

Programmable voltage reference

Features

- Adjustable output voltage: 2.5 to 36 V
- Sink current capability: 1 to 100 mA
- Typical output impedance: 0.22 Ω
- 1% and 2% voltage precision
- Automotive temperature range -40°C to +125°C

Applications

- Power supply
- Industrial
- Automotive

Description

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

The device's temperature range is extended for the automotive version from -40° C up to +125° C.

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

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



Z
TO-92
(Plastic package)



D
SO-8
(Batwing plastic micropackage)

1 Schematic diagrams

Figure 1. TO-92 pin connections (top view)

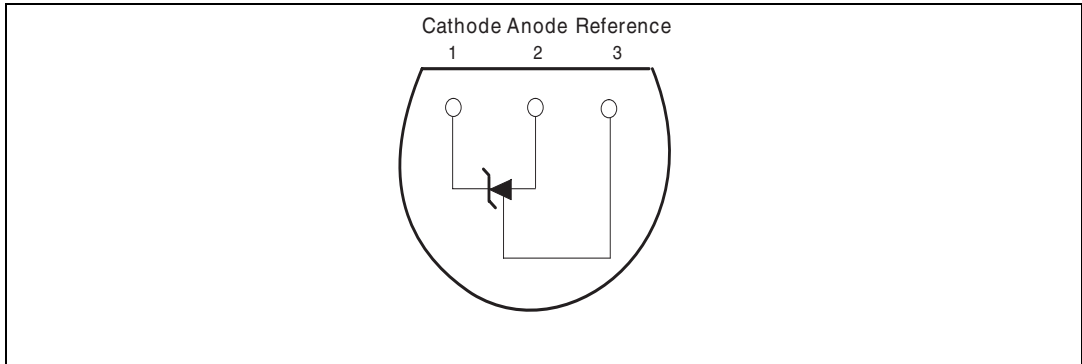


Figure 2. SO-8 batwing pin connections (top view)

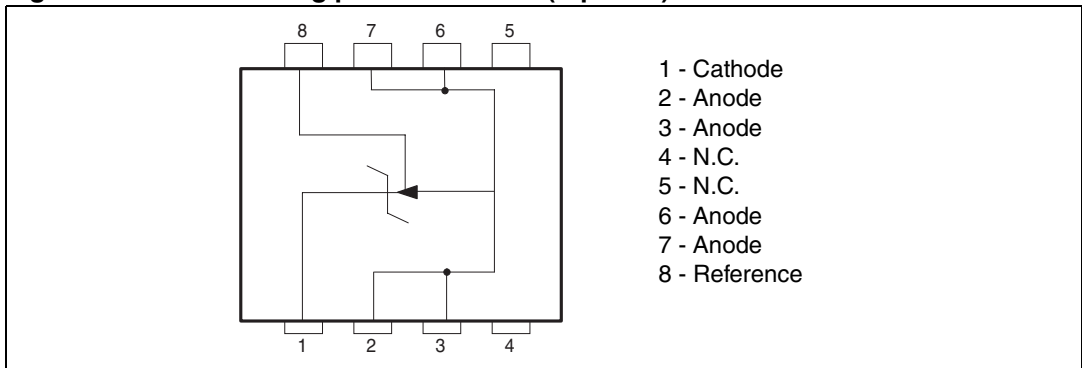
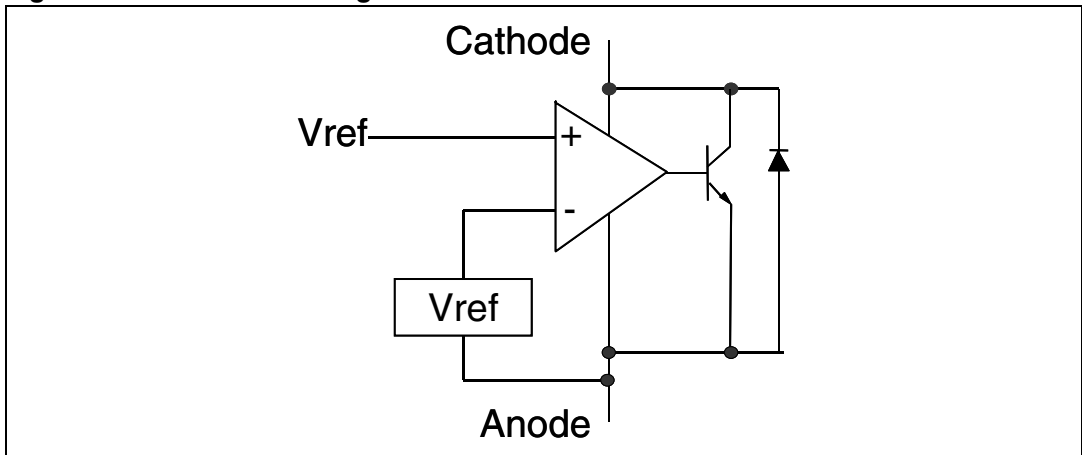


