

Programmable Voltage Reference

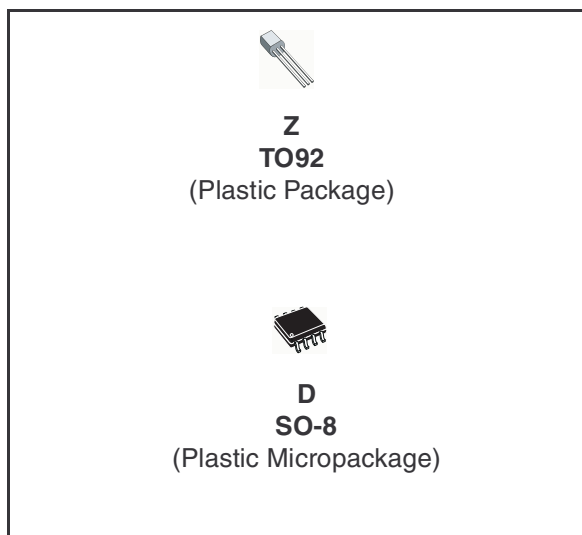
- Adjustable output voltage: 2.5 to 36V
- Sink current capability: 1 to 100mA
- Typical output impedance: 0.22Ω
- 1% and 2% voltage precision

Description

The TL431 is a programmable shunt voltage reference with guaranteed temperature stability over the entire temperature range of operation.

The output voltage may be set to any value between 2.5V and 36V with two external resistors.

The TL431 operates with a wide current range from 1 to 100mA with a typical dynamic impedance of 0.22Ω.



Order Codes

| Part Number | Temperature Range | Package | Packing | Marking |
|----------------------|-------------------|-------------------------------|---------------------|---------|
| TL431CD/CDT | 0, +70°C | SO-8 | Tube or Tape & Reel | 431C |
| TL431ACD/ACDT | | | | 431AC |
| TL431CZ/CZT/CZ-AP | | TO92 | | TL431C |
| TL431ACZ/ACZT/ACZ-AP | | | | TL431AC |
| TL431ID/IDT | -40, + 105°C | SO-8 | | 431I |
| TL431AID/AIDT | | | | 431AI |
| TL431IZ/IZT/IZ-AP | | TO92 | | TL431I |
| TL431AIZ/AIZT/AIZ-AP | | | | TL431AI |
| TL431IYD/IYDT | | SO-8 (automotive grade level) | 431IY | |
| TL431AIYD/AIYDT | | | 431AIY | |

1 Pin Diagrams

Figure 1. T092 pin connections (top view)

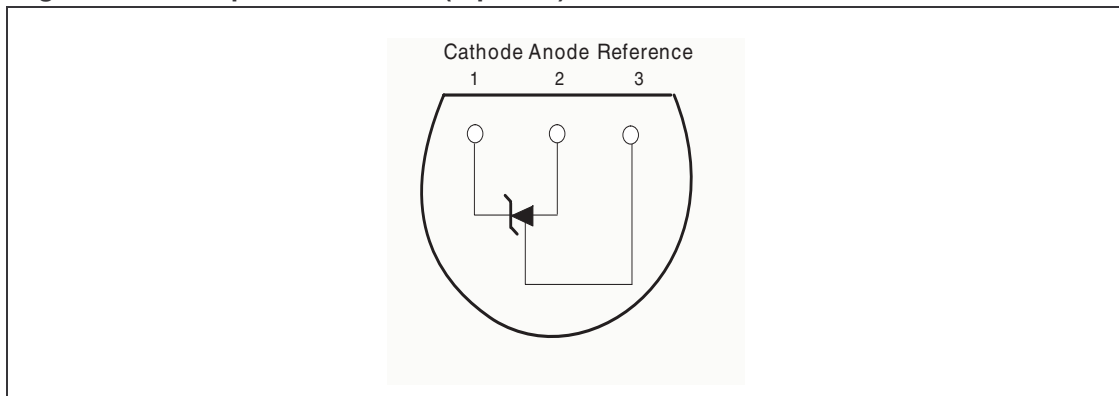
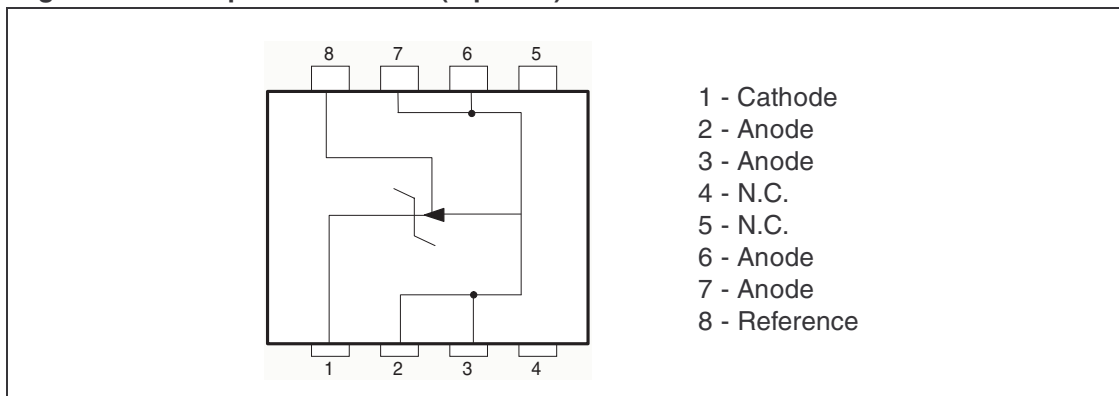


Figure 2. SO-8 pin connections (top view)



