# TS432I

## Adjustable Precision Shunt Regulator

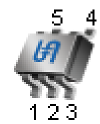
**TO-92**


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

**SOT-23**


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

**SOT-25**




**Pin Definition:**
1. N/C
2. N/C *
3. Cathode
4. Reference
5. Anode

* (pin 2 is connect to substrate and must be connected to Anode or left open)

## General Description

The TS432I/432AI/TS432BI is a three-terminal adjustable shunt regulator with specified thermal stability. The output voltage may be set to any value between Vref (approximately 1.24V) and 18V with two external resistors. The TS432I/432AI/TS432BI has a typical output impedance of 0.05Ω. Active output circuitry provides a very sharp turn-on characteristic, making the TS432I/432AI/TS432BI excellent replacement for zener diode in many applications.

## Features

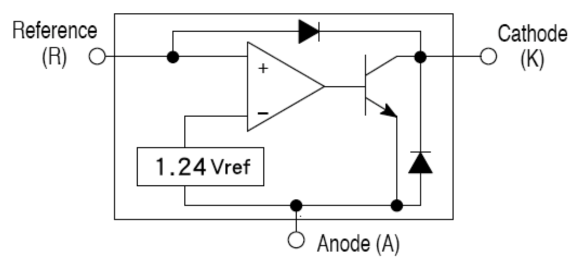
- Precision Reference Voltage
  TS432I – 1.24V±2%
  TS432AI – 1.24V±1%
  TS432BI – 1.24V±0.5%
- Minimum Cathode Current for Regulation: 20uA(typ.)
- Equivalent Full Range Temp. Coefficient: 50ppm/ °C
- Programmable Output Voltage up to 18V
- Fast Turn-On Response
- Sink Current Capability of 80uA to 100mA
- Low Dynamic Output Impedance: 0.2Ω
- Low Output Noise

## Ordering Information

| Part No. | Package | Packing |
|---|---|---|
| TS432**x**IT B0 | TO-92 | 1Kpcs / Bulk |
| TS432**x**IT A3 | TO-92 | 2Kpcs / Ammo |
| TS432**x**IX RF | SOT-23 | 3Kpcs / 7" Reel |
| TS432**x**IX5 RF | SOT-25 | 3Kpcs / 7" Reel |

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

## Block Diagram




## Application

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

## Absolute Maximum Rating (Ta = 25 oC unless otherwise noted)

| Parameter | | Symbol | Limit | Unit |
|---|---|---|---|---|
| Cathode Voltage (Note 1) | | Vka | 18 | V |
| Continuous Cathode Current Range | | Ik | 100 | mA |
| Reference Input Current Range | | Iref | 3 | mA |
| Power Dissipation | TO-92 | Pd | 0.625 | W |
| | SOT-23 | | 0.35 | |
| | SOT-25 | | 0.35 | |
| Junction Temperature | | $T_J$ | +150 | $^oC$ |
| Operation Temperature Range | | $T_{OPER}$ | -40 ~ +105 | $^oC$ |
| Storage Temperature Range | | $T_{STG}$ | -65 ~ +150 | $^oC$ |

Note 1: Voltage values are with respect to the anode terminal unless otherwise noted.
Note 2: Rating apply to ambient temperature at $25^oC$

## Recommend Operating Condition

| Parameter | Symbol | Limit | Unit |
|---|---|---|---|
| Cathode Voltage (Note 1) | Vka | 18 | V |
| Continuous Cathode Current Range | Ik | 100 | mA |

