

Programmable voltage reference

Features

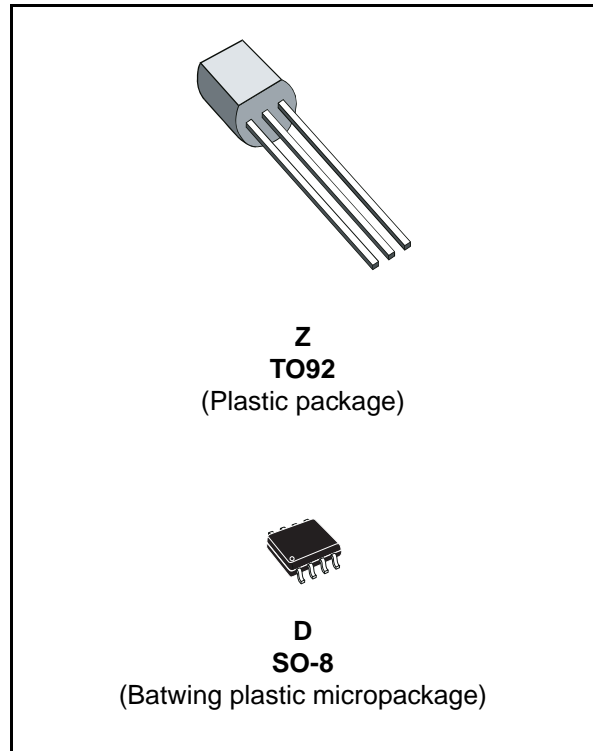
- Adjustable output voltage: V_{REF} to 36 V
- Sink current capability: 1 to 100 mA
- Typical output impedance: 0.22 Ω
- 0.4% and 0.25% voltage precision

Description

The TL1431 is a programmable shunt voltage reference with guaranteed temperature stability over the entire operating temperature range.

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

The TL1431 operates with a wide current range from 1 to 100 mA with a typical dynamic impedance of 0.2 Ω .



1 Schematic diagrams

Figure 1. T092 pin connections (top view)

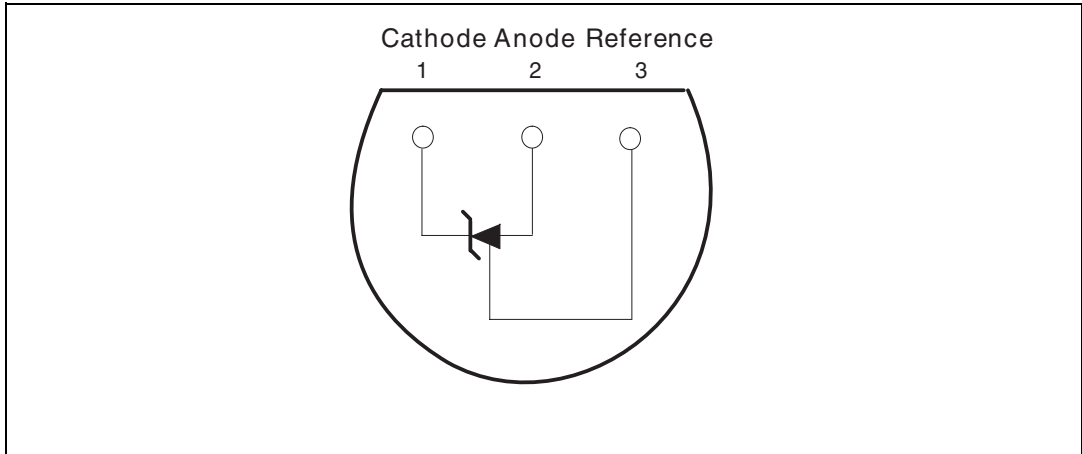


Figure 2. SO-8 pin connections (top view)

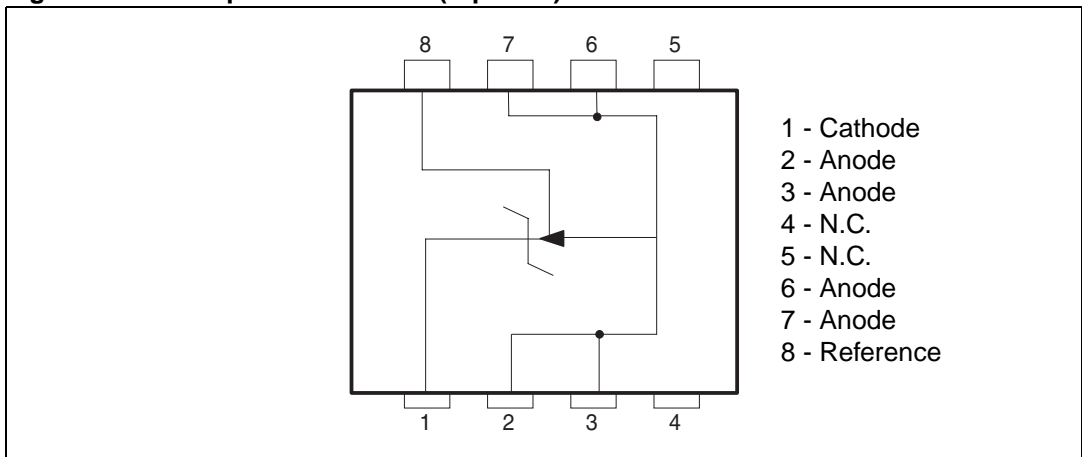
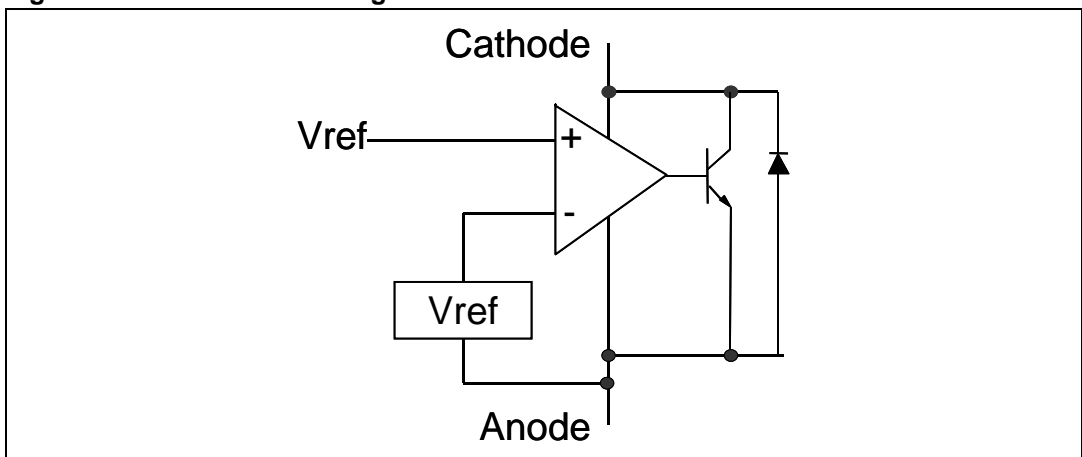