2 Absolute Maximum Ratings

Table 1. Key parameters and their absolute maximum ratings

| Symbol | Parameter | Value | Unit |
|-----------|--|--------------|------|
| V_{KA} | Cathode to Anode Voltage | 37 | V |
| I_k | Continuous Cathode Current Range | -100 to +150 | mA |
| I_{ref} | Reference Input Current Range | -0.05 to +10 | mA |
| P_d | Power Dissipation ⁽¹⁾ TO92 SO-8 batwing | 625 960 | mW |
| T_{stg} | Storage Temperature Range | -65 to +150 | °C |

1. P_d is calculated with $T_{amb} = +25^{\circ}\text{C}$, $T_j = +150^{\circ}\text{C}$ and
 $R_{thja} = 200^{\circ}\text{C/W}$ for TO92 package
 $R_{thja} = 130^{\circ}\text{C/W}$ for SO-8 batwing package

Table 2. Operating conditions

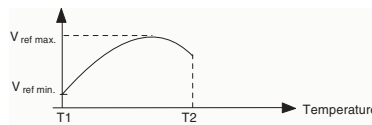
| Symbol | Parameter | Value | Unit |
|------------|--|-------------------------|------|
| V_{KA} | Cathode to Anode Voltage | V_{ref} to 36 | V |
| I_k | Cathode Current | 1 to 100 | mA |
| T_{oper} | Operating Free-air Temperature Range TL431C/AC TL431I/AI | 0 to +70 -40 to +105 | °C |

3 Electrical Characteristics

Table 3. $T_{amb} = 25^{\circ}\text{C}$ (unless otherwise specified)

| Symbol | Parameter | TL431C | | | TL431AC | | | Unit |
|--|---|---------------|------------|---------------|---------------|------------|---------------|---------------|
| | | Min. | Typ. | Max. | Min. | Typ. | Max. | |
| V_{ref} | Reference Input Voltage $V_{KA} = V_{ref}$, $I_k = 10\text{ mA}$, $T_{amb} = 25^{\circ}\text{C}$ $T_{min} \leq T_{amb} \leq T_{max}$ | 2.44 2.423 | 2.495 | 2.55 2.567 | 2.47 2.453 | 2.495 | 2.52 2.537 | V |
| ΔV_{ref} | Reference Input Voltage Deviation Over Temperature Range ⁽¹⁾ $V_{KA} = V_{ref}$, $I_k = 10\text{ mA}$, $T_{min} \leq T_{amb} \leq T_{max}$ | | 3 | 17 | | 3 | 15 | mV |
| $\frac{\Delta V_{ref}}{\Delta V_{ka}}$ | Ratio of Change in Reference Input Voltage to Change in Cathode to Anode Voltage $I_k = 10\text{ mA}$ - $\Delta V_{KA} = 10\text{ V}$ to V_{ref} $\Delta V_{KA} = 36\text{ V}$ to 10 V | | -1.4 -1 | -2.7 -2 | | -1.4 -1 | -2.7 -2 | mV/V |
| I_{ref} | Reference Input Current $I_k = 10\text{ mA}$, $R1 = 10\text{ k}\Omega$, $R2 = \infty$ $T_{amb} = 25^{\circ}\text{C}$ $T_{min} \leq T_{amb} \leq T_{max}$ | | 1.8 | 4 5.2 | | 1.8 | 4 5.2 | μA |
| ΔI_{ref} | Reference Input Current Deviation Over Temperature Range $I_k = 10\text{ mA}$, $R1 = 10\text{ k}\Omega$, $R2 = \infty$ $T_{min} \leq T_{amb} \leq T_{max}$ | | 0.4 | 1.2 | | 0.4 | 1.2 | μA |
| I_{min} | Minimum Cathode Current for Regulation $V_{KA} = V_{ref}$ | | 0.5 | 1 | | 0.5 | 0.6 | mA |
| I_{off} | Off-State Cathode Current | | 2.6 | 1000 | | 2.6 | 1000 | nA |
| $ Z_{KA} $ | Dynamic Impedance ⁽²⁾ $V_{KA} = V_{ref}$, $\Delta I_k = 1$ to 100 mA , $f \leq 1\text{ kHz}$ | | 0.22 | 0.5 | | 0.22 | 0.5 | Ω |

1. ΔV_{ref} is defined as the difference between the maximum and minimum values obtained over the full temperature range.
 $\Delta V_{ref} = V_{ref\ max.} - V_{ref\ min.}$

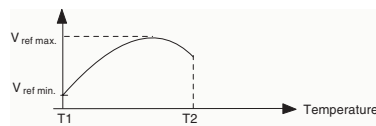


2. The dynamic Impedance is defined as $|Z_{KA}| = \frac{\Delta V_{KA}}{\Delta I_k}$

Table 4. $T_{amb} = 25^{\circ}\text{C}$ (unless otherwise specified)

