

## PROGRAMMABLE VOLTAGE REFERENCE

- ADJUSTABLE OUTPUT VOLTAGE :  
2.5 to 36V
- SINK CURRENT CAPABILITY : 1 to 100mA
- TYPICAL OUTPUT IMPEDANCE :  $0.22\Omega$
- 1% AND 2% VOLTAGE PRECISION

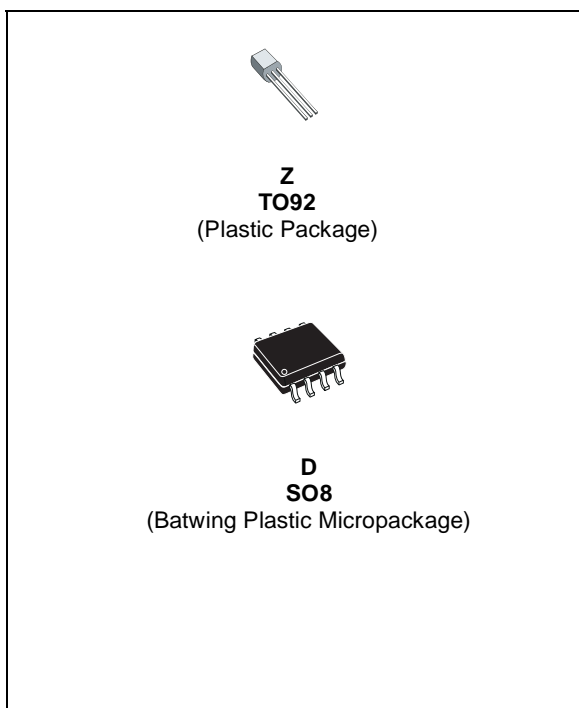
### DESCRIPTION

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  $0.22\Omega$ .

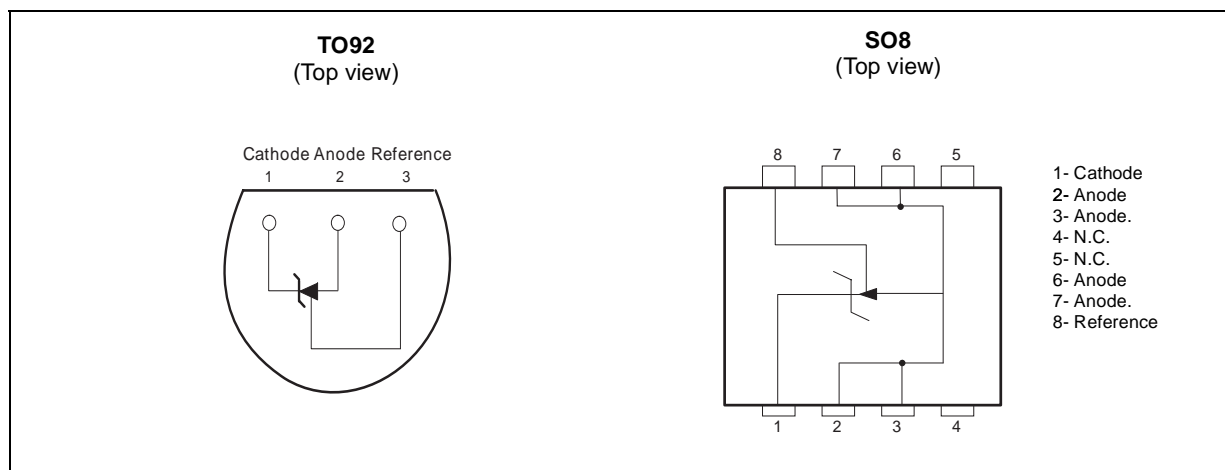
### ORDER CODE

| Part Number | Temperature Range | Package |   |
|-------------|-------------------|---------|---|
|             |                   | Z       | D |
| TL431C/AC   | 0°C, +70°C        | •       | • |
| TL431I/AI   | -40°C, +105°C     | •       | • |

Z = TO92 Plastic package - also available in Bulk (Z), Tape & Reel (ZT) and Ammo Pack (AP)  
D = Small Outline Package (SO) - also available in Tape & Reel (DT)



### PIN CONNECTIONS (top view)



**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 <sup>1)</sup><br>TO92<br>SO8 batwing | 625<br>960   | mW   |
| $T_{stg}$ | Storage Temperature Range                              | -65 to +150  | °C   |

1.  $P_d$  is calculated with  $T_{amb} = +25^{\circ}C$ ,  $T_j = +150^{\circ}C$  and  $R_{thja} = 200^{\circ}C/W$  for TO92 package  
 $= 130^{\circ}C/W$  for SO8 batwing package