Figure 3. TL1431 block diagram



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 |
| T_j | Junction temperature | +150 | °C |
| P_d | Power dissipation ⁽¹⁾ | | |
| | TO92 SO-8 batwing | 625 960 | mW |
| T_{stg} | Storage temperature range | -65 to +150 | °C |
| ESD | HBM: human body model ⁽²⁾ | 2000 | V |
| | MM: machine model ⁽³⁾ | 200 | |
| | CDM: charged device model ⁽⁴⁾ | 1500 | |

1. Calculated with $T_j=+150^{\circ}\text{C}$ and $T_{amb}=+25^{\circ}\text{C}$ with relative R_{thja} depending on the package.
2. Human body model: A 100 pF capacitor is charged to the specified voltage, then discharged through a 1.5 k Ω resistor between two pins of the device. This is done for all couples of connected pin combinations while the other pins are floating.
3. 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.
4. 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 | | °C |
| | TL1431C/AC TL1431I/AI | -20 to +70 -40 to +105 | |
| R_{thja} | Thermal resistance junction to ambient | | °C/W |
| | SO-8 batwing TO92 | 130 200 | |

3 Electrical characteristics

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

| Symbol | Parameter | TL1431C | | | TL1431AC | | | Unit |
|--|---|---------|----------|----------|----------|----------|----------|-------------------------|
| | | Min. | Typ. | Max. | Min. | Typ. | Max. | |
| V_{ref} | Reference input voltage - see Figure 4 $V_{KA} = V_{ref}$, $I_k = 10\text{ mA}$ | 2.490 | 2.500 | 2.510 | 2.493 | 2.500 | 2.507 | V |
| ΔV_{ref} | Reference input voltage deviation over temperature range ⁽¹⁾ - see Figure 4 $V_{KA} = V_{ref}$, $I_k = 10\text{ mA}$, $T_{min} \leq T_{amb} \leq T_{max}$ | | 3 | 20 | | 3 | 20 | mV |
| $\frac{\Delta V_{ref}}{\Delta T}$ | Temperature coefficient of reference input voltage ⁽²⁾ $V_{KA} = V_{ref}$, $I_k = 10\text{ mA}$, $T_{min} \leq T_{amb} \leq T_{max}$ | | ± 13 | ± 90 | | ± 13 | ± 90 | ppm/ $^{\circ}\text{C}$ |
| $\frac{\Delta V_{ref}}{\Delta V_{ka}}$ | Ratio of change in reference input voltage to change in cathode to anode voltage - see Figure 5 $I_k = 10\text{ mA}$ - $\Delta V_{KA} = 36\text{V}$ to 3V | -2 | -1.1 | | -2 | -1.1 | | mV/V |
| I_{ref} | Reference input current $I_k = 10\text{ mA}$, $R1 = 10\text{ k}\Omega$, $R2 = \infty$ $T_{min} \leq T_{amb} \leq T_{max}$ | | 1.5 | 2.5 3 | | 1.5 | 2.5 3 | μA |
| ΔI_{ref} | Reference input current deviation over temperature range $I_k = 10\text{ mA}$, $R1 = 10\text{ k}\Omega$, $R2 = \infty$, $T_{min} \leq T_{amb} \leq T_{max}$ | | 0.2 | 1.2 | | 0.2 | 1.2 | μA |
| I_{min} | Minimum cathode current for regulation - Figure 4 $V_{KA} = V_{ref}$ | | 0.5 | 1 | | 0.5 | 0.6 | mA |
| I_{off} | Off-state cathode current - see Figure 6 | | 180 | 500 | | 180 | 500 | nA |
| $ Z_{KA} $ | Dynamic impedance ⁽³⁾ $V_{KA} = V_{ref}$, $\Delta I_k = 1$ to 100 mA , $f \leq 1\text{ kHz}$ | | 0.2 | 0.5 | | 0.2 | 0.5 | Ω |