| Symbol | Parameter | TL431I | | | TL431AI | | | Unit |
|--|---|--------------|------------|--------------|--------------|------------|--------------|---------------|
| | | Min. | Typ. | Max. | Min. | Typ. | Max. | |
| V_{ref} | Reference Input Voltage $V_{KA} = V_{ref}$, $I_k = 10\text{ mA}$, $T_{amb} = 25^{\circ}\text{C}$ $T_{min} \leq T_{amb} \leq T_{max}$ | 2.44 2.41 | 2.49 5 | 2.55 2.58 | 2.47 2.44 | 2.49 5 | 2.52 2.55 | V |
| ΔV_{ref} | Reference Input Voltage Deviation Over Temperature Range ⁽¹⁾ $V_{KA} = V_{ref}$, $I_k = 10\text{ mA}$, $T_{min} \leq T_{amb} \leq T_{max}$ | | 7 | 30 | | 7 | 30 | mV |
| $\frac{\Delta V_{ref}}{\Delta V_{ka}}$ | Ratio of Change in Reference Input Voltage to Change in Cathode to Anode Voltage $I_k = 10\text{ mA}$, $\Delta V_{KA} = 10\text{ V to } V_{ref}$ $\Delta V_{KA} = 36\text{ V to } 10\text{ V}$ | | -1.4 -1 | -2.7 -2 | | -1.4 -1 | -2.7 -2 | mV/V |
| I_{ref} | Reference Input Current $I_k = 10\text{ mA}$, $R1 = 10\text{ k}\Omega$, $R2 = \infty$ $T_{amb} = 25^{\circ}\text{C}$ $T_{min} \leq T_{amb} \leq T_{max}$ | | 1.8 | 4 6.5 | | 1.8 | 4 6.5 | μA |
| ΔI_{ref} | Reference Input Current Deviation Over Temperature Range $I_k = 10\text{ mA}$, $R1 = 10\text{ k}\Omega$, $R2 = \infty$ $T_{min} \leq T_{amb} \leq T_{max}$ | | 0.8 | 2.5 | | 0.8 | 1.2 | μA |
| I_{min} | Minimum Cathode Current for Regulation $V_{KA} = V_{ref}$ | | 0.5 | 1 | | 0.5 | 0.7 | mA |
| I_{off} | Off-State Cathode Current | | 2.6 | 1000 | | 2.6 | 1000 | nA |
| $ Z_{KA} $ | Dynamic Impedance ⁽²⁾ $V_{KA} = V_{ref}$, $\Delta I_k = 1\text{ to }100\text{ mA}$, $f \leq 1\text{ kHz}$ | | 0.22 | 0.5 | | 0.22 | 0.5 | Ω |

- ΔV_{ref} is defined as the difference between the maximum and minimum values obtained over the full temperature range.
 $\Delta V_{ref} = V_{ref\ max.} - V_{ref\ min.}$



- The dynamic Impedance is defined as $|Z_{KA}| = \frac{\Delta V_{KA}}{\Delta I_k}$