**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<br>TL431I/AI | 0 to +70<br>-40 to +105 | °C   |

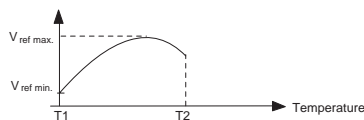
**ELECTRICAL CHARACTERISTICS**

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

| Symbol                                 | Parameter  | TL431C        |            |               | TL431AC       |            |               | Unit          |
|--|--|---------------|------------|---------------|---------------|------------|---------------|---------------|
|  |  | Min.          | Typ.       | Max.          | Min.          | Typ.       | Max.          |               |
| $V_{ref}$                              | Reference Input Voltage<br>$V_{KA} = V_{ref}$ , $I_k = 10\text{ mA}$ $T_{amb} = 25^{\circ}C$<br>$T_{min} \leq T_{amb} \leq T_{max}$  | 2.44<br>2.423 | 2.495      | 2.55<br>2.567 | 2.47<br>2.453 | 2.495      | 2.52<br>2.537 | V             |
| $\Delta V_{ref}$                       | Reference Input Voltage Deviation Over-Temperature Range - note 1<br>$V_{KA} = V_{ref}$ , $I_k = 10\text{ mA}$ , $T_{min} \leq T_{amb} \leq T_{max}$   |               | 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 - (figure 2)<br>$I_k = 10\text{ mA}$<br>$\Delta V_{KA} = 10\text{V to } V_{ref}$<br>$\Delta V_{KA} = 36\text{V to } 10\text{V}$ |               | -1.4<br>-1 | -2.7<br>-2    |               | -1.4<br>-1 | -2.7<br>-2    | mV/V          |
| $I_{ref}$                              | Reference Input Current<br>$I_k = 10\text{ mA}$ , $R_1 = 10\text{ k}\Omega$ , $R_2 = \infty$<br>$T_{amb} = 25^{\circ}C$<br>$T_{min} \leq T_{amb} \leq T_{max}$   |               | 1.8        | 4<br>5.2      |               | 1.8        | 4<br>5.2      | $\mu\text{A}$ |
| $\Delta I_{ref}$                       | Reference Input Current Deviation Over Temperature Range<br>$I_k = 10\text{ mA}$ , $R_1 = 10\text{ k}\Omega$ , $R_2 = \infty$<br>$T_{min} \leq T_{amb} \leq T_{max}$   |               | 0.4        | 1.2           |               | 0.4        | 1.2           | $\mu\text{A}$ |
| $I_{min}$                              | Minimum Cathode Current for Regulation<br>$V_{KA} = V_{ref}$   |               | 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 - note 2<br>$V_{KA} = V_{ref}$ , $\Delta I_k = 1\text{ to }100\text{ mA}$ , $f \leq 1\text{ kHz}$  |               | 0.22       | 0.5           |               | 0.22       | 0.5           | $\Omega$      |

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

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



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

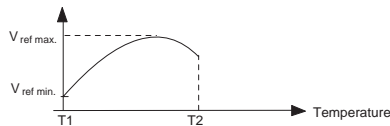


**ELECTRICAL CHARACTERISTICS**

T<sub>amb</sub> = 25°C (unless otherwise specified)

| Symbol                                 | Parameter  | TL431I       |            |              | TL431AI      |            |              | Unit |
|--|--|--------------|------------|--------------|--------------|------------|--------------|------|
|  |  | Min.         | Typ.       | Max.         | Min.         | Typ.       | Max.         |      |
| V <sub>ref</sub>                       | Reference Input Voltage<br>V <sub>KA</sub> = V <sub>ref</sub> , I <sub>k</sub> = 10 mA, T <sub>amb</sub> = 25°C<br>T <sub>min</sub> ≤ T <sub>amb</sub> ≤ T <sub>max</sub>                | 2.44<br>2.41 | 2.495      | 2.55<br>2.58 | 2.47<br>2.44 | 2.495      | 2.52<br>2.55 | V    |
| ΔV <sub>ref</sub>                      | Reference Input Voltage Deviation Over-Temperature Range - note 1<br>V <sub>KA</sub> = V <sub>ref</sub> , I <sub>k</sub> = 10 mA, T <sub>min</sub> ≤ T <sub>amb</sub> ≤ T <sub>max</sub> |              | 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<br>I <sub>k</sub> = 10mA, ΔV <sub>KA</sub> = 10V to V <sub>ref</sub><br>ΔV <sub>KA</sub> = 36V to 10V   |              | -1.4<br>-1 | -2.7<br>-2   |              | -1.4<br>-1 | -2.7<br>-2   | mV/V |
| I <sub>ref</sub>                       | Reference Input Current<br>I <sub>k</sub> = 10mA, R1 = 10kΩ, R2 = ∞<br>T <sub>amb</sub> = 25°C<br>T <sub>min</sub> ≤ T <sub>amb</sub> ≤ T <sub>max</sub>                                 |              | 1.8        | 4<br>6.5     |              | 1.8        | 4<br>6.5     | μA   |
| ΔI <sub>ref</sub>                      | Reference Input Current Deviation Over Temperature Range<br>I <sub>k</sub> = 10mA, R1 = 10kΩ, R2 = ∞<br>T <sub>min</sub> ≤ T <sub>amb</sub> ≤ T <sub>max</sub>                           |              | 0.8        | 2.5          |              | 0.8        | 1.2          | μA   |
| I <sub>min</sub>                       | Minimum Cathode Current for Regulation<br>V <sub>KA</sub> = V <sub>ref</sub>   |              | 0.5        | 1            |              | 0.5        | 0.7          | mA   |
| I <sub>off</sub>                       | Off-State Cathode Current  |              | 2.6        | 1000         |              | 2.6        | 1000         | nA   |
| Z <sub>KA</sub>                        | Dynamic Impedance note 2<br>V <sub>KA</sub> = V <sub>ref</sub> , ΔI <sub>k</sub> = 1 to 100mA, f ≤ 1kHz  |              | 0.22       | 0.5          |              | 0.22       | 0.5          | Ω    |