1. See [Reference input voltage deviation over temperature range](#) in [Section 4: Parameter definitions on page 9](#).

2. See [Temperature coefficient of reference input voltage](#) in [Section 4: Parameter definitions on page 9](#).

3. See [Dynamic impedance](#) in [Section 4: Parameter definitions on page 9](#).

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

| Symbol | Parameter | TL1431I | | | TL1431AI | | | Unit |
|--|---|---------|----------|-----------|----------|----------|-----------|-------------------------|
| | | Min. | Typ. | Max. | Min. | Typ. | Max. | |
| V_{ref} | Reference input voltage - see Figure 4 $V_{KA} = V_{ref}$, $I_k = 10\text{ mA}$ | 2.490 | 2.500 | 2.510 | 2.493 | 2.500 | 2.507 | V |
| ΔV_{ref} | Reference input voltage deviation over temperature range ⁽¹⁾ - see Figure 4 $V_{KA} = V_{ref}$, $I_k = 10\text{ mA}$, $T_{min} \leq T_{amb} \leq T_{max}$ | | 7 | 30 | | 7 | 30 | mV |
| $\frac{\Delta V_{ref}}{\Delta T}$ | Temperature coefficient of reference input voltage ⁽²⁾ $V_{KA} = V_{ref}$, $I_k = 10\text{ mA}$, $T_{min} \leq T_{amb} \leq T_{max}$ | | ± 22 | ± 100 | | ± 22 | ± 100 | ppm/ $^{\circ}\text{C}$ |
| $\frac{\Delta V_{ref}}{\Delta V_{ka}}$ | Ratio of change in reference input voltage to change in cathode to anode voltage - see Figure 5 $I_k = 10\text{ mA}$ - $\Delta V_{KA} = 36\text{V}$ to 3V | -2 | -1.1 | | -2 | -1.1 | | mV/V |
| I_{ref} | Reference input current $I_k = 10\text{ mA}$, $R1 = 10\text{ k}\Omega$, $R2 = \infty$ $T_{min} \leq T_{amb} \leq T_{max}$ | | 1.5 | 2.5 3 | | 1.5 | 2.5 3 | μA |
| ΔI_{ref} | Reference input current deviation over temperature range $I_k = 10\text{ mA}$, $R1 = 10\text{ k}\Omega$, $R2 = \infty$, $T_{min} \leq T_{amb} \leq T_{max}$ | | 0.5 | 1 | | 0.8 | 1.2 | μA |
| I_{min} | Minimum cathode current for regulation - see Figure 4 $V_{KA} = V_{ref}$ | | 0.5 | 1 | | 0.5 | 0.7 | mA |
| I_{off} | Off-state cathode current - see Figure 6 | | 180 | 500 | | 180 | 500 | nA |
| $ Z_{KA} $ | Dynamic impedance ⁽³⁾ $V_{KA} = V_{ref}$, $\Delta I_k = 1\text{ to }100\text{ mA}$, $f \leq 1\text{ kHz}$ | | 0.2 | 0.5 | | 0.2 | 0.5 | Ω |