Figure 3. Test circuit for $V_{KA} = V_{REF}$

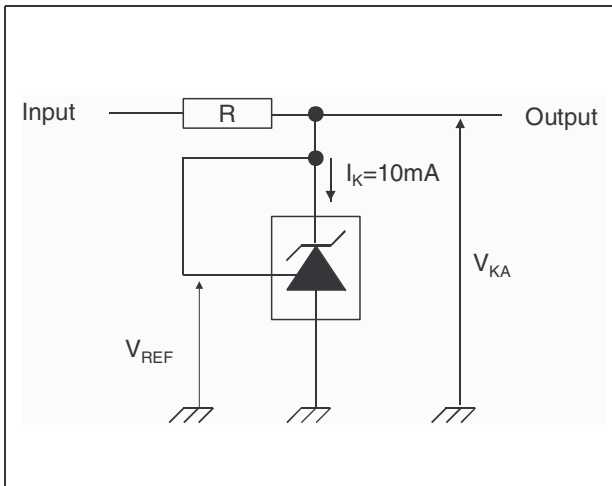


Figure 4. Test circuit for $V_{KA} = V_{REF}$

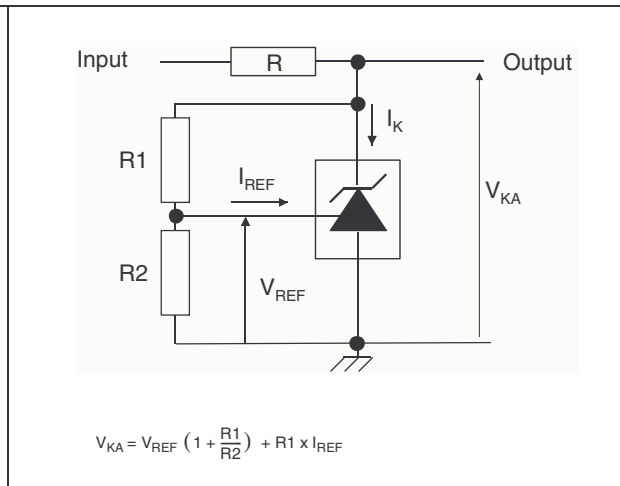


Figure 5. Test circuit for I_{OFF}

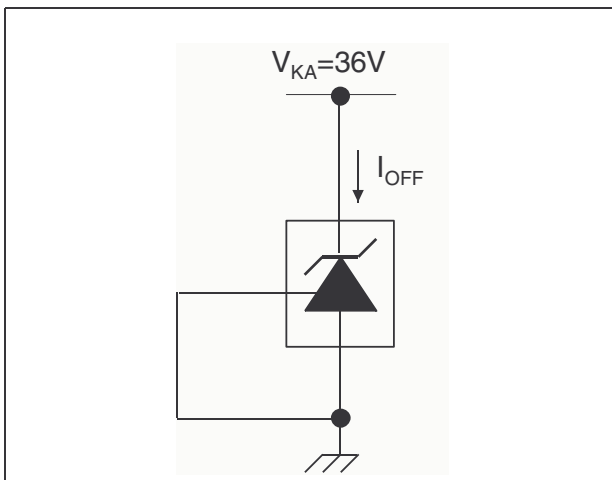


Figure 6. Test circuit for phase margin and voltage gain

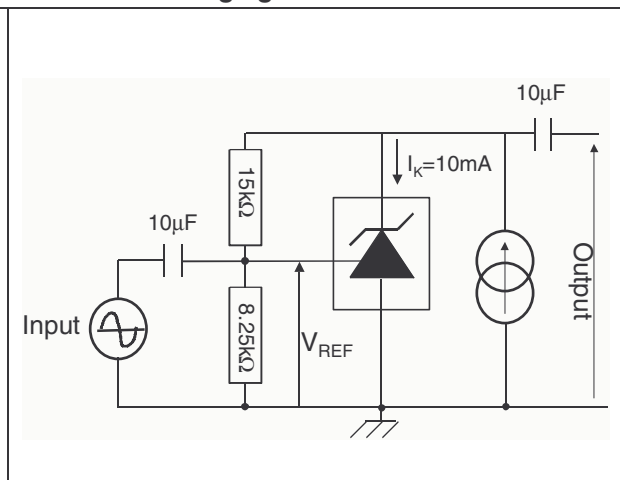


Figure 7. Block diagram of TL431

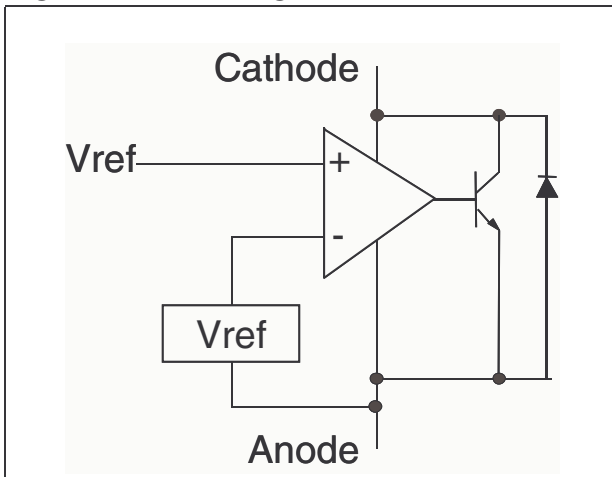


Figure 8. Test circuit for response time

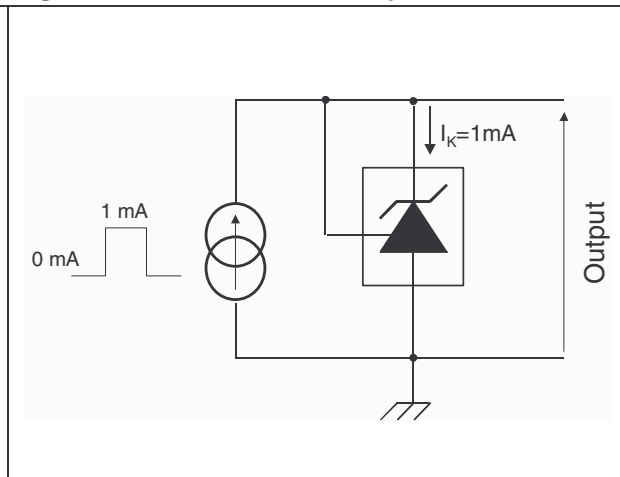


Figure 9. Reference voltage vs. temp.

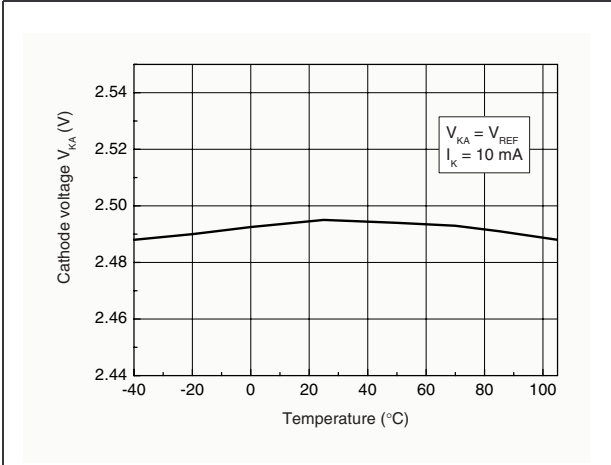


Figure 10. Reference voltage vs. cathode current

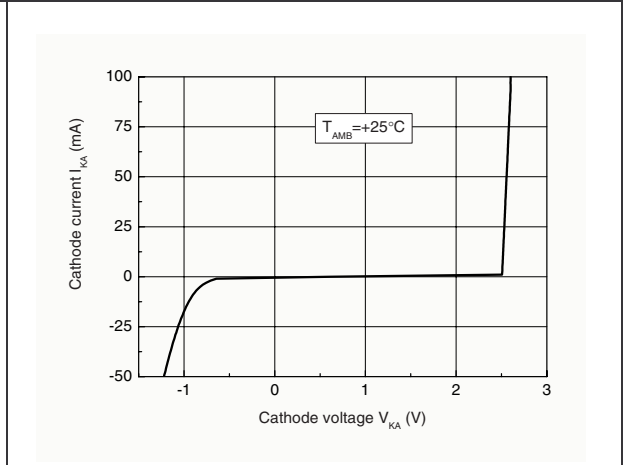


Figure 11. Reference voltage vs. cathode current Figure 12. Reference current vs. temp.