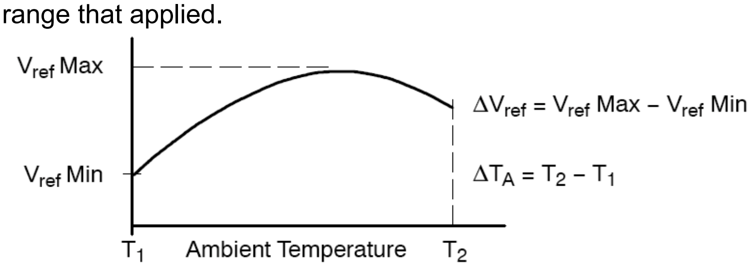
## Recommend Operating Condition

| Parameter | | Symbo | Test Conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|---|
| Reference voltage | TS432I | Vref | Vka =Vref, Ik=10mA (Figure 1) Ta=25 °C | 1.215 | 1.240 | 1.264 | V |
| | TS432AI | | | 1.227 | | 1.252 | |
| | TS432BI | | | 1.233 | | 1.246 | |
| Deviation of reference input voltage | | ΔVref | Vka =Vref, Ik=10mA Ta= full range (Figure 1) | -- | 10 | 25 | mV |
| Radio of change in Vref to change in cathode Voltage | | ΔVref/ΔVka | Ika=10mA, Vka = 18V to Vref (Figure 2) | -- | -1.0 | -2.7 | mV/V |
| Reference Input current | | Iref | R1=10KΩ, R2=∞, Ika=10mA Ta= full range (Figure 2) | -- | 0.25 | 0.5 | uA |
| Deviation of reference input current, over temp. | | ΔIref | R1=10KΩ, R2=∞, Ika=10mA Ta= full range (Figure 2) | -- | 0.04 | 0.08 | uA |
| Off-state Cathode Current | | Ika(off) | Vref=0V (Figure 3), Vka=18V | -- | 0.125 | 0.5 | uA |
| Dynamic Output Impedance | | \|Zka\| | f<1KHz, Vka=Vref Ika=1mA to 100mA (Figure 1) | -- | 0.2 | 0.4 | Ω |
| Minimum operating cathode current | | Ika(min) | Vka=Vref (Figure 1) | -- | 60 | 80 | uA |

* 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 Vref Min. or Vref Max occurs at the lower ambient temperature. Example: ΔVref=7.2mV and the slope is postive, Vref=1.241V at 25°C, ΔT=125 °C

$$\alpha V_{ref}\left(\frac{ppm}{^\circ C}\right) = \frac{\frac{0.0072}{1.241} \times 10^6}{125} = 46\ ppm/^\circ C$$

* The dynamic impedance $Z_{KA}$ 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

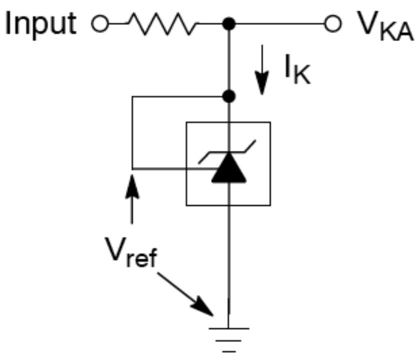
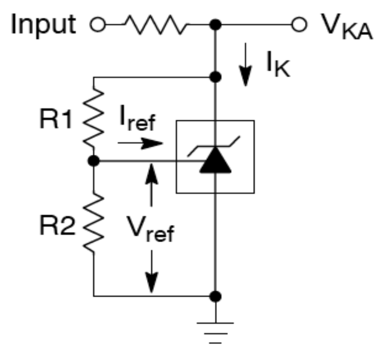



**Figure 1: Vka = Vref**




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

**Figure 2: Vka > Vref**

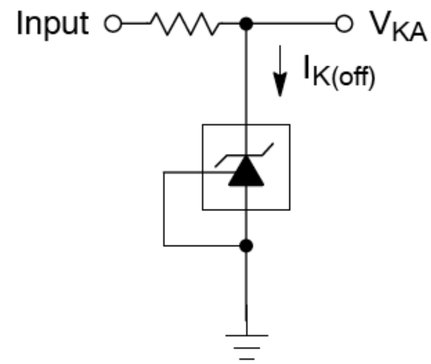



**Figure 3: Off-State Current**

## Additional Information – Stability

When The TS432I/432AI/432BI is used as a shunt regulator, there are two options for selection of $C_L$, are recommended for optional stability:

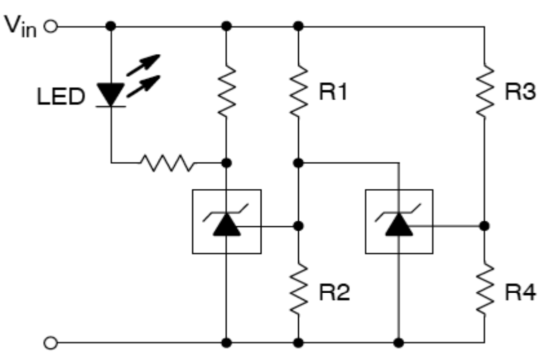
A) No load capacitance across the device, decouple at the load.

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

The reason for this is that TS432I/432AI/432BI 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 TS432I/432AI/432BI 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