Figure 3. TL431 block diagram



2 Absolute maximum ratings and operating conditions

Table 1. 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 |
| R_{thja} | Thermal resistance junction to ambient ⁽¹⁾ TO-92 SO-8 batwing | 200 85 | °C/W |
| R_{thjc} | Thermal resistance junction to case ⁽¹⁾ SO-8 batwing | 30 | °C/W |
| T_{stg} | Storage temperature range | -65 to +150 | °C |
| ESD | TL431IY TL431AIY: HBM: human body model ⁽²⁾ | 3000 | V |
| | TL431: HBM: human body model | 2000 | |
| | MM: machine model ⁽³⁾ | 200 | |
| | CDM: charged device model ⁽⁴⁾ | 1500 | |

- Short-circuits can cause excessive heating. These values are typical.
- Human body model: a 100 pF capacitor is charged to the specified voltage, then discharged through a 1.5 kΩ resistor between two pins of the device. This is done for all couples of connected pin combinations while the other pins are floating.
- Machine model: a 200 pF capacitor is charged to the specified voltage, then discharged directly between two pins of the device with no external series resistor (internal resistor < 5 Ω). This is done for all couples of connected pin combinations while the other pins are floating.
- Charged device model: all pins and the package are charged together to the specified voltage and then discharged directly to the ground through only one pin. This is done for all pins.

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 TL431/AI TL431IY/AIY | 0 to +70 -40 to +105 -40 to +125 | °C |

3 Electrical characteristics

Table 3. TL431C: 0° C to 70° C ($T_{amb} = 25^{\circ} \text{C}$ 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 | -2.7 -2 | -1.4 -1 | | -2.7 -2 | -1.4 -1 | | 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. See definition of [Section 3.1: Reference input voltage deviation over temperature range](#).

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

Table 4. TL431I: -40° C to 105° C, $T_{amb} = 25^{\circ}\text{C}$ (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 | 2.495 | 2.55 2.58 | 2.47 2.44 | 2.495 | 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 $I_k = 10\text{ mA}$, $\Delta V_{KA} = 10\text{ V to } V_{ref}$ $\Delta V_{KA} = 36\text{ V to } 10\text{ V}$ | -2.7 -2 | -1.4 -1 | | -2.7 -2 | -1.4 -1 | | 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 |

1. See definition of [Section 3.1: Reference input voltage deviation over temperature range](#) below.

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

Table 5. TL431IY: -40° C to 125° C, T_{amb} = 25° C (unless otherwise specified)

| Symbol | Parameter | TL431IY | | | TL431AIY | | | Unit |
|--|--|--------------|------------|--------------|--------------|------------|--------------|------|
| | | Min. | Typ. | Max. | Min. | Typ. | Max. | |
| V _{ref} | Reference input voltage V _{KA} = V _{ref} , I _k = 10 mA T _{min} ≤ T _{amb} ≤ T _{max} | 2.44 2.41 | 2.495 | 2.55 2.58 | 2.47 2.44 | 2.495 | 2.52 2.55 | V |
| ΔV _{ref} | Reference input voltage deviation over temperature range ⁽¹⁾ V _{KA} = V _{ref} , I _k = 10 mA, T _{min} ≤ T _{amb} ≤ 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 mA, ΔV _{KA} = 10 V to V _{ref} I _k = 10 mA, ΔV _{KA} = 36 V to 10 V | -2.7 -2 | -1.4 -1 | | -2.7 -2 | -1.4 -1 | | mV/V |
| I _{ref} | Reference input current I _k = 10 mA, R1 = 10 kΩ, R2 = ∞ T _{min} ≤ T _{amb} ≤ 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 mA, R1 = 10 kΩ, R2 = ∞, T _{min} ≤ T _{amb} ≤ 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 | 0.6 | mA |
| I _{off} | Off-state cathode current T _{min} ≤ T _{amb} ≤ T _{max} | | 2.6 | 1000 3000 | | 2.6 | 1000 3000 | nA |
| Z _{KA} | Dynamic impedance ⁽²⁾ V _{KA} = V _{ref} , ΔI _k = 1 to 100 mA, F ≤ 1 kHz | | 0.22 | 0.5 | | 0.22 | 0.5 | Ω |

1. See definition of [Section 3.1: Reference input voltage deviation over temperature range](#) below.

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

3.1 Reference input voltage deviation over temperature range

ΔV_{ref} is defined as the difference between the maximum and minimum values obtained over the full temperature range.