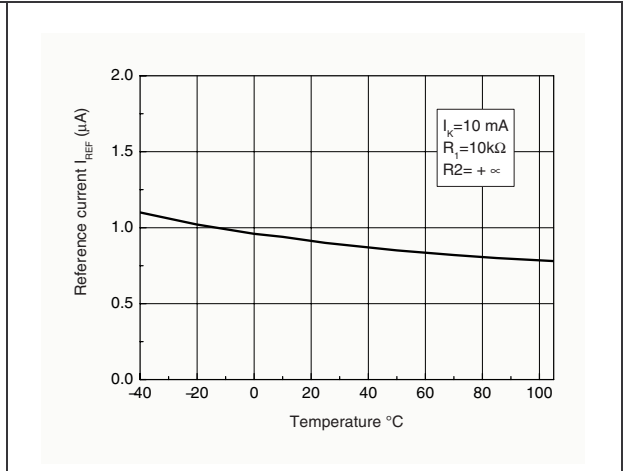
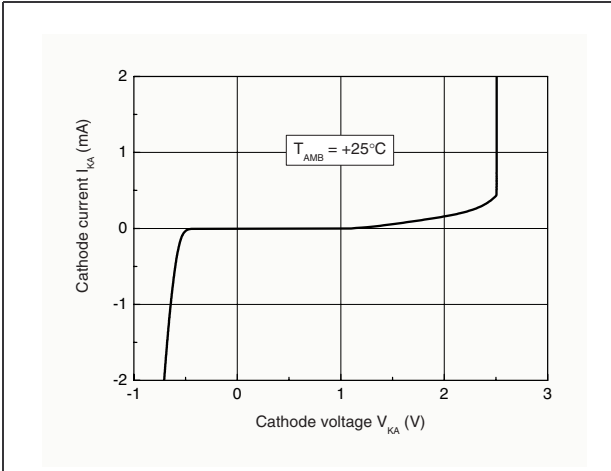


Figure 13. Off-state cathode current vs. temp. Figure 14. Ratio of change in V_{REF} to change in V_{KA} vs. temp.

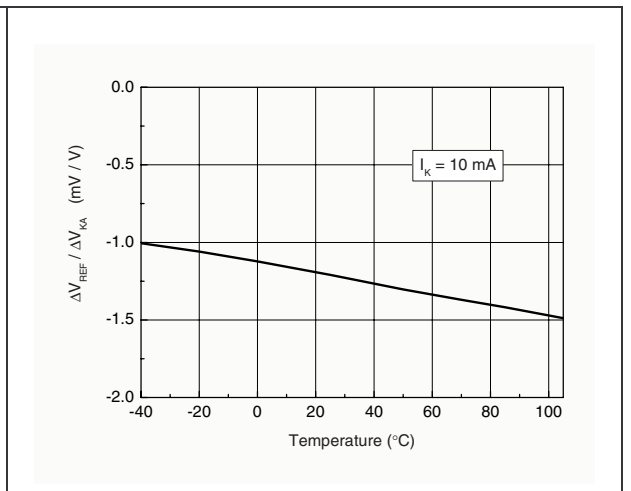
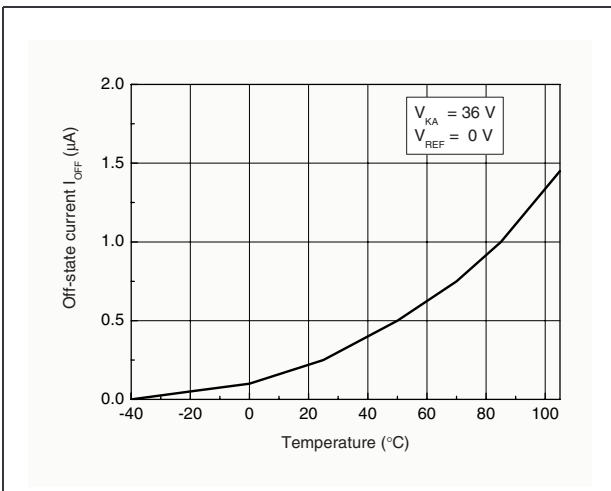


Figure 15. Static impedance R_{KA} vs. temp.

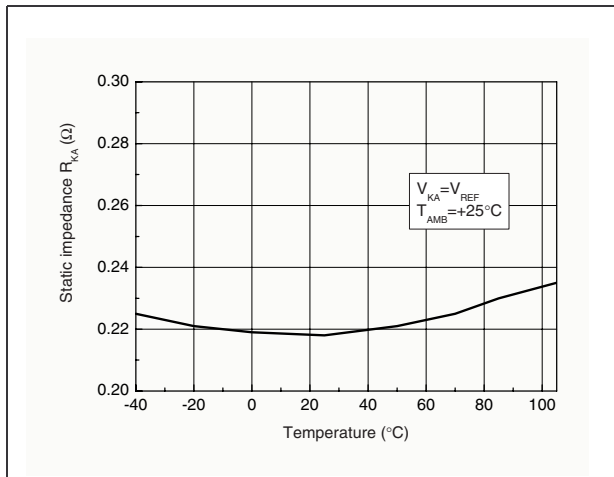


Figure 16. Maximum operating current vs. temp.