1. See [Reference input voltage deviation over temperature range](#) in [Section 4: Parameter definitions on page 9](#).

2. See [Temperature coefficient of reference input voltage](#) in [Section 4: Parameter definitions on page 9](#).

3. See [Dynamic impedance](#) in [Section 4: Parameter definitions on page 9](#).

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

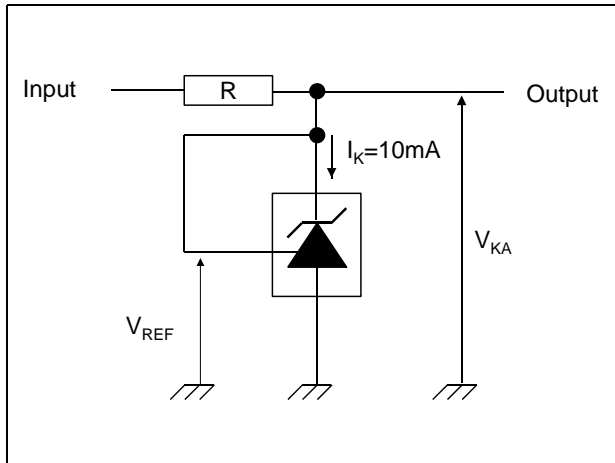


Figure 5. Test circuit for $V_{KA} = V_{REF}$

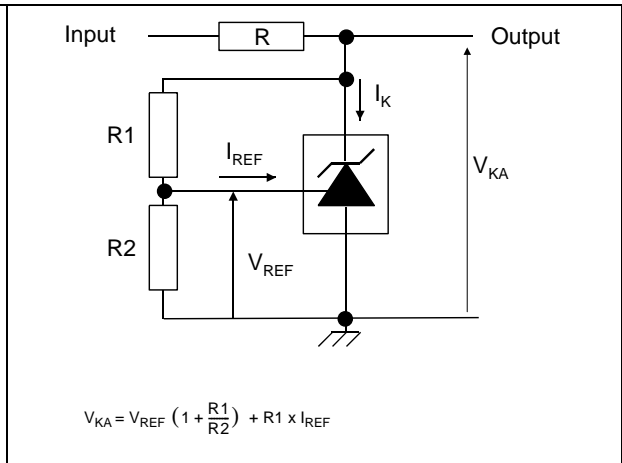


Figure 6. Test circuit for I_{OFF}

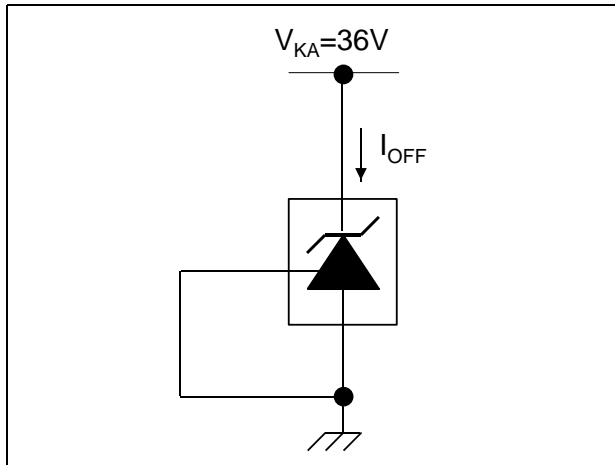


Figure 7. Test circuit for phase margin and voltage gain