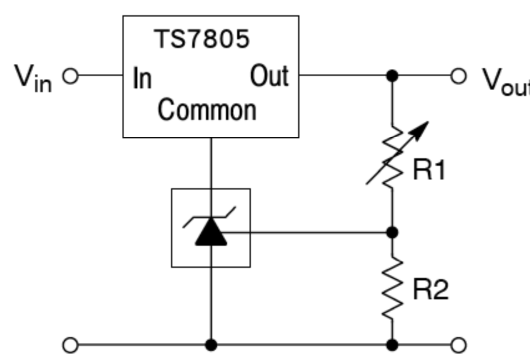



L.E.D. indicator is 'ON' when $V_{in}$ is between the upper and lower limits,

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

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

**Figure 4: Voltage Monitor**

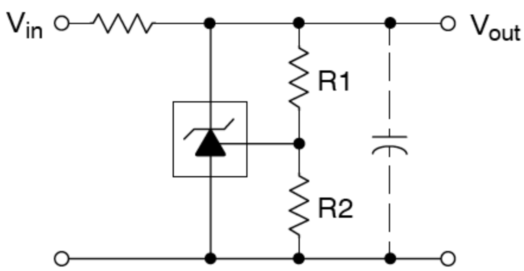



$$V_{out} = \left(1 + \frac{R1}{R2}\right) V_{ref}$$

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

**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**

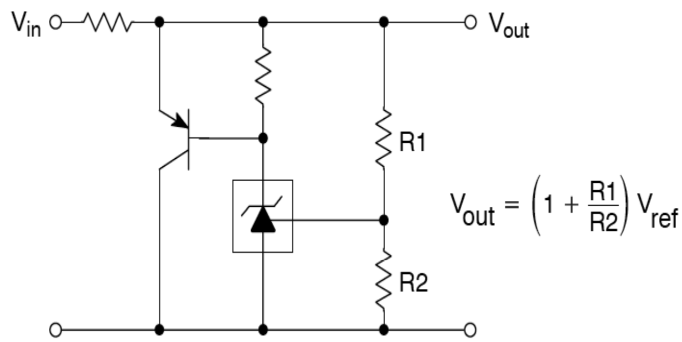
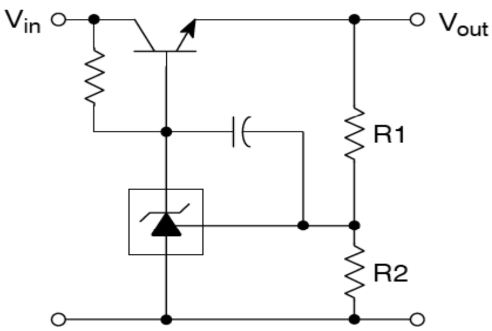


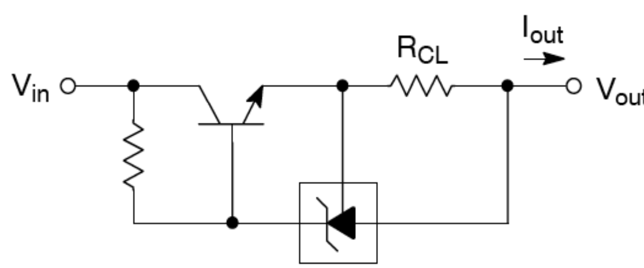

**Figure 7: High Current Shunt Regulator**




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

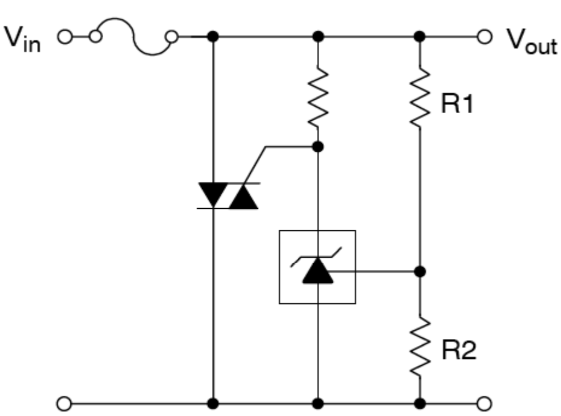
$$V_{out(min)} = V_{ref} + V_{be} \approx 2.0\ V$$