$$\Delta V_{ref} = V_{ref\ max} - V_{ref\ min}$$

Figure 4. Reference input voltage deviation over temperature range

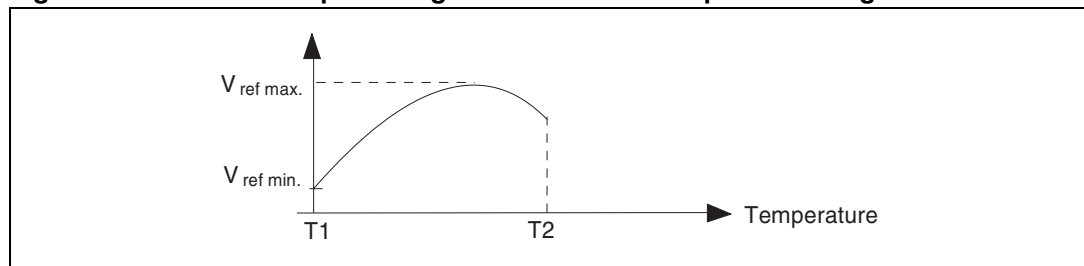


Figure 5. Test circuit for $V_{KA} = V_{ref}$

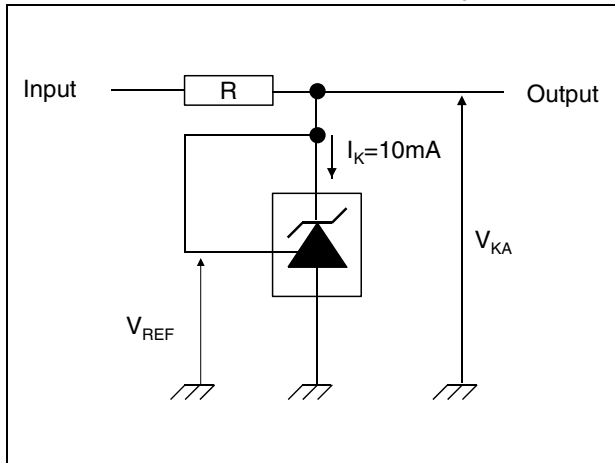


Figure 6. Test circuit for programming mode

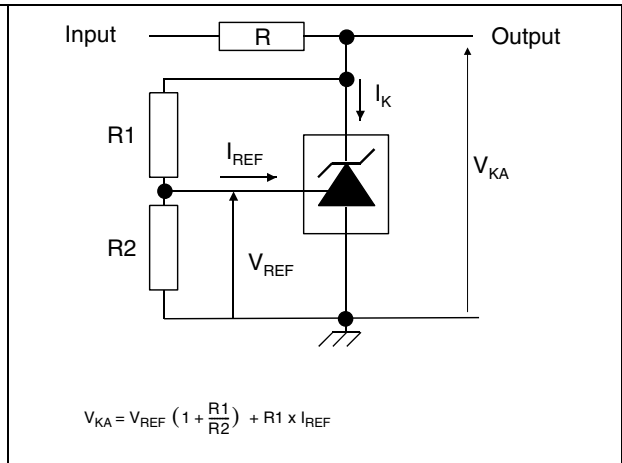


Figure 7. Test circuit for I_{off}

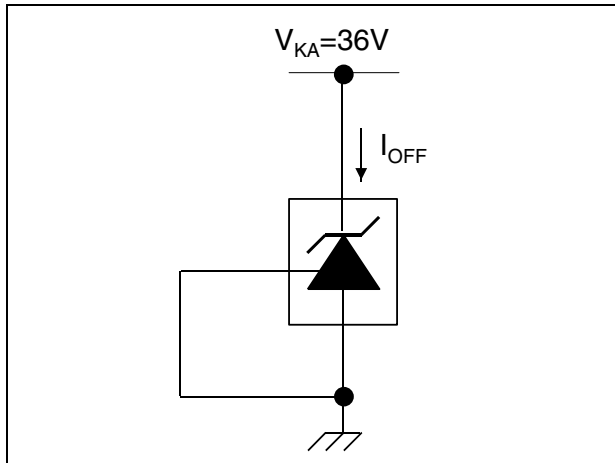


Figure 8. Test circuit for phase margin and voltage gain

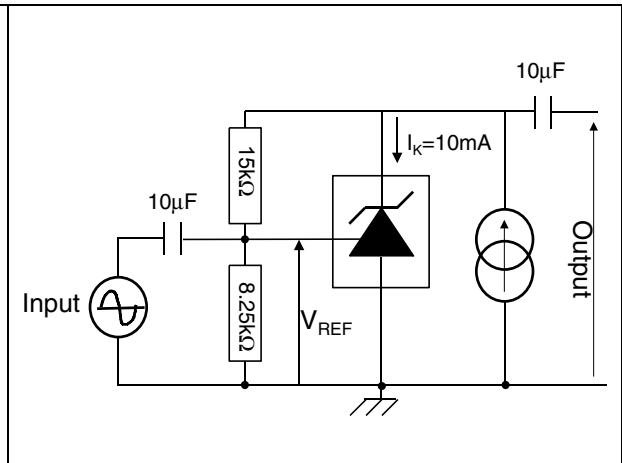