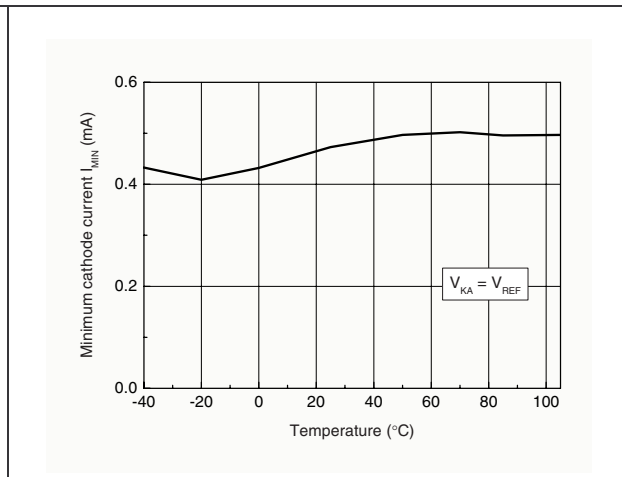


Figure 17. Gain & phase vs. frequency

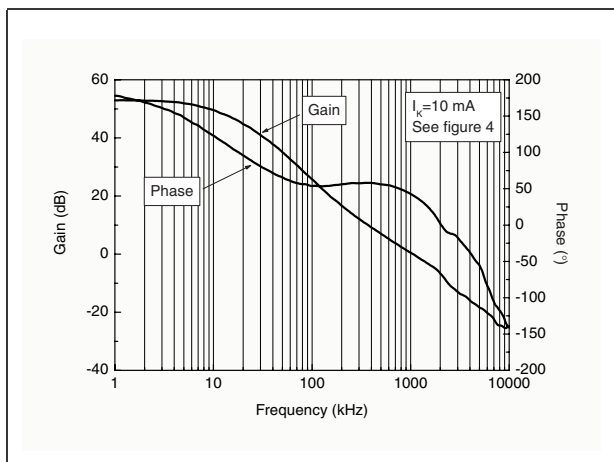


Figure 18. Stability behaviour with capacitive loads

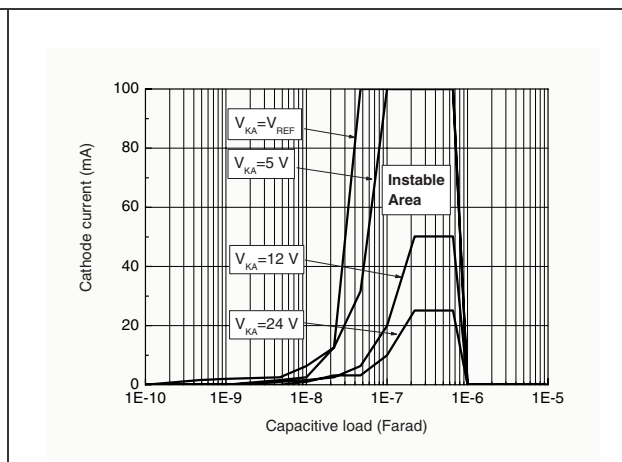


Figure 19. Maximum power dissipation

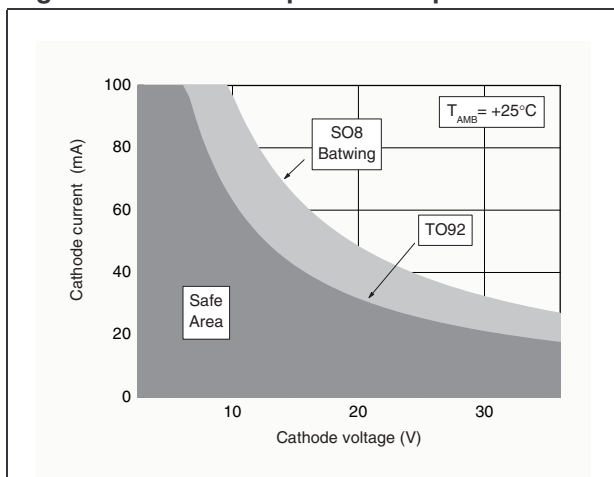
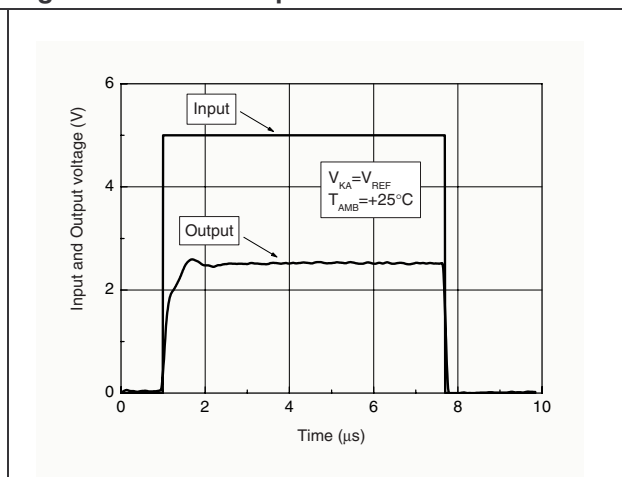


Figure 20. Pulse response for $I_K = 1\text{mA}$



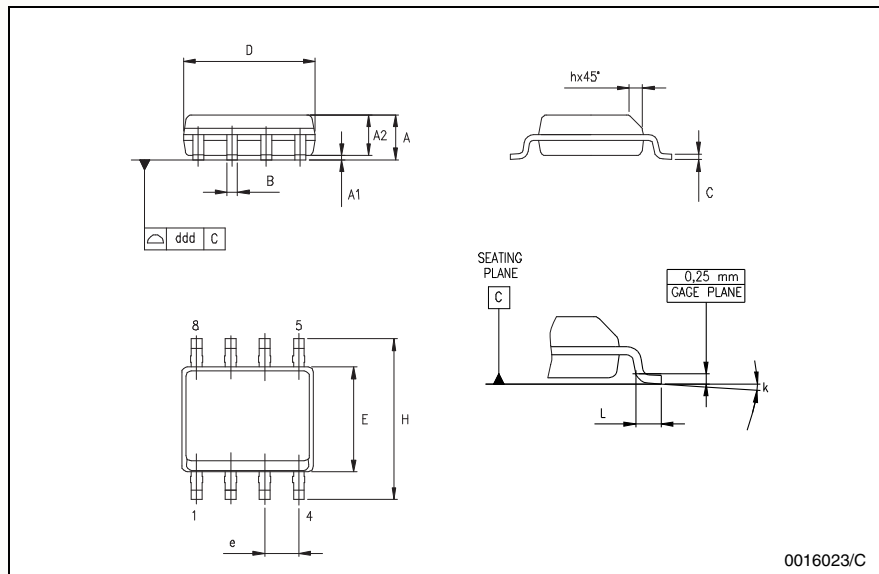
4 Package Mechanical Data

In order to meet environmental requirements, ST offers these devices in ECOPACK® packages. These packages have a Lead-free second level interconnect. The category of second level interconnect is marked on the package and on the inner box label, in compliance with JEDEC Standard JESD97. The maximum ratings related to soldering conditions are also marked on the inner box label. ECOPACK is an ST trademark. ECOPACK specifications are available at: www.st.com.