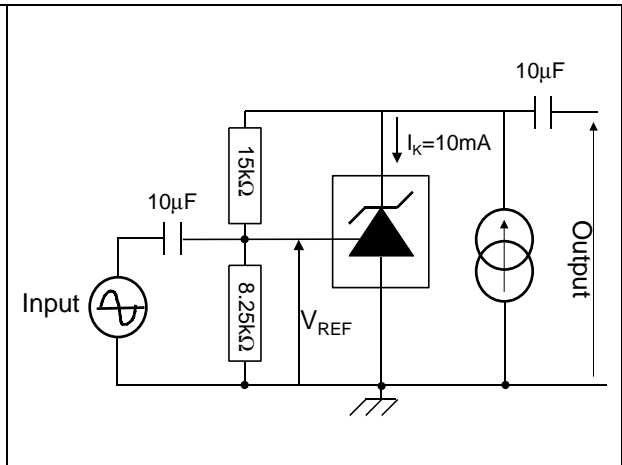


Figure 8. Test circuit for response time

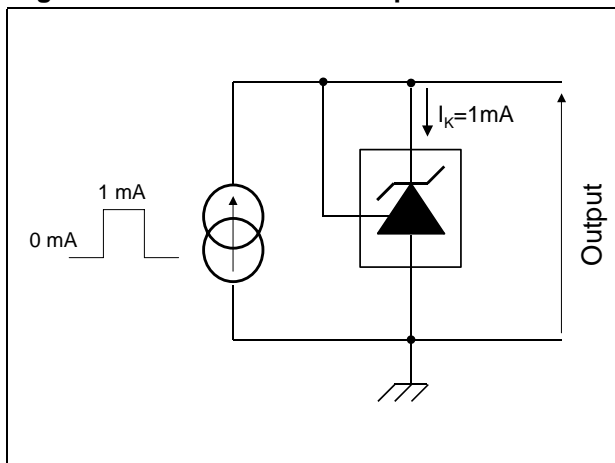


Figure 9. Reference voltage vs. temperature

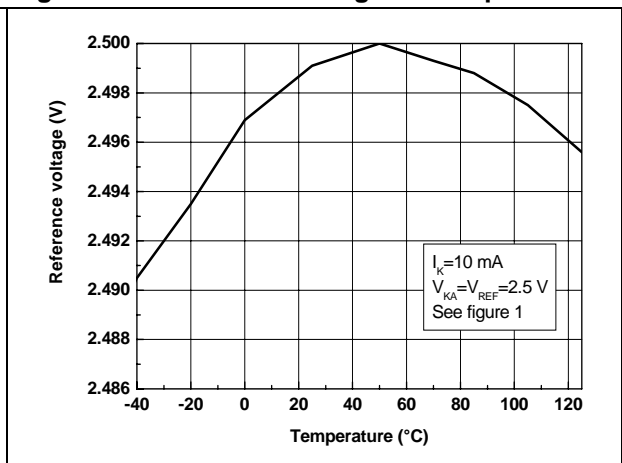


Figure 10. Reference voltage vs. cathode current

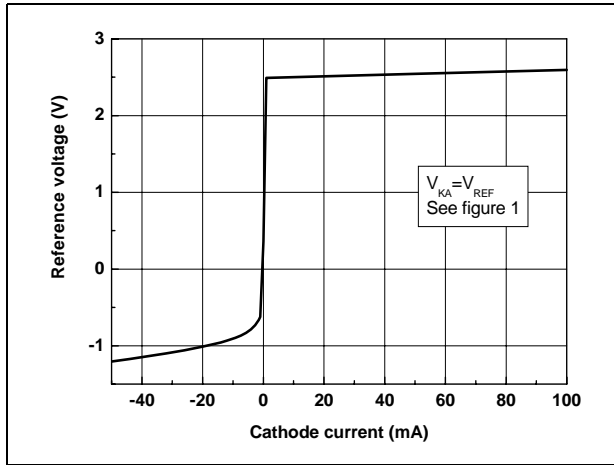


Figure 11. Reference voltage vs. cathode current

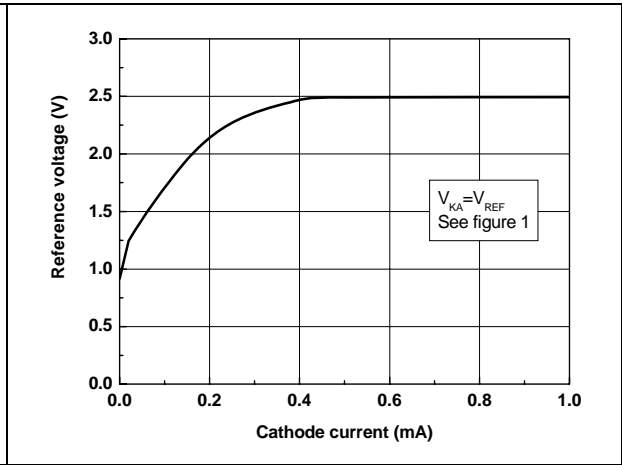


Figure 12. Reference current vs. temperature

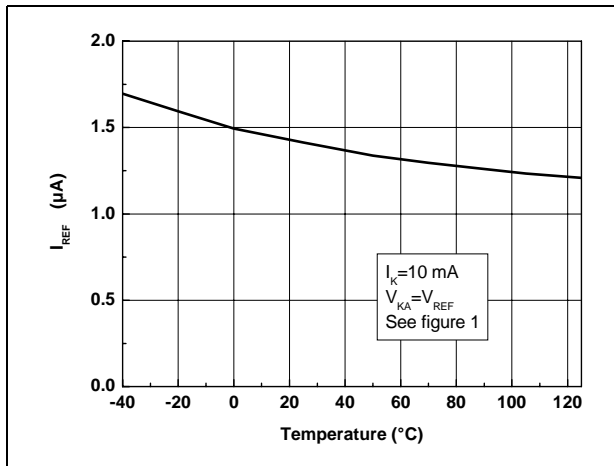


Figure 13. Off-state cathode current vs. temperature

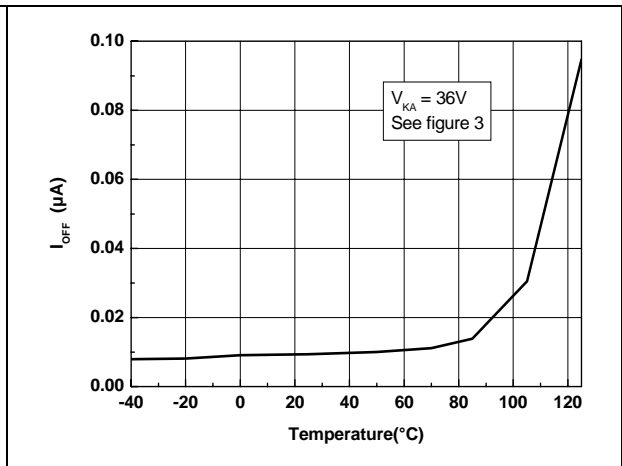


Figure 14. Ratio of change in V_REF to change in V_KA vs. temperature

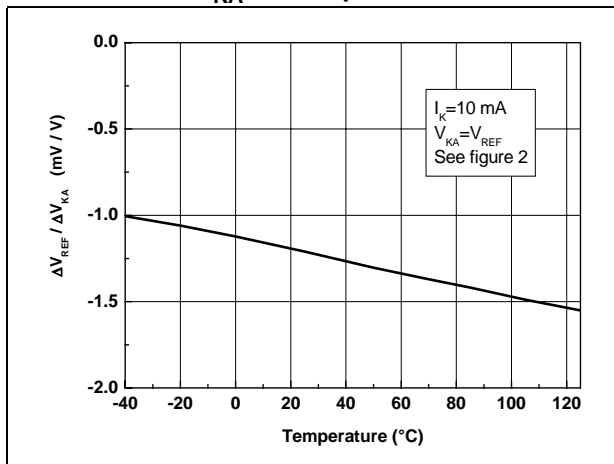