**Figure 8: Series Pass Regulator**



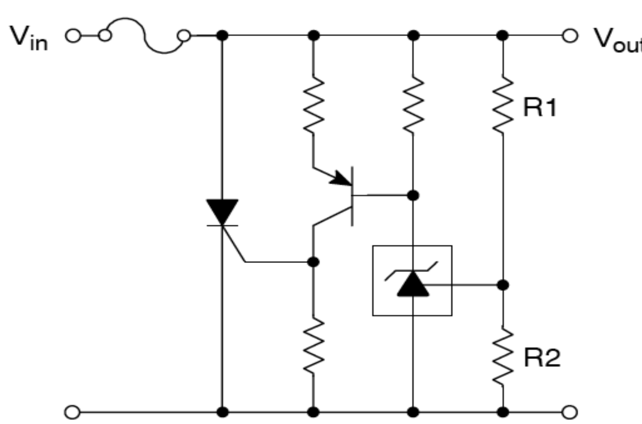

$$I_{out} = \frac{V_{ref}}{R_{CL}}$$

**Figure 9: Constant Current Source**




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

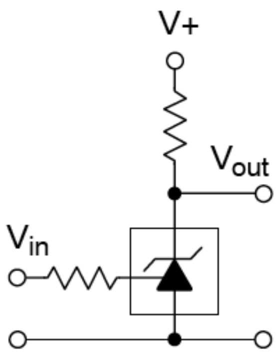
**Figure 10: TRIAC Crowbar**




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

**Figure 11: SCR Crowbar**

## Applications Examples (Continue)




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

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

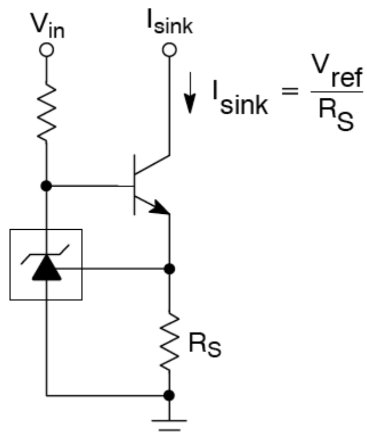
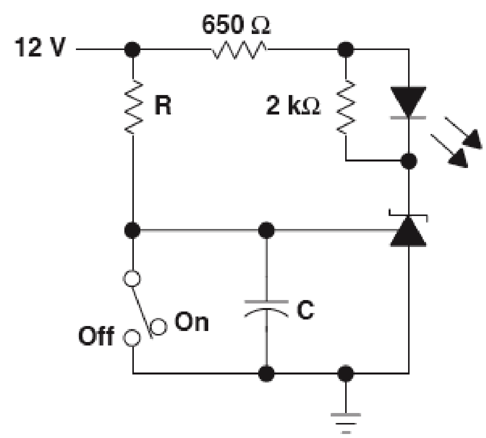