1) ΔV<sub>ref</sub> is defined as the difference between the maximum and minimum values obtained over the full temperature range.  
ΔV<sub>ref</sub> = V<sub>ref max.</sub> - V<sub>ref min.</sub>



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

Figure 1 : Test Circuit for  $V_{KA} = V_{REF}$

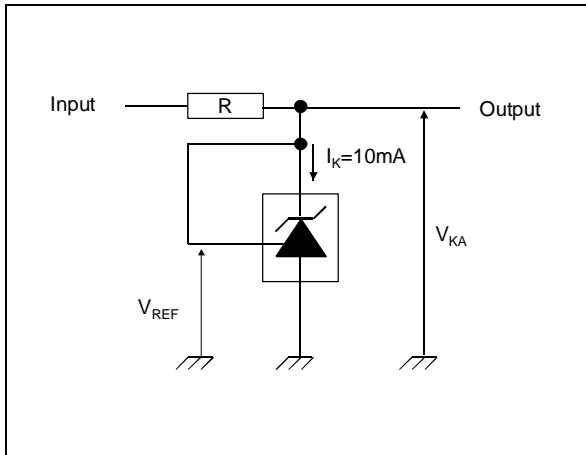


Figure 3 : Test Circuit for  $I_{OFF}$

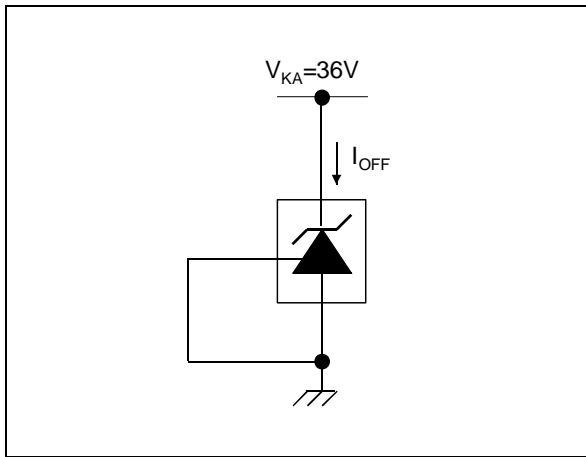