Figure 9. Test circuit for response time

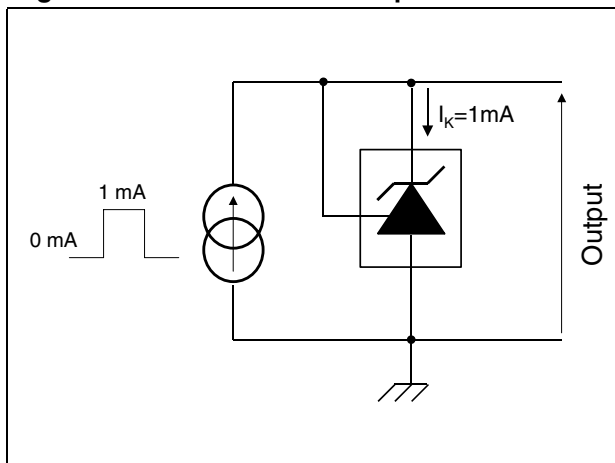


Figure 10. Reference voltage vs. temperature

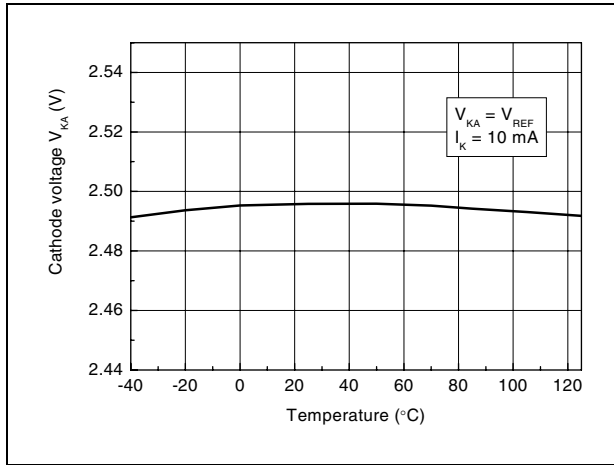


Figure 11. Reference voltage vs. cathode current

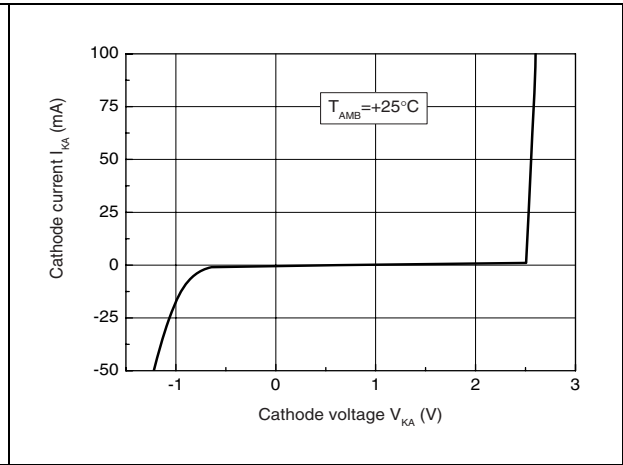


Figure 12. Zoom on reference voltage vs. cathode current

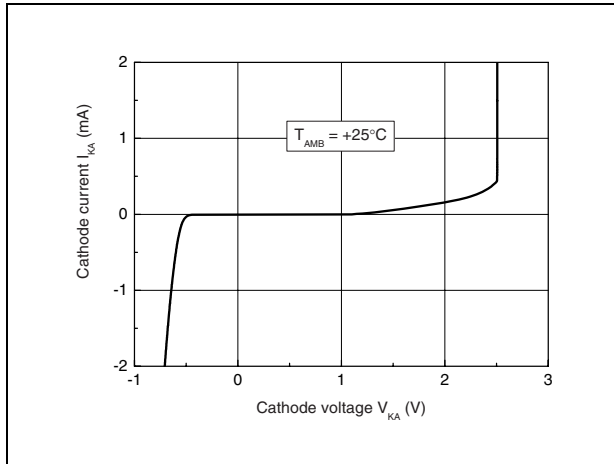


Figure 13. Reference current vs. temperature

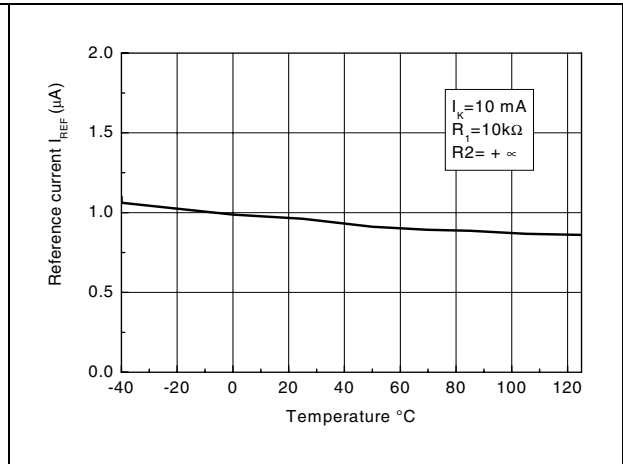


Figure 14. Off-state cathode current vs. temperature