Figure 15. Drift of R_KA vs. temperature

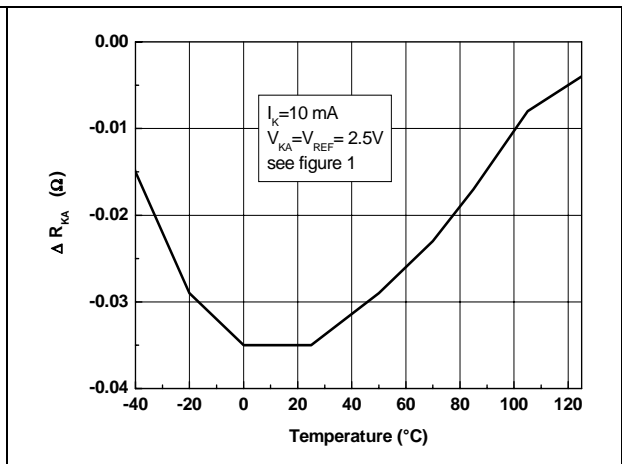


Figure 16. Maximum operating current vs. temperature

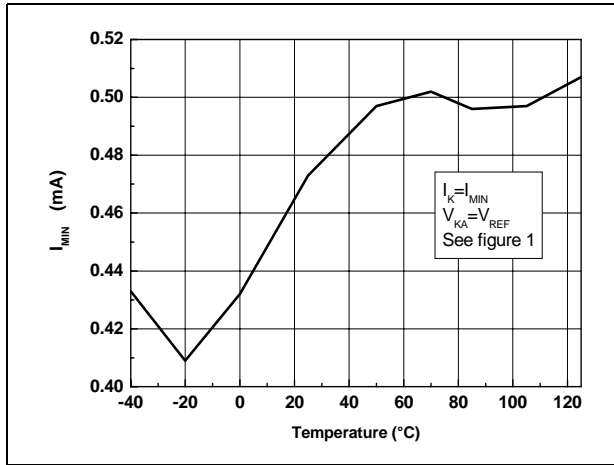


Figure 17. Gain and phase vs. frequency

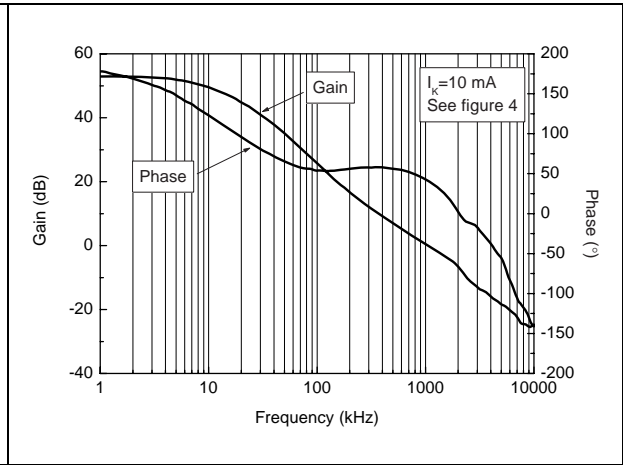


Figure 18. Stability behavior with capacitive loads

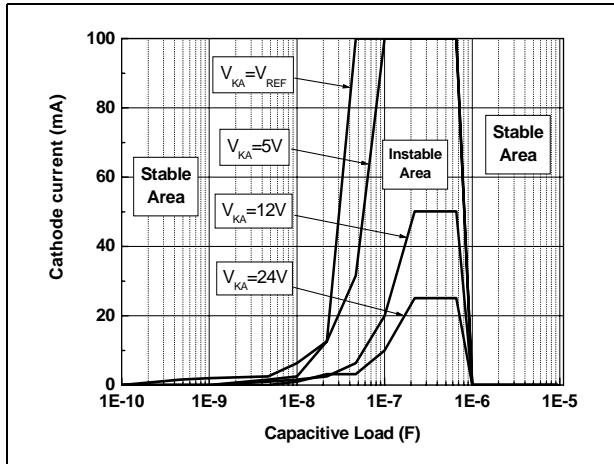


Figure 19. Maximum power dissipation

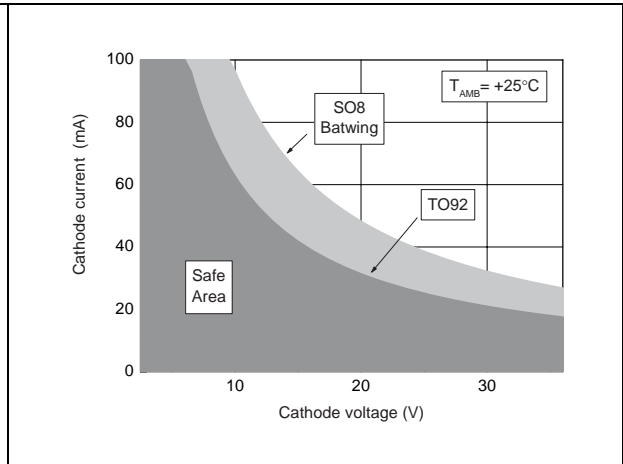
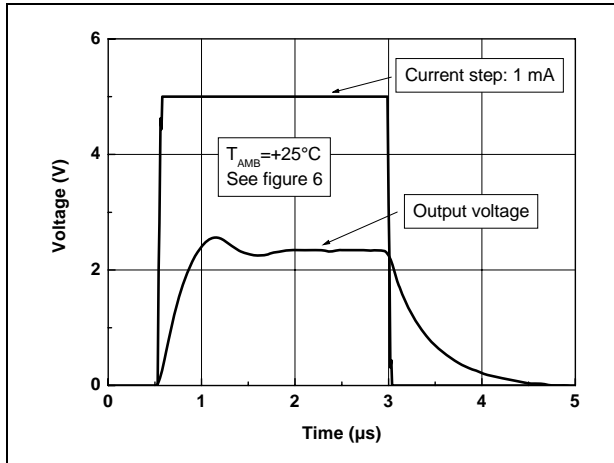


Figure 20. Pulse response for I_K = 1 mA



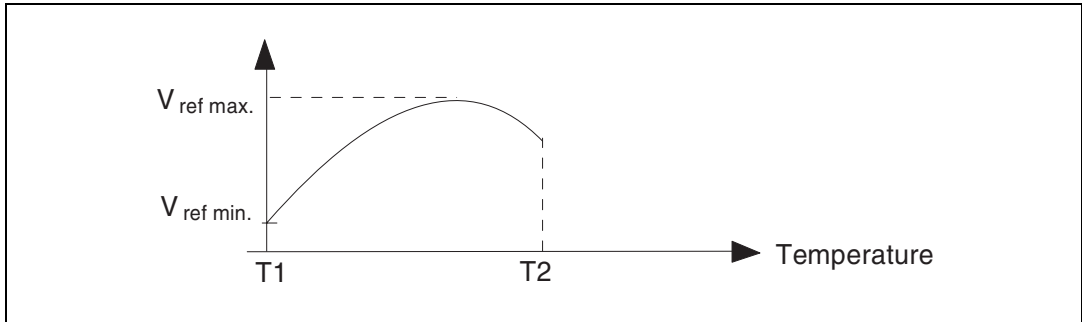
4 Parameter definitions

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.