Figure 5 : Block diagram of TL431

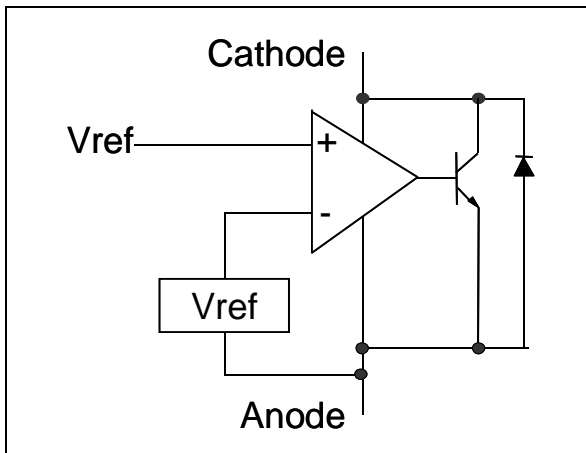


Figure 2 : Test Circuit for  $V_{KA} > V_{REF}$

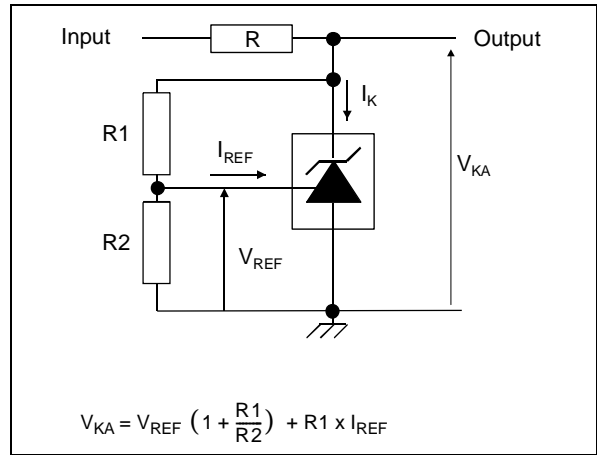


Figure 4 : Test Circuit for Phase Margin and Voltage Gain

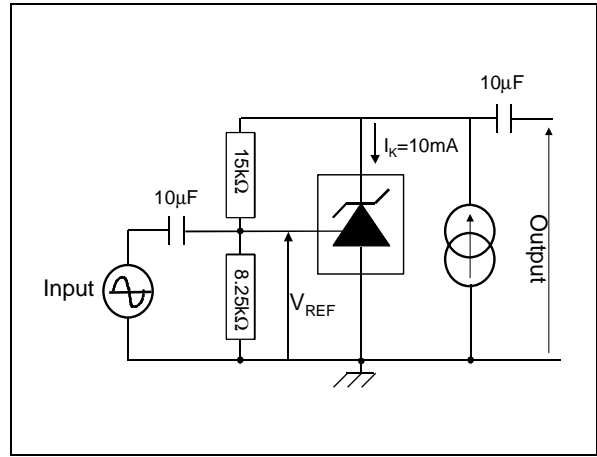
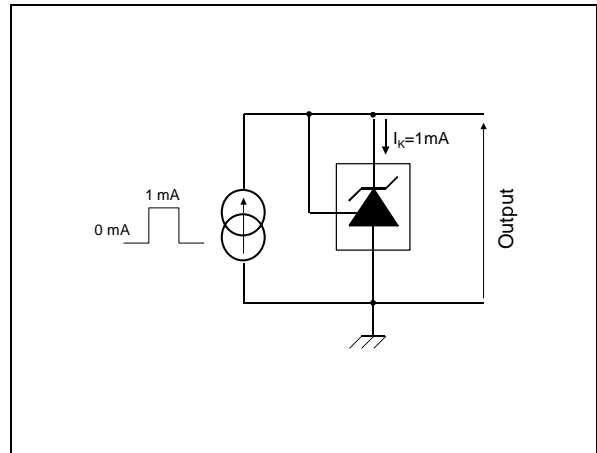
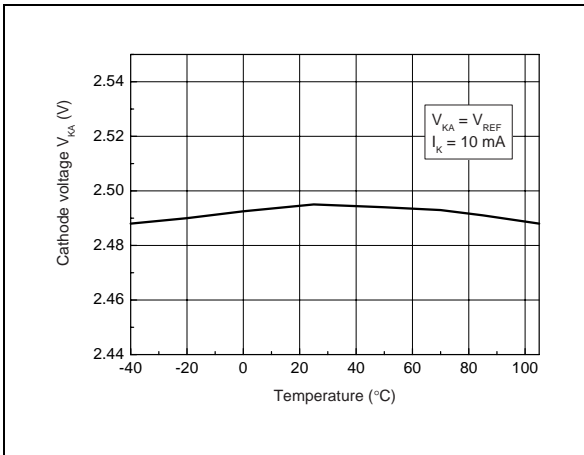


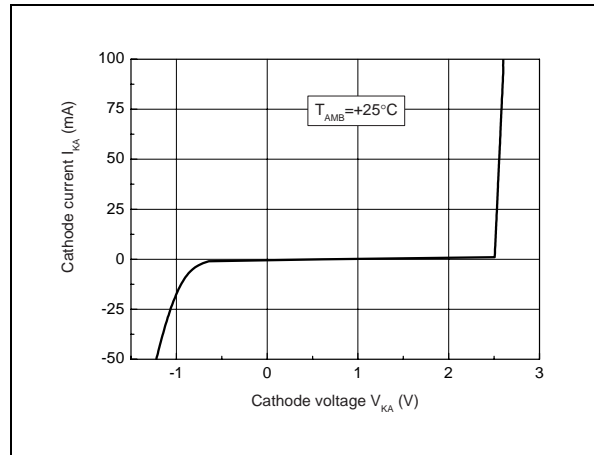
Figure 6 : Test Circuit for Response time