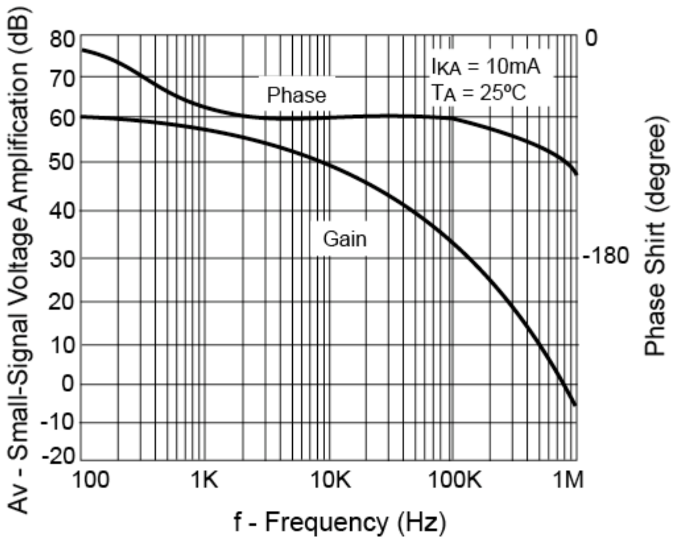

**Figure 13: Constant Current Sink**

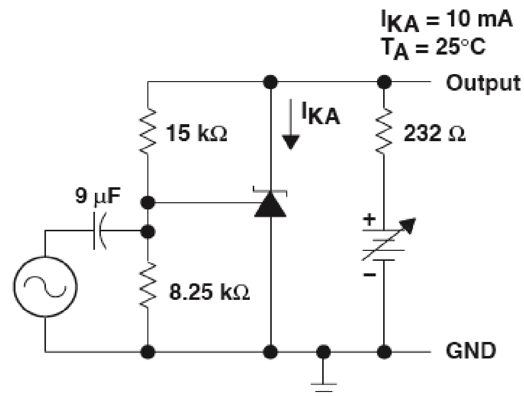



$$Delay = R \times C \times l_n\left(\frac{12\ V}{12\ V - V_{ref}}\right)$$

**Figure 14: Delay Timer**

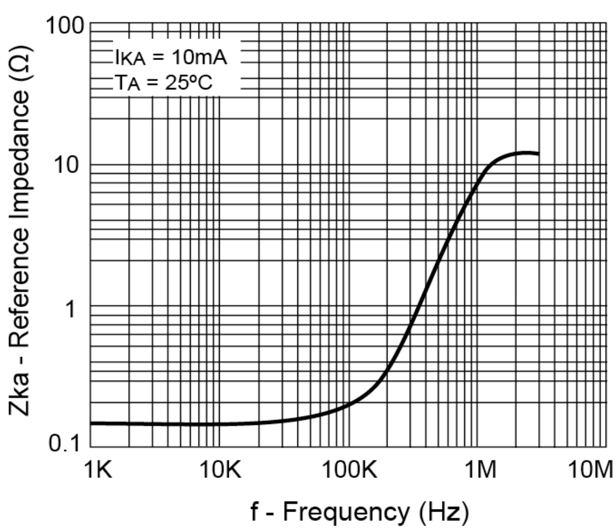
## Typical Performance Characteristics

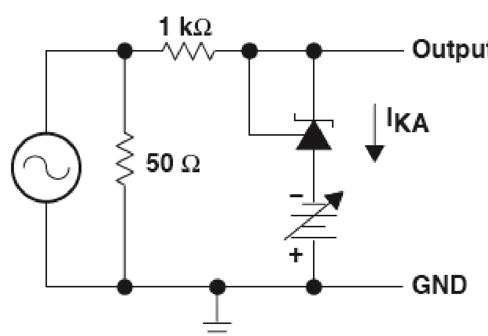



**Test Circuit for Voltage Amplification**

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

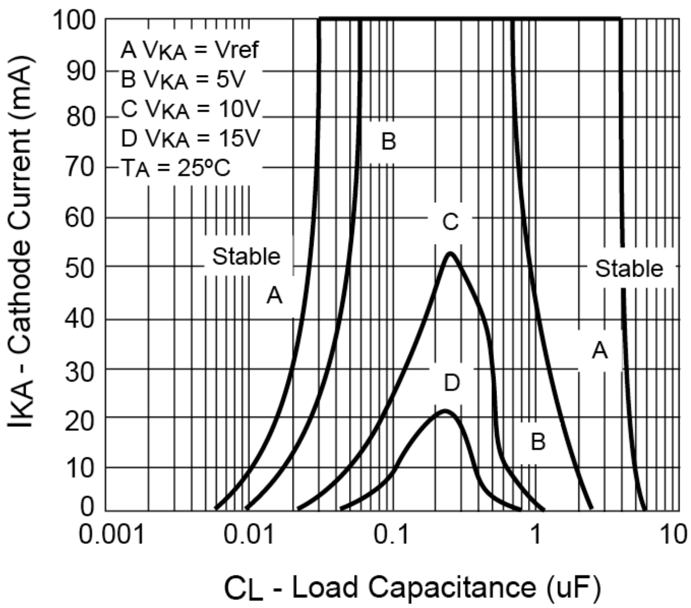


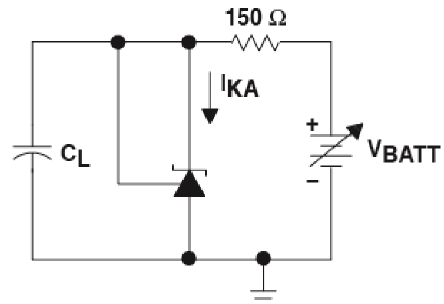




**Test Circuit for Reference Impedance**

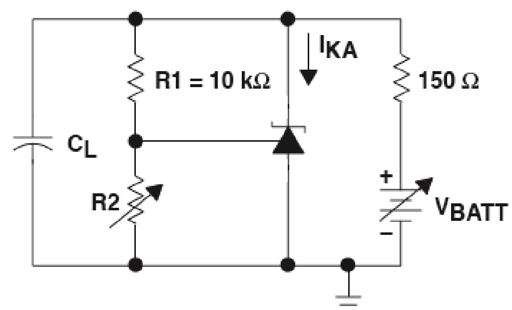
**Figure 15: Reference Impedance vs. Frequency**