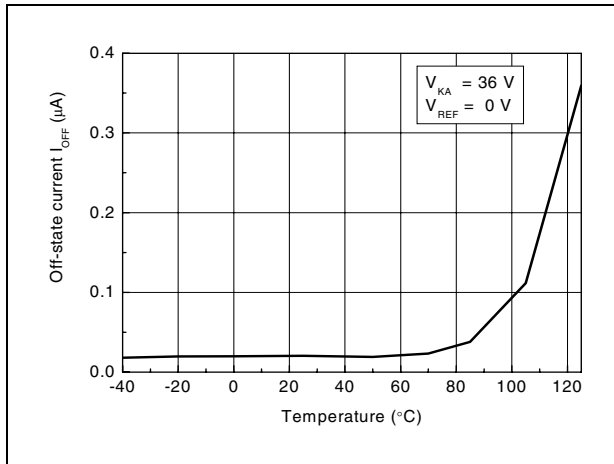


Figure 15. Ratio of change in V_{REF} to change in V_{KA} vs. temperature

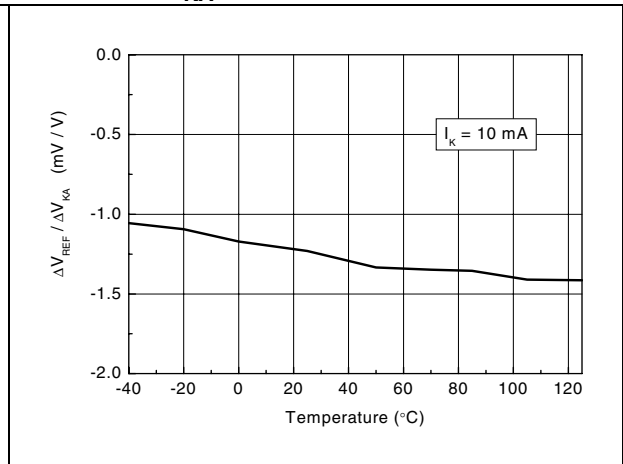


Figure 16. Static impedance R_{KA} vs. temperature

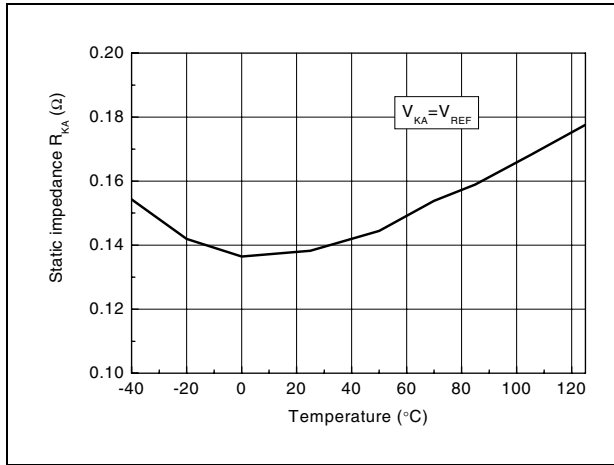


Figure 17. Minimum operating current vs. temperature

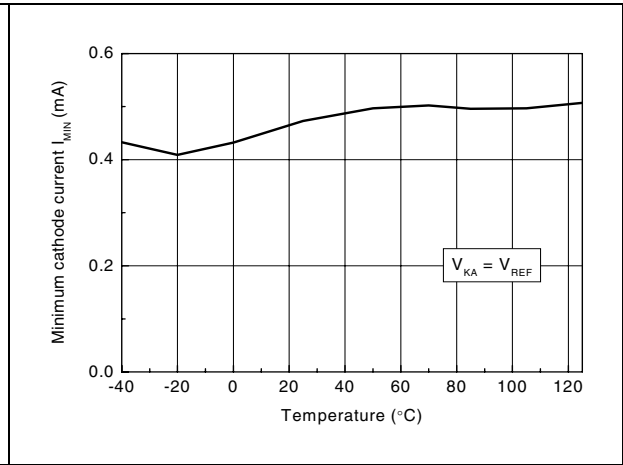


Figure 18. Gain and phase vs. frequency

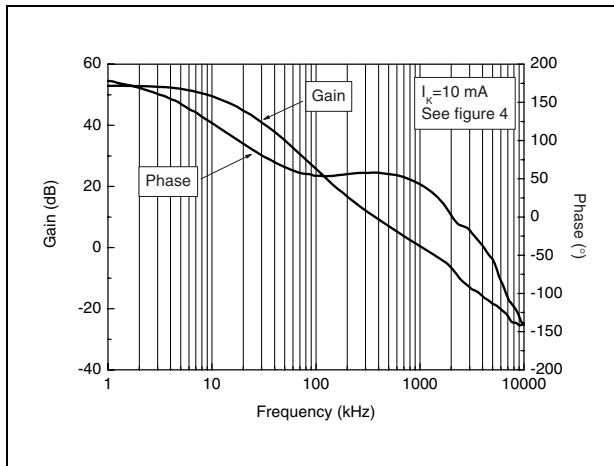


Figure 19. Stability behavior with capacitive loads