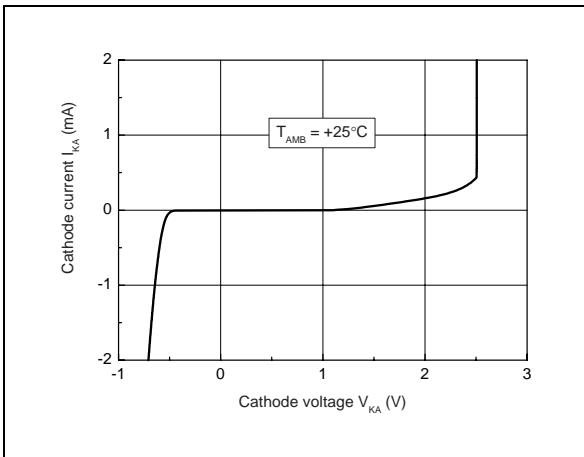
Reference voltage vs Temperature



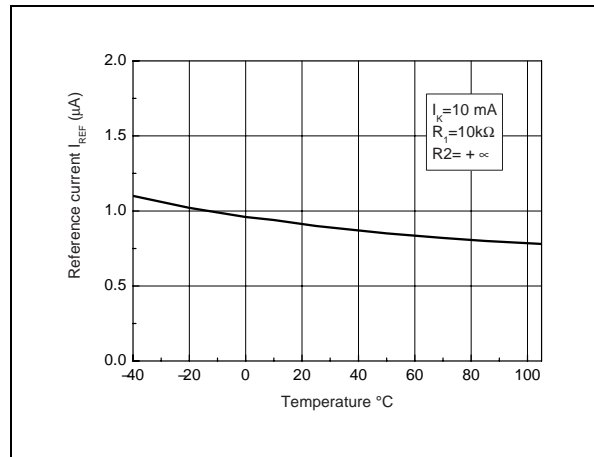
Reference voltage vs cathode current



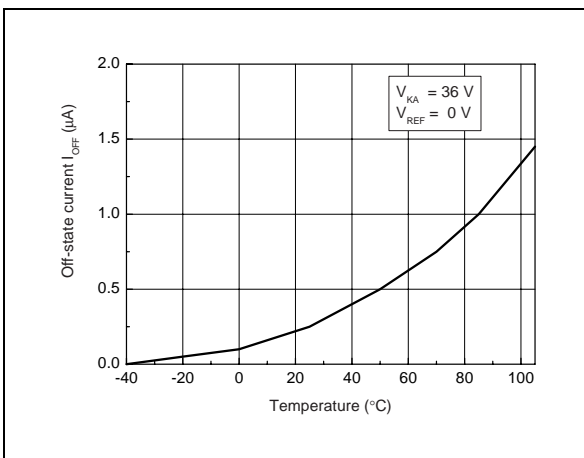
Reference voltage vs cathode current



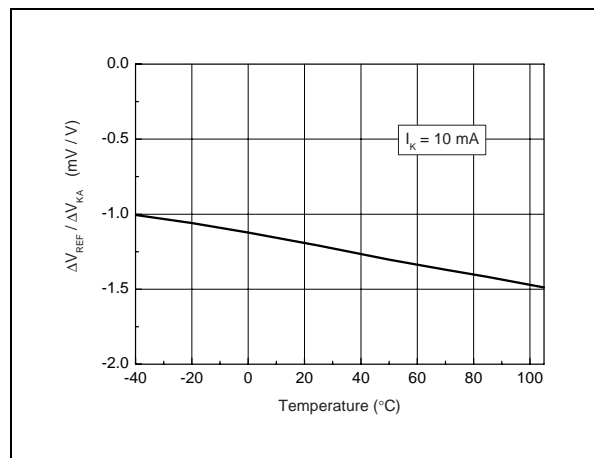
Reference current vs temperature



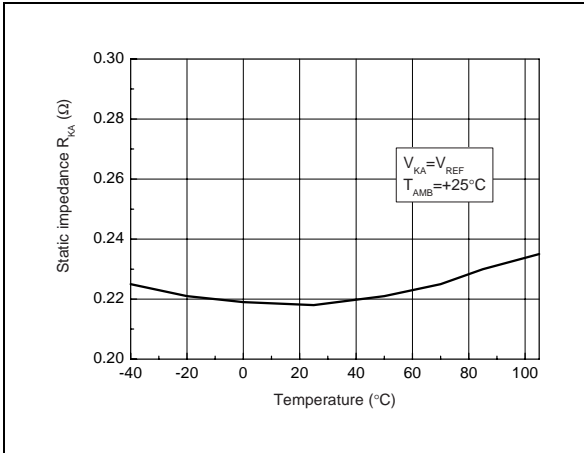
Off-state cathode current vs temperature



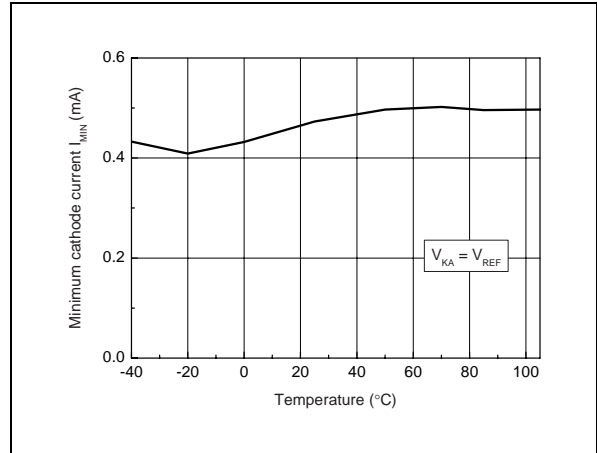
Ratio of change in  $V_{REF}$  to change in  $V_{KA}$  vs Temperature



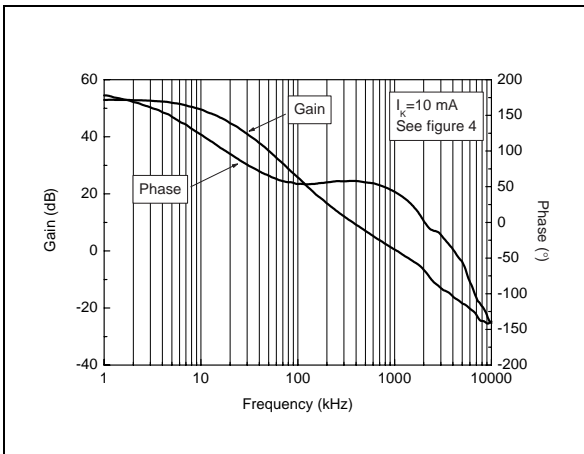
Static impedance  $R_{KA}$  vs Temperature