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

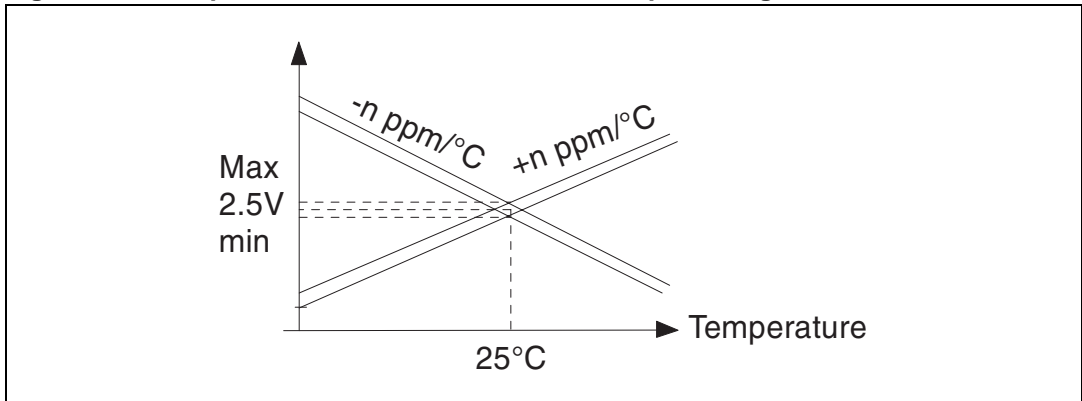
Figure 21. Reference input voltage deviation over temperature range



Temperature coefficient of reference input voltage

The temperature coefficient is defined as the slopes (positive and negative) of the voltage versus temperature limits within which the reference is guaranteed.

Figure 22. Temperature coefficient of reference input voltage



Dynamic impedance

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

5 Package information

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.

5.1 SO-8 batwing package information

Figure 23. SO-8 batwing package mechanical drawing

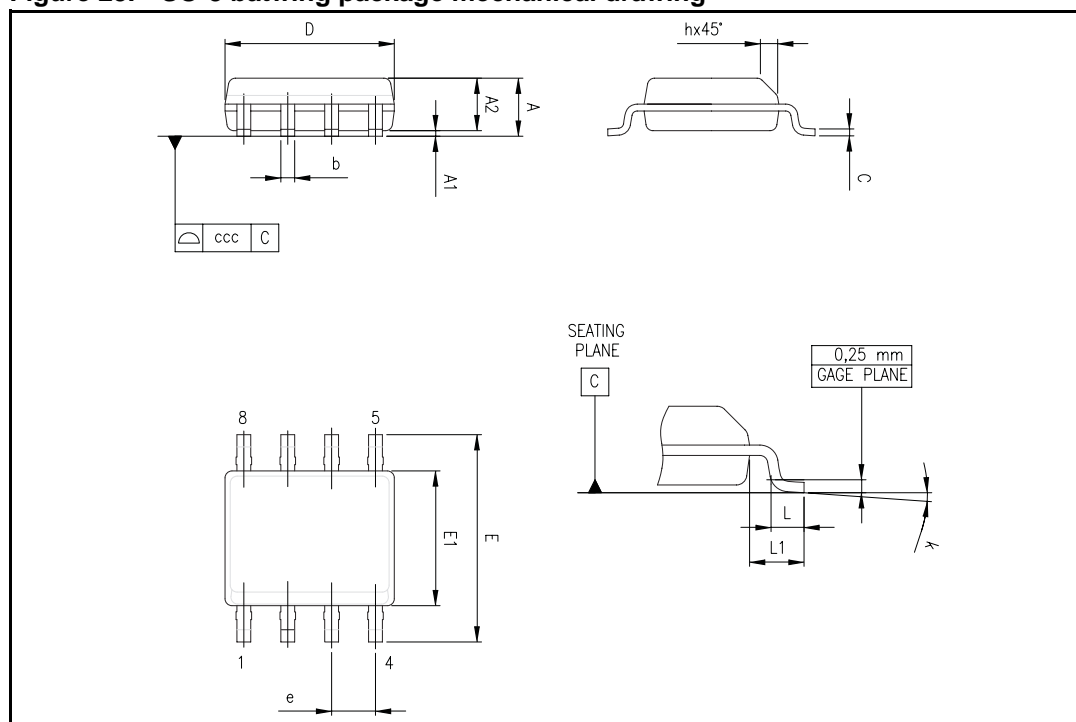


Table 5. SO-8 batwing package mechanical data

| 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 |
| k | 1° | | 8° | 1° | | 8° |
| ccc | | | 0.10 | | | 0.004 |