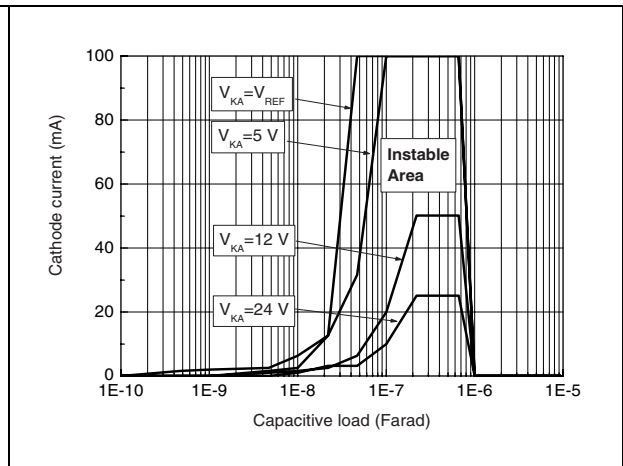


Figure 20. Maximum power dissipation

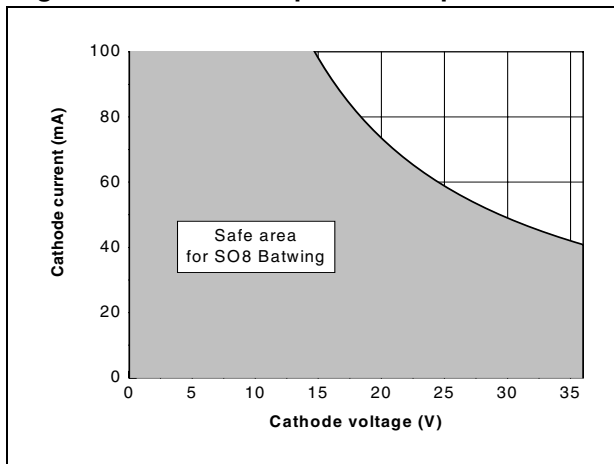
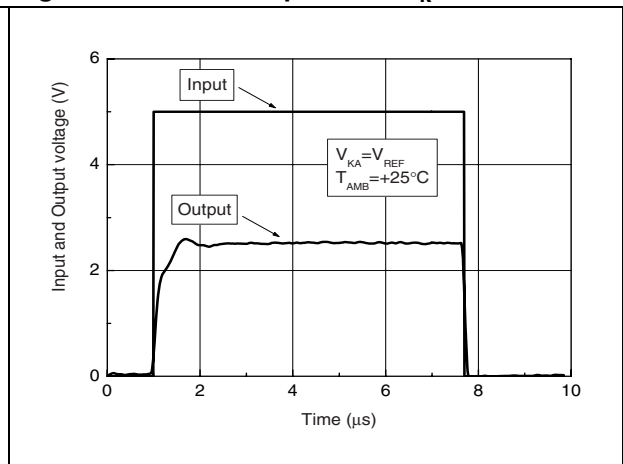


Figure 21. Pulse response for $I_K = 1$ mA



4 Package information

In order to meet environmental requirements, ST offers these devices in different grades of ECOPACK[®] packages, depending on their level of environmental compliance. ECOPACK[®] specifications, grade definitions and product status are available at: www.st.com. ECOPACK[®] is an ST trademark.

