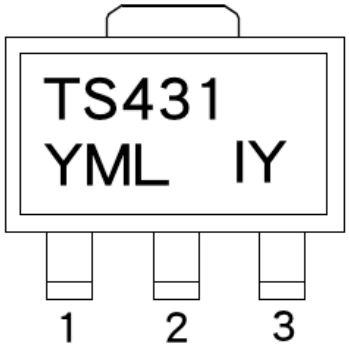

**X** = Device Code
(**A** = TS431AI, **B** = TS431BI, **C** = TS431I,)
**3** = SOT-23 package
**Y** = Year Code
**M** = Month Code
(**A**=Jan, **B**=Feb, **C**=Mar, **D**=Apl, **E**=May, **F**=Jun, **G**=Jul, **H**=Aug, **I**=Sep, **J**=Oct, **K**=Nov, **L**=Dec)
**L** = Lot Code

## SOT-89 Mechanical Drawing



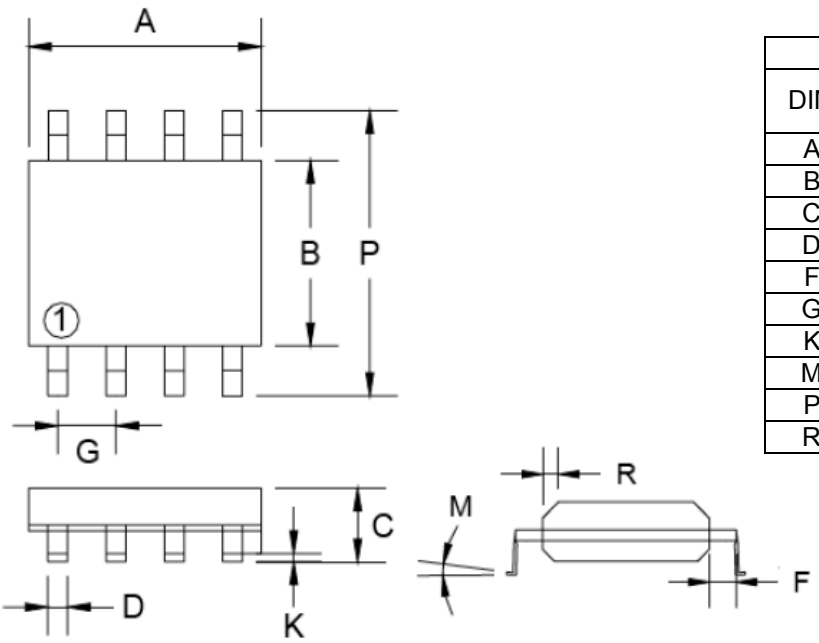

| SOT-89 DIMENSION | | | | |
|---|---|---|---|---|
| DIM | MILLIMETERS | | INCHES | |
| | MIN | MAX | MIN | MAX |
| A | 4.40 | 4.60 | 0.173 | 0.181 |
| B | 1.50 | 1.7 | 0.059 | 0.070 |
| C | 2.30 | 2.60 | 0.090 | 0.102 |
| D | 0.40 | 0.52 | 0.016 | 0.020 |
| E | 1.50 | 1.50 | 0.059 | 0.059 |
| F | 3.00 | 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



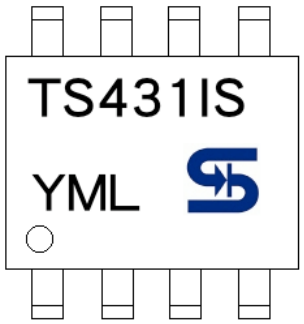

**Y** = Year Code
**M** = Month Code
(**A**=Jan, **B**=Feb, **C**=Mar, **D**=Apl, **E**=May, **F**=Jun, **G**=Jul, **H**=Aug, **I**=Sep, **J**=Oct, **K**=Nov, **L**=Dec)
**L** = Lot Code
**IY** = Package Code

## 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 | 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

## Notice

Specifications of the products displayed herein are subject to change without notice. TSC or anyone on its behalf, assumes no responsibility or liability for any errors or inaccuracies.

Information contained herein is intended to provide a product description only. No license, express or implied, to any intellectual property rights is granted by this document. Except as provided in TSC's terms and conditions of sale for such products, TSC assumes no liability whatsoever, and disclaims any express or implied warranty, relating to sale and/or use of TSC products including liability or warranties relating to fitness for a particular purpose, merchantability, or infringement of any patent, copyright, or other intellectual property right.

The products shown herein are not designed for use in medical, life-saving, or life-sustaining applications. Customers using or selling these products for use in such applications do so at their own risk and agree to fully indemnify TSC for any damages resulting from such improper use or sale.