## Typical Performance Characteristics



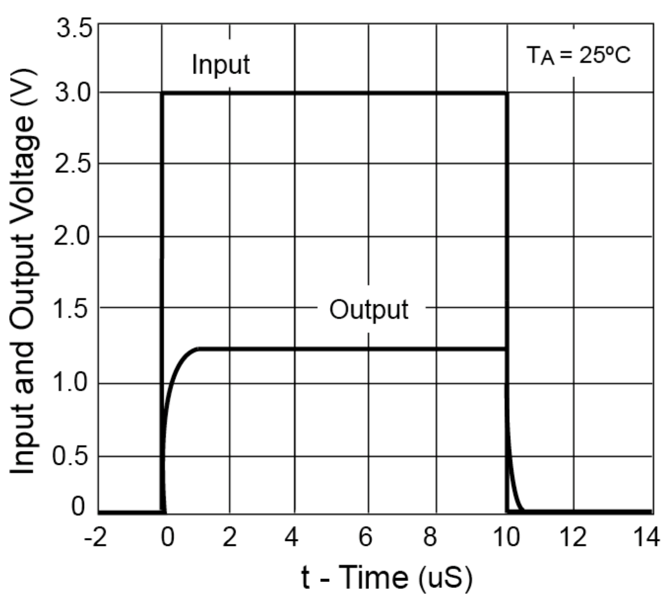

Test Circuit for Curve A

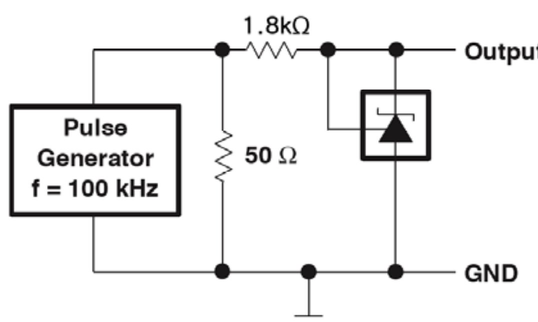



Test Circuit for Curve B, C and D

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

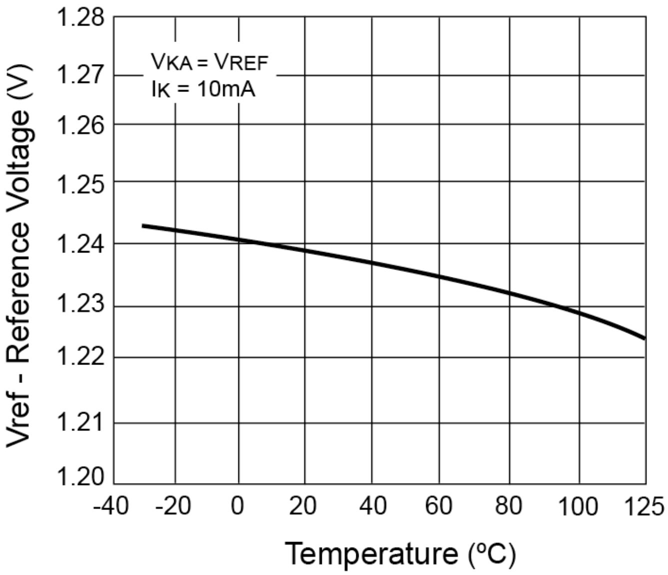



**Figure 18: Reference Voltage vs. Temperature**

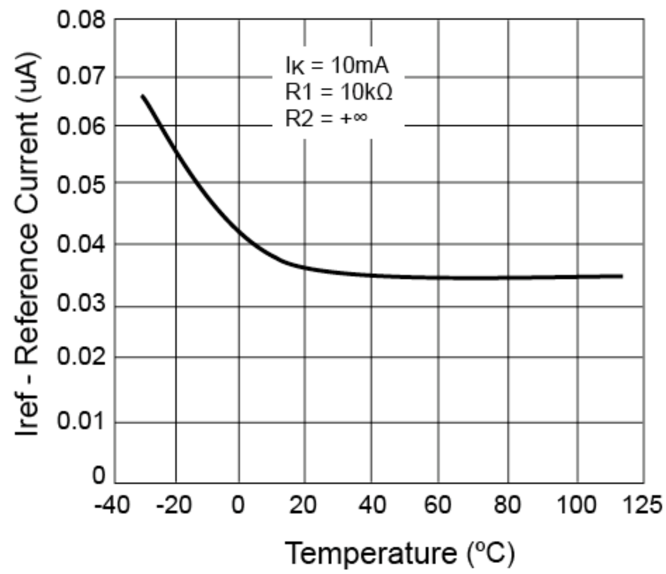



**Figure 19: Reference Current vs. Temperature**

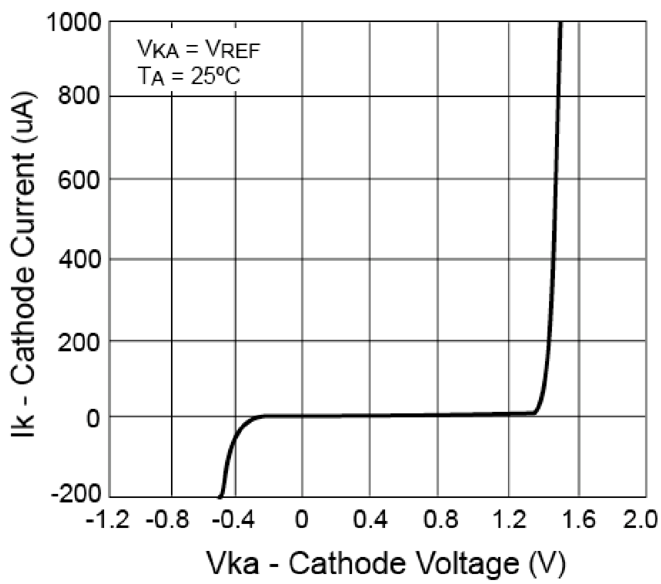
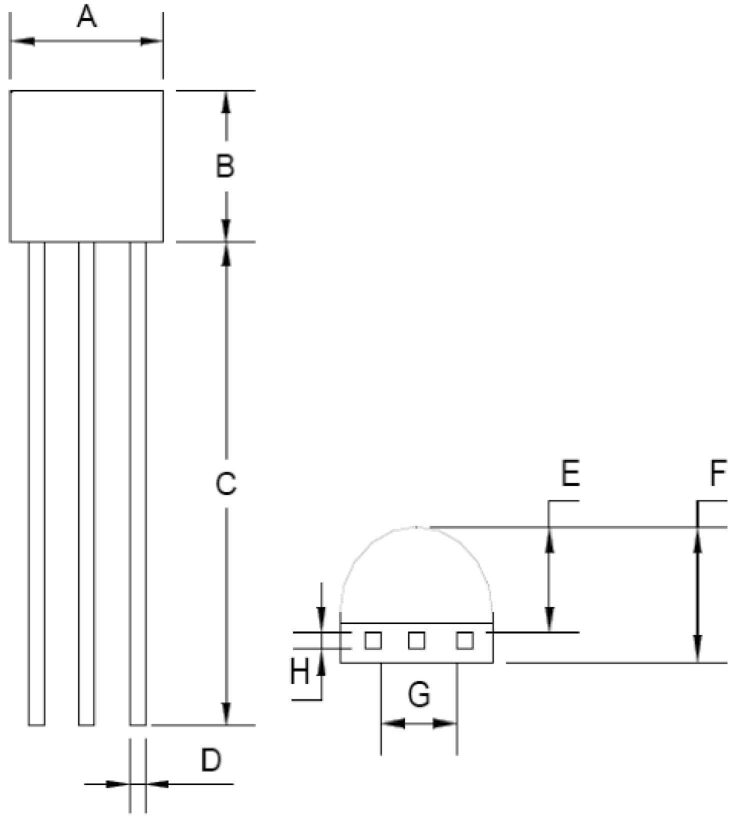