5.2 TO92 (ammopack and tape and reel) package information

Figure 24. TO-92 ammopack and tape and reel package mechanical drawing

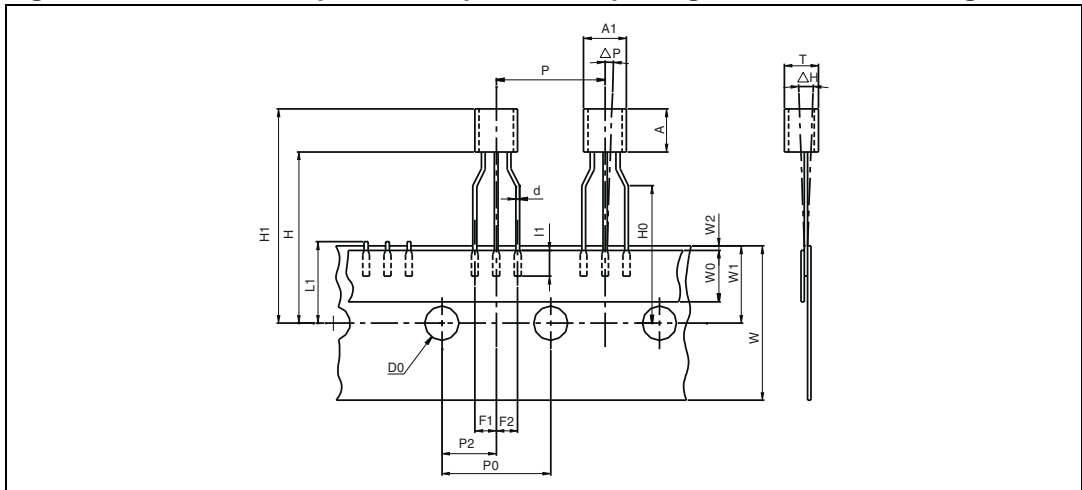


Table 6. TO-92 ammopack and tape and reel package mechanical data

| 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 | |
| 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 |

5.3 TO92 (bulk) package information

Figure 25. TO-92 bulk package mechanical drawing

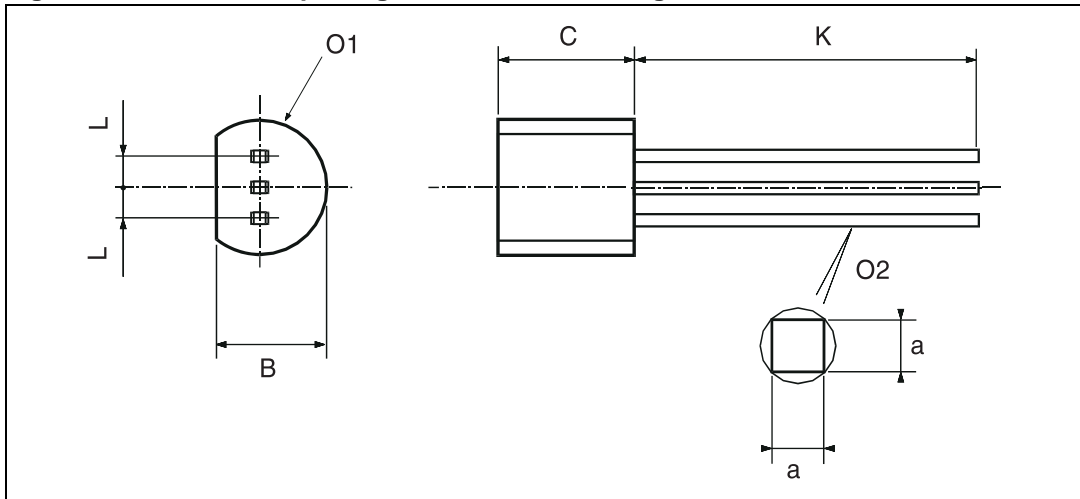


Table 7. TO-92 bulk package mechanical data

| 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 | | |

6 Ordering information

Table 8. Order codes

| Order code | Temperature range | Package | Packing | Marking |
|---|-------------------|----------------------------|--------------------------------|----------|
| TL1431CD TL1431CDT | -20°C, +70°C | SO-8 | Tube or tape and reel | 1431C |
| TL1431ACD TL1431ACDT | | | | 1431AC |
| TL1431CZ TL1431CZT TL1431CZ-AP | | TO92 | Bulk or Tape or Ammopack | TL1431C |
| TL1431ACZ TL1431ACZT TL1431ACZ-AP | | | | TL1431AC |
| TL1431ID TL1431IDT | -40°C, + 105°C | SO-8 | Tube or tape and reel | 1431I |
| TL1431AID TL1431AIDT | | | | 1431AI |
| TL1431IZ TL1431IZT TL1431IZ-AP | | TO92 | Bulk or Tape or Ammopack | TL1431I |
| TL1431AIZ TL1431AIZT TL1431AIZ-AP | | | | TL1431AI |
| TL1431IYD ⁽¹⁾ TL1431IYDT ⁽¹⁾ | | SO-8 (Automotive grade) | Tube or tape and reel | 1431IY |

1. Qualification and characterization according to AEC Q100 and Q003 or equivalent, advanced screening according to AEC Q001 and Q 002 or equivalent are on-going.

7 Revision history

Table 9. Document revision history

| Date | Revision | Changes |
|-------------|----------|---|
| 01-Mar-2002 | 1 | Initial release. |
| 01-Nov-2005 | 2 | PPAP references inserted in the datasheet see Table 8: Order codes on page 14 . |
| 25-Apr-2007 | 3 | <p>Minimum value for temperature range updated in Table 2: Operating conditions.</p> <p>Minimum values added and maximum values deleted for $\frac{\Delta V_{ref}}{\Delta V_{ka}}$ parameter in Table 4 in Section 3: Electrical characteristics.</p> <p>Package information for TO92 tape and reel updated, see Section 5: Package information.</p> <p>Format update.</p> |
| 11-Mar-2008 | 4 | <p>Corrected SO-8 package mechanical data.</p> <p>Corrected footnote for automotive grade order codes in order code table.</p> <p>Corrected packing information for TO92 devices in order code table.</p> |

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