4.1 SO-8 package information

Figure 22. SO-8 package mechanical drawing

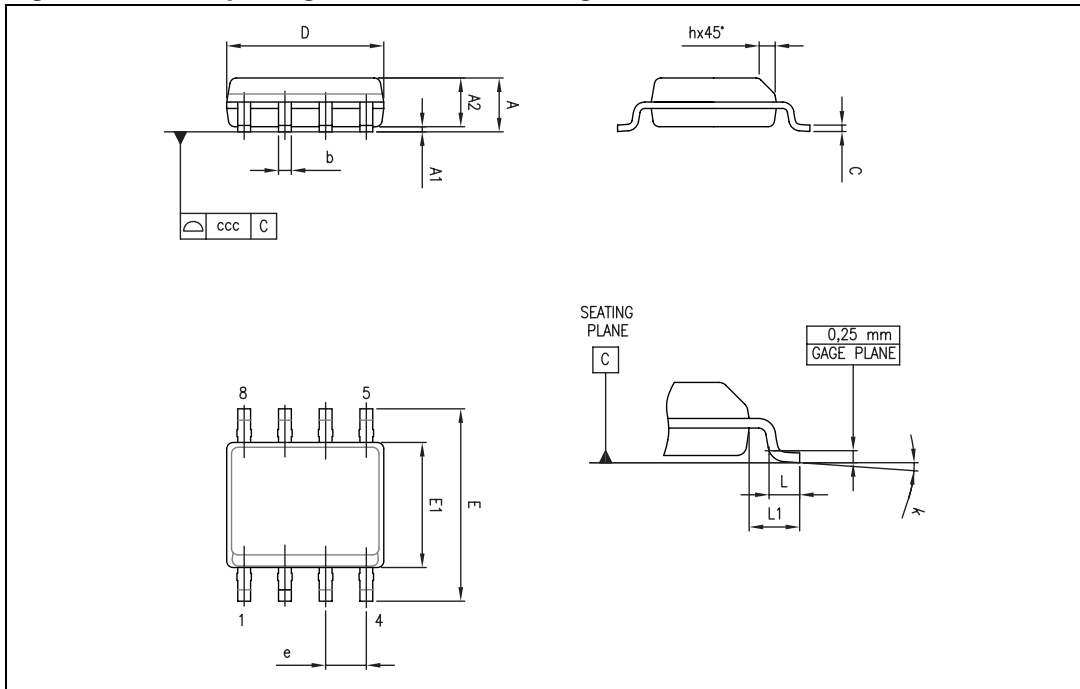


Table 6. SO-8 package mechanical data

| Ref. | Dimensions | | | | | |
|------|-------------|------|------|--------|-------|-------|
| | Millimeters | | | Inches | | |
| | Min. | Typ. | Max. | Min. | Typ. | Max. |
| A | | | 1.75 | | | 0.069 |
| A1 | 0.10 | | 0.25 | 0.004 | | 0.010 |
| A2 | 1.25 | | | 0.049 | | |
| b | 0.28 | | 0.48 | 0.011 | | 0.019 |
| c | 0.17 | | 0.23 | 0.007 | | 0.010 |
| D | 4.80 | 4.90 | 5.00 | 0.189 | 0.193 | 0.197 |
| E | 5.80 | 6.00 | 6.20 | 0.228 | 0.236 | 0.244 |
| E1 | 3.80 | 3.90 | 4.00 | 0.150 | 0.154 | 0.157 |
| e | | 1.27 | | | 0.050 | |
| h | 0.25 | | 0.50 | 0.010 | | 0.020 |
| L | 0.40 | | 1.27 | 0.016 | | 0.050 |
| L1 | | 1.04 | | | 0.040 | |
| k | 1° | | 8° | 1° | | 8° |
| ccc | | | 0.10 | | | 0.004 |

4.2 TO-92 ammopack and tape and reel package information

Figure 23. TO-92 ammopack and tape and reel package mechanical drawing

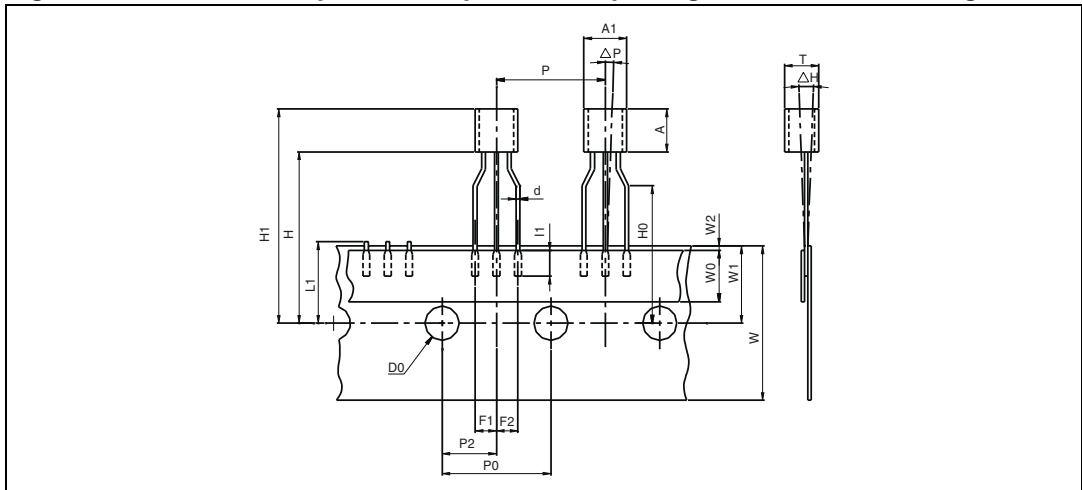


Table 7. TO-92 ammopack and tape and reel package mechanical data

| 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 | |
| l1 | 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 |