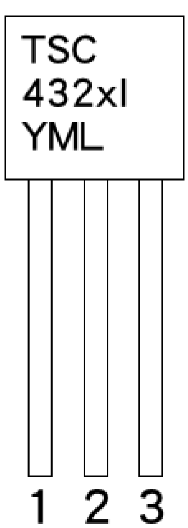

**Figure 20: Cathode Current vs. Cathode Voltage**

## TO-92 Mechanical Drawing



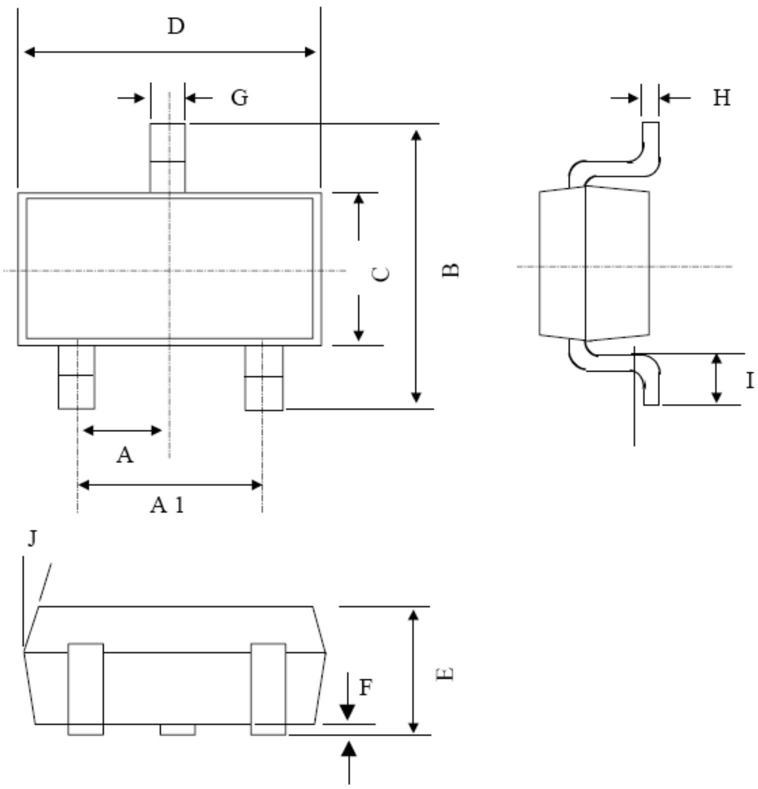

| TO-92 DIMENSION | | | | |
|---|---|---|---|---|
| DIM | MILLIMETERS | | INCHES | |
| | MIN | MAX | MIN | MAX |
| A | 4.30 | 4.70 | 0.169 | 0.185 |
| B | 4.30 | 4.70 | 0.169 | 0.185 |
| C | 14.30(typ) | | 0.563(typ) | |
| D | 0.43 | 0.49 | 0.017 | 0.019 |
| E | 2.19 | 2.81 | 0.086 | 0.111 |
| F | 3.30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