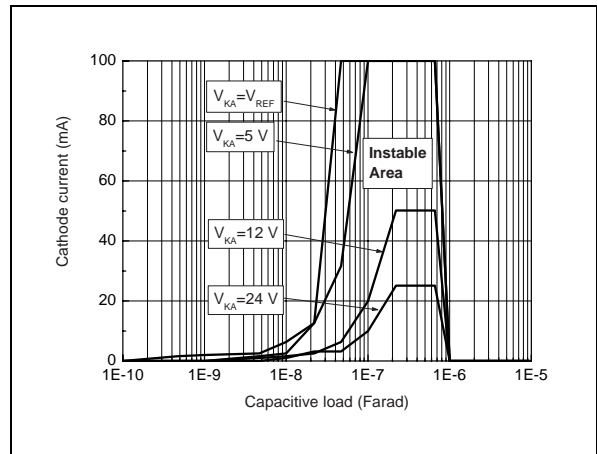
Minimum operating current vs temperature



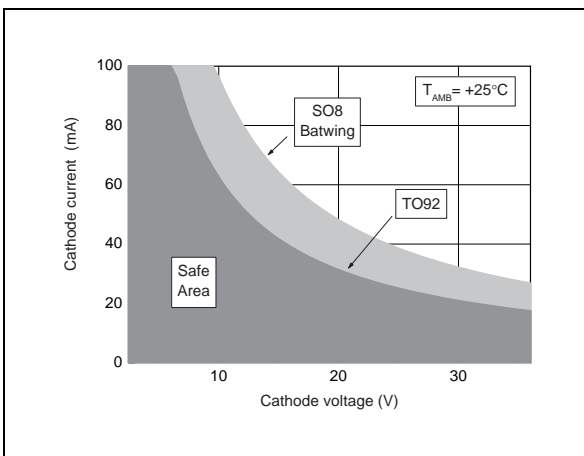
Gain & Phase vs Frequency



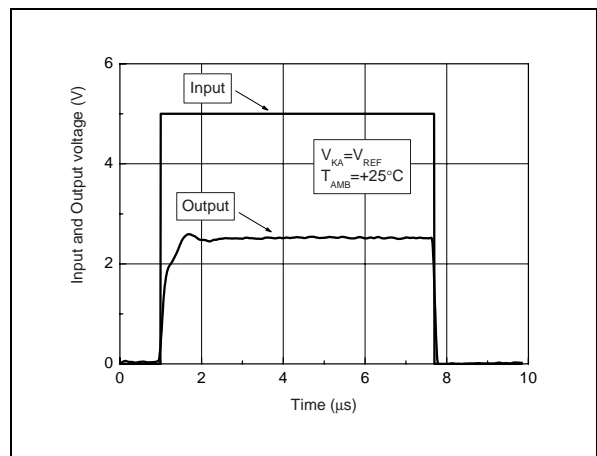
Stability behaviour with capacitive loads