4.1 SO-8 Package

SO-8 MECHANICAL DATA

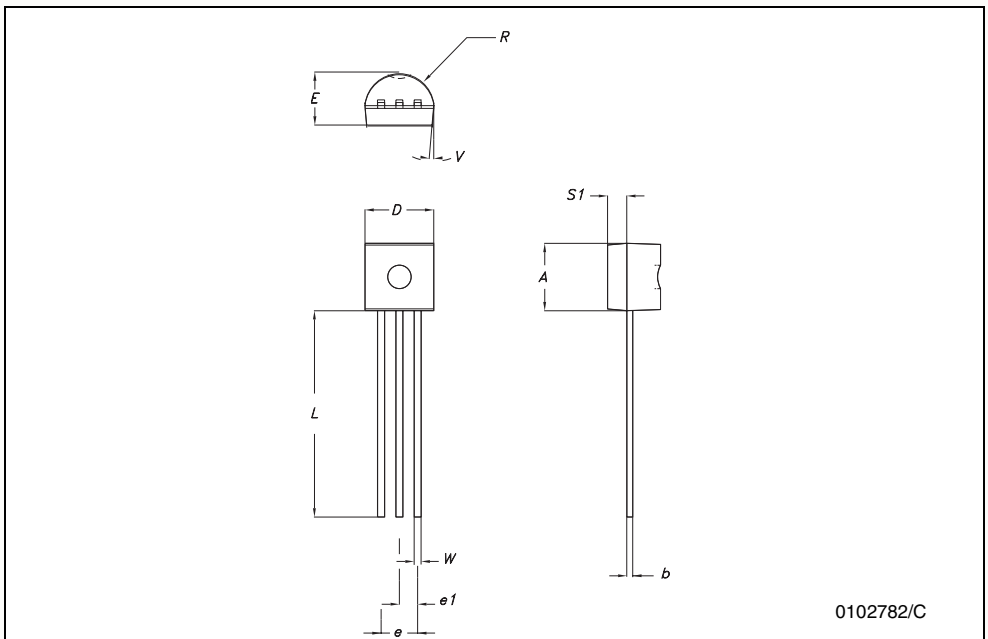
| DIM. | mm. | | | inch | | |
|------|-------------------------|------|------|-------|-------|-------|
| | MIN. | TYP. | MAX. | MIN. | TYP. | MAX. |
| A | 1.35 | | 1.75 | 0.053 | | 0.069 |
| A1 | 0.10 | | 0.25 | 0.04 | | 0.010 |
| A2 | 1.10 | | 1.65 | 0.043 | | 0.065 |
| B | 0.33 | | 0.51 | 0.013 | | 0.020 |
| C | 0.19 | | 0.25 | 0.007 | | 0.010 |
| D | 4.80 | | 5.00 | 0.189 | | 0.197 |
| E | 3.80 | | 4.00 | 0.150 | | 0.157 |
| e | | 1.27 | | | 0.050 | |
| H | 5.80 | | 6.20 | 0.228 | | 0.244 |
| h | 0.25 | | 0.50 | 0.010 | | 0.020 |
| L | 0.40 | | 1.27 | 0.016 | | 0.050 |
| k | δ° (max.) | | | | | |
| ddd | | | 0.1 | | | 0.04 |