4.3 TO-92 (bulk) package information

Figure 24. TO-92 bulk package mechanical drawing

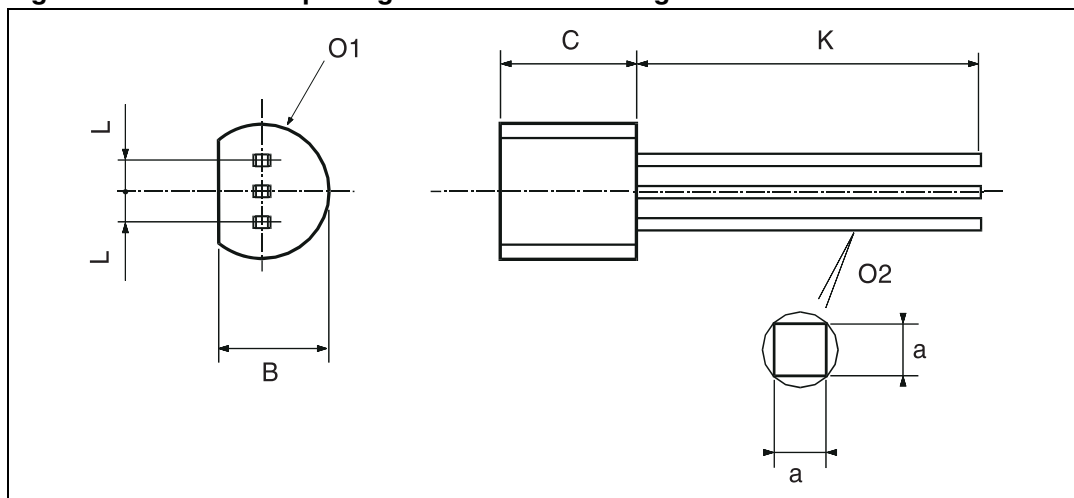


Table 8. TO-92 bulk package mechanical data

| 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 Ordering information

Table 9. Order codes

| Order code | Accuracy (%) | Temperature range | Package | Packing | Marking |
|---|--------------|-------------------|-------------------------------------|--------------------------------|---------|
| TL431CD TL431CDT | 2 | 0°C to +70°C | SO-8 | Tube or Tape and reel | 431C |
| TL431ACD TL431ACDT | 1 | | | | 431AC |
| TL431CZ TL431CZT TL431CZ-AP | 2 | | TO-92 | Bulk or Tape or Ammopack | TL431C |
| TL431ACZ TL431ACZT TL431ACZ-AP | 1 | | | | TL431AC |
| TL431ID TL431IDT | 2 | -40°C to + 105°C | SO-8 | Tube or tape and reel | 431I |
| TL431AID TL431AIDT | 1 | | | | 431AI |
| TL431IZ TL431IZT TL431IZ-AP | 2 | | TO-92 | Bulk or Tape or Ammopack | TL431I |
| TL431AIZ TL431AIZT TL431AIZ-AP | 1 | | | | TL431AI |
| TL431IYD ⁽¹⁾ TL431IYDT ⁽¹⁾ | 2 | -40°C to + 125°C | SO-8 (Automotive grade level) | Tube or tape and reel | 431IY |
| TL431AIYD ⁽¹⁾ TL431AIYDT ⁽¹⁾ | 1 | | | | 431AIY |

1. Qualification and characterization according to AEC Q100 and Q003 or equivalent, advanced screening according to AEC Q001 & Q 002 or equivalent.

6 Revision history

Table 10. Document revision history

| Date | Revision | Changes |
|-------------|----------|---|
| 01-Mar-2002 | 1 | Initial release. |
| 01-Nov-2005 | 2 | PPAP references inserted in order codes table on cover page. |
| 13-Dec-2006 | 3 | Corrected TO-92 package information. |
| 08-Jun-2007 | 4 | Specified that SO-8 package is batwing package. In electrical characteristics tables, moved negative values from max column to min column. Corrected captions of Figure 5 and of Figure 16 . Added footnote to Table 8: Order codes . |
| 25-Feb-2008 | 5 | Corrected SO-8 package mechanical data. Corrected footnote for automotive grade order codes in order code table. Corrected packing information for TO-92 devices in order code table. |
| 04-Jun-2009 | 6 | Changed I_{min} to 0.6 mA in Table 3 and Table 4 . Increased temperature range to 125°C in temperature curves. Added Table 5 , dedicated to automotive version. Increased high temperature for automotive range up to +125°C in Table 5 and in Table 9: Order codes . Inserted accuracy column in Table 9 . |
| 09-Jun-2009 | 7 | Corrected minor error in package column in Table 9 . |

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