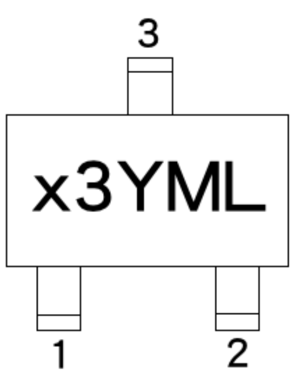

**X** = Tolerance Code
(**A** = ±1%, **B** = ±0.5%, **Blank** = ±2%,)
**Y** = Year Code
**M** = Month Code
(**A**=Jan, **B**=Feb, **C**=Mar, **D**=Apl, **E**=May, **F**=Jun, **G**=Jul, **H**=Aug, **I**=Sep, **J**=Oct, **K**=Nov, **L**=Dec)
**L** = Lot Code

## SOT-23 Mechanical Drawing



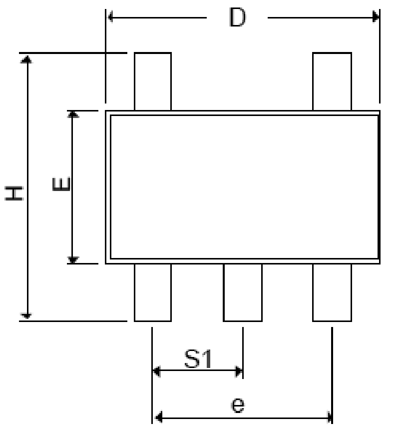

| SOT-23 DIMENSION | | | | |
|---|---|---|---|---|
| DIM | MILLIMETERS | | INCHES | |
| | MIN | MAX | MIN | MAX. |
| A | 0.95 BSC | | 0.037 BSC | |
| A1 | 1.9 BSC | | 0.074 BSC | |
| B | 2.60 | 3.00 | 0.102 | 0.118 |
| C | 1.40 | 1.70 | 0.055 | 0.067 |
| D | 2.80 | 3.10 | 0.110 | 0.122 |
| E | 1.00 |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

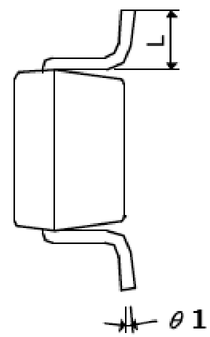
### Marking Diagram




**X** = Device Code
(**D** = TS432AI, **E** = TS432BI, **F** = TS432I,)
**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-25 Mechanical Drawing

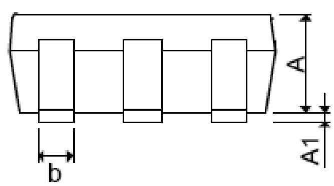


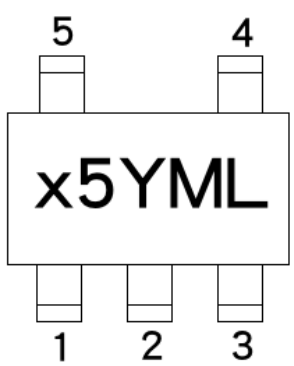

| DIM | MILLIMETERS | | INCHES | |
|---|---|---|---|---|
| | MIN | MAX | MIN | MAX. |
| A+A1 | 0.09 | 1.25 | 0.0354 | 0.0492 |
| B | 0.30 | 0.50 | 0.0118 | 0.0197 |
| C | 0.09 | 0.25 | 0.0035 | 0.0098 |
| D | 2.70 | 3.10 | 0.1063 | 0.1220 |
| E | 1.40 | 1.80 | 0.0551 | 0.0709 |
| E | 1.90 BSC | | 0.0748 BSC | |
| H | 2.40 | 3.00 | 0.09449 | 0.1181 |
| L | 0.35 BSC | | 0.0138 BSC | |
| Θ1 | 0º | 10º | 0º | 10º |
| S1 | 0.95 BSC | | 0.0374 BSC | |

SOT-25 DIMENSION

Front View




## Marking Diagram




**X** = Device Code
(**D** = TS432AI, **E** = TS432BI, **F** = TS432I,)
**5** = SOT-25 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

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