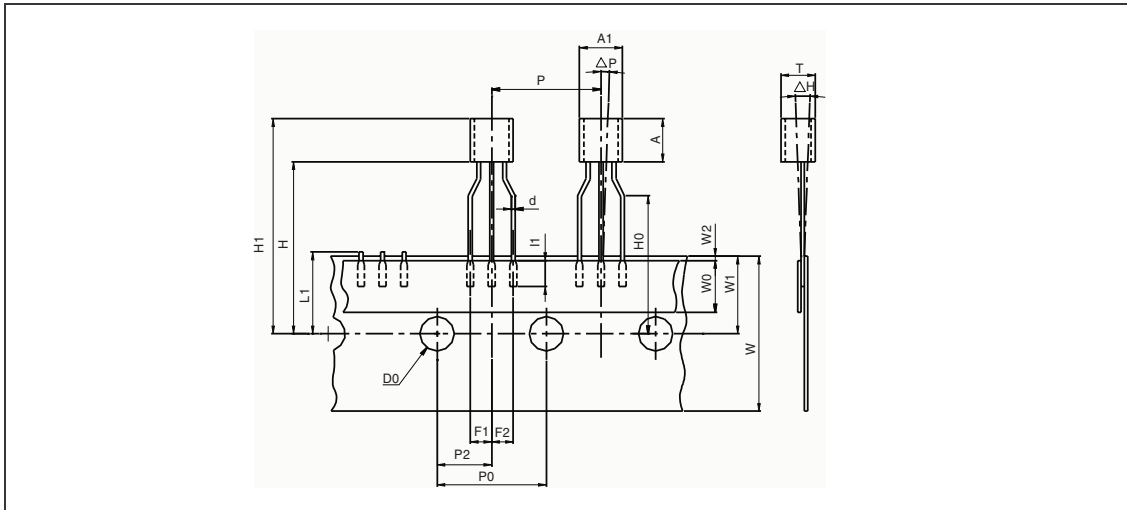
4.2 TO92 (Tape & Reel) Package

TO-92 MECHANICA DATA

| DIM. | mm. | | | mils | | |
|------|------|------|-------|-------|------|-------|
| | MIN. | TYP. | MAX. | MIN. | TYP. | MAX. |
| A | 4.32 | | 4.95 | 170.1 | | 194.9 |
| b | 0.36 | | 0.51 | 14.2 | | 20.1 |
| D | 4.45 | | 4.95 | 175.2 | | 194.9 |
| E | 3.30 | | 3.94 | 129.9 | | 155.1 |
| e | 2.41 | | 2.67 | 94.9 | | 105.1 |
| e1 | 1.14 | | 1.40 | 44.9 | | 55.1 |
| L | 12.7 | | 15.49 | 500.0 | | 609.8 |
| R | 2.16 | | 2.41 | 85.0 | | 94.9 |
| S1 | 0.92 | | 1.52 | 36.2 | | 59.8 |
| W | 0.41 | | 0.56 | 16.1 | | 22.0 |

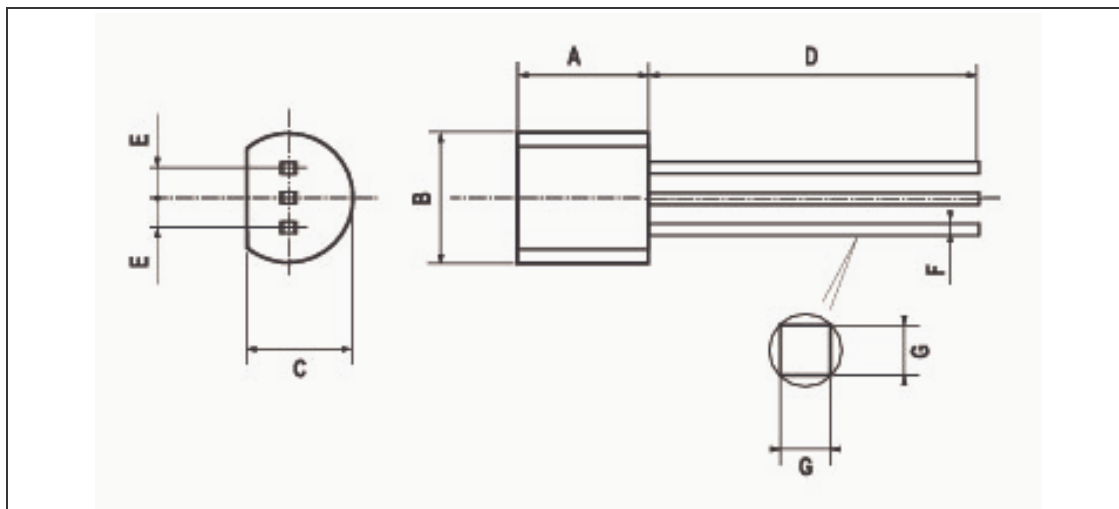


4.3 TO92 (Tape Ammo Pack) Package



| Dim. | Millimeters | | | Inches | | |
|-------|-------------|------|------|--------|-------|-------|
| | Min | Typ. | Max. | Min. | Typ. | Max. |
| AL | | | 5.0 | | | 0.197 |
| A | | | 5.0 | | | 0.197 |
| T | | | 4.0 | | | 0.157 |
| d | | 0.45 | | | 0.018 | |
| I1 | 2.5 | | | 0.098 | | |
| P | 11.7 | 12.7 | 13.7 | 0.461 | 0.500 | 0.539 |
| PO | 12.4 | 12.7 | 13 | 0.488 | 0.500 | 0.512 |
| P2 | 5.95 | 6.35 | 6.75 | 0.234 | 0.250 | 0.266 |
| F1/F2 | 2.4 | 2.5 | 2.8 | 0.094 | 0.098 | 0.110 |
| Δh | -1 | 0 | 1 | -0.039 | 0 | 0.039 |
| ΔP | -1 | 0 | 1 | -0.039 | 0 | 0.039 |
| W | 17.5 | 18.0 | 19.0 | 0.689 | 0.709 | 0.748 |
| W0 | 5.7 | 6 | 6.3 | 0.224 | 0.236 | 0.248 |
| W1 | 8.5 | 9 | 9.75 | 0.335 | 0.354 | 0.384 |
| W2 | | | 0.5 | | | 0.020 |
| H | | | 20 | | | 0.787 |
| H0 | 15.5 | 16 | 16.5 | 0.610 | 0.630 | 0.650 |
| H1 | | | 25 | | | 0.984 |
| DO | 3.8 | 4.0 | 4.2 | 0.150 | 0.157 | 0.165 |
| L1 | | | 11 | | | 0.433 |

4.4 TO92 (Bulk) Package



| Dim. | Millimeters | | | Inches | | |
|------|-------------|------|-------|--------|--------|--------|
| | Min | Typ. | Max. | Min. | Typ. | Max. |
| L | | 1.27 | | | 0.05 | |
| B | 3.2 | 3.7 | 4.2 | 0.126 | 0.1457 | 0.1654 |
| O1 | 4.45 | 5.00 | 5.2 | 0.1752 | 0.1969 | 0.2047 |
| C | 4.58 | 5.03 | 5.33 | 0.1803 | 0.198 | 0.2098 |
| K | 12.7 | | | 0.5 | | |
| O2 | 0.407 | 0.5 | 0.508 | 0.016 | 0.0197 | 0.02 |
| a | 0.35 | | | 0.0138 | | |

5 Revision History

| Date | Revision | Changes |
|------------|----------|---|
| March 2002 | 1 | Initial release. |
| Nov. 2005 | 2 | PPAP references inserted in the datasheet see <i>Table : Order Codes on page 1.</i> |

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