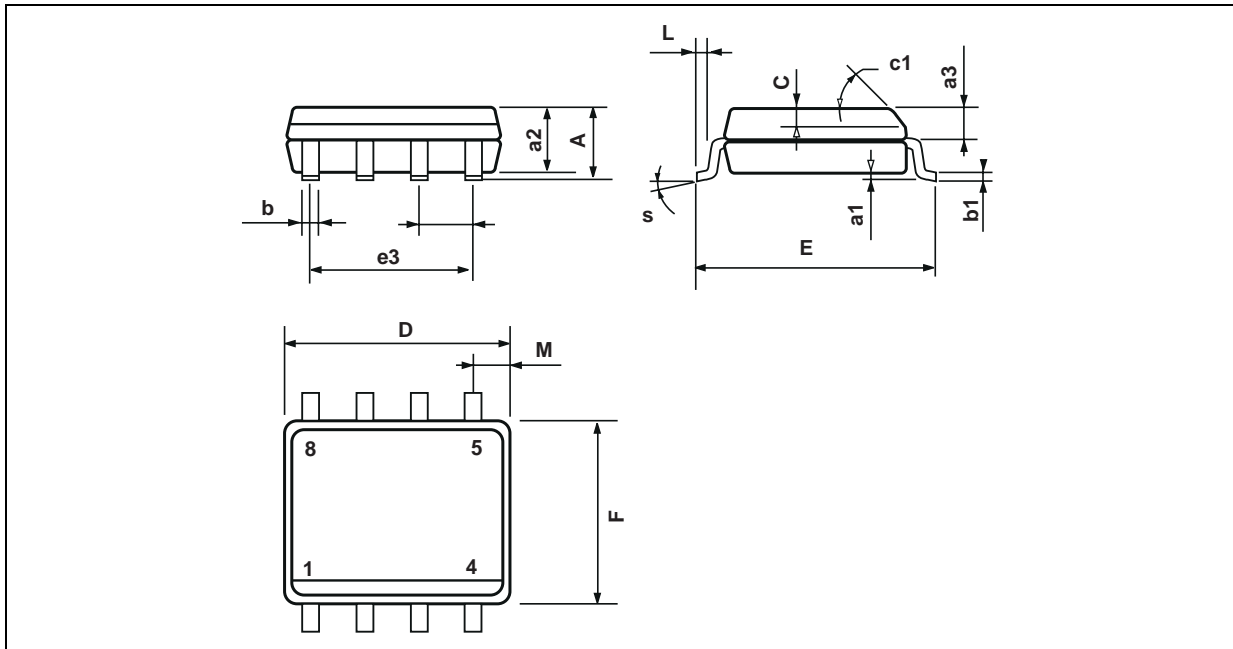
Maximum Power dissipation



Pulse response for  $I_K=1mA$

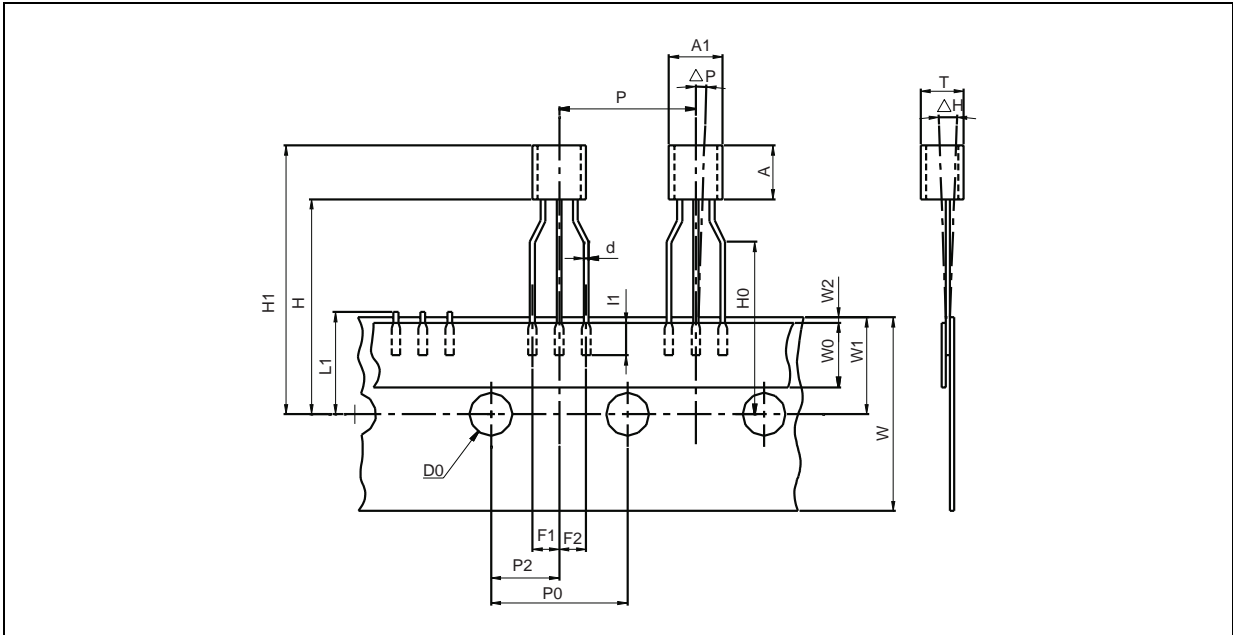


**PACKAGE MECHANICAL DATA**  
**8 PINS - BATWING PLASTIC MICROPACKAGE (SO)**



| Dim. | Millimeters |      |      | Inches |       |       |
|------|-------------|------|------|--------|-------|-------|
|      | Min.        | Typ. | Max. | Min.   | Typ.  | Max.  |
| A    |             |      | 1.75 |        |       | 0.069 |
| a1   | 0.1         |      | 0.25 | 0.004  |       | 0.010 |
| a2   |             |      | 1.65 |        |       | 0.065 |
| a3   | 0.65        |      | 0.85 | 0.026  |       | 0.033 |
| b    | 0.35        |      | 0.48 | 0.014  |       | 0.019 |
| b1   | 0.19        |      | 0.25 | 0.007  |       | 0.010 |
| C    | 0.25        |      | 0.5  | 0.010  |       | 0.020 |
| c1   | 45° (typ.)  |      |      |        |       |       |
| D    | 4.8         |      | 5.0  | 0.189  |       | 0.197 |
| E    | 5.8         |      | 6.2  | 0.228  |       | 0.244 |
| e    |             | 1.27 |      |        | 0.050 |       |
| e3   |             | 3.81 |      |        | 0.150 |       |
| F    | 3.8         |      | 4.0  | 0.150  |       | 0.157 |
| L    | 0.4         |      | 1.27 | 0.016  |       | 0.050 |
| M    |             |      | 0.6  |        |       | 0.024 |
| S    | 8° (max.)   |      |      |        |       |       |

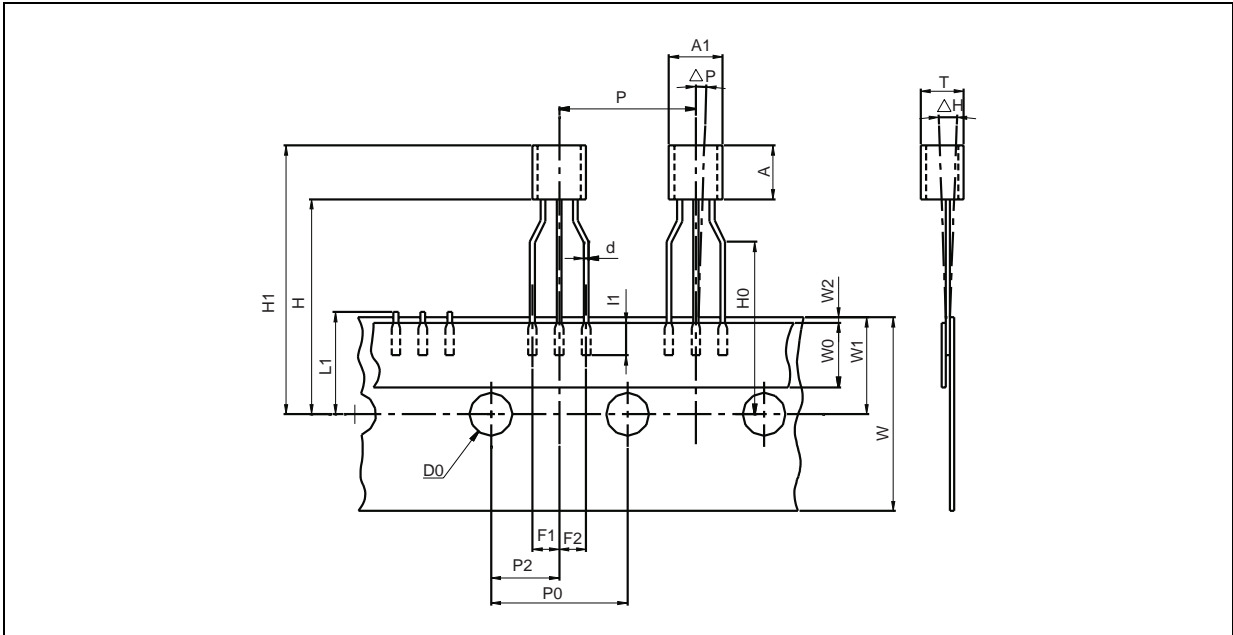
**PACKAGE MECHANICAL DATA**  
**3 PINS - PLASTIC PACKAGE TO92 (TAPE & REEL)**



| 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 |

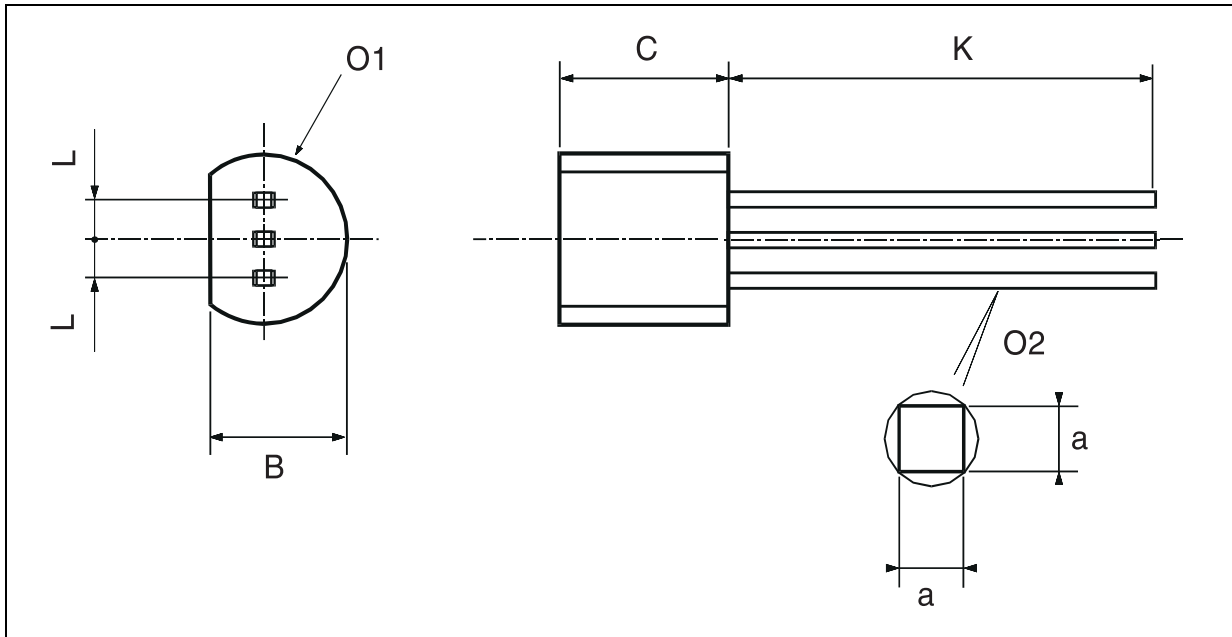


**PACKAGE MECHANICAL DATA**  
**3 PINS - PLASTIC PACKAGE TO92 (TAPE AMMO PACK)**



| 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 |

**PACKAGE MECHANICAL DATA**  
**3 PINS - PLASTIC PACKAGE TO92 (BULK)**



| 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 |        |        |

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