

**Programmable voltage reference**

Datasheet – production data

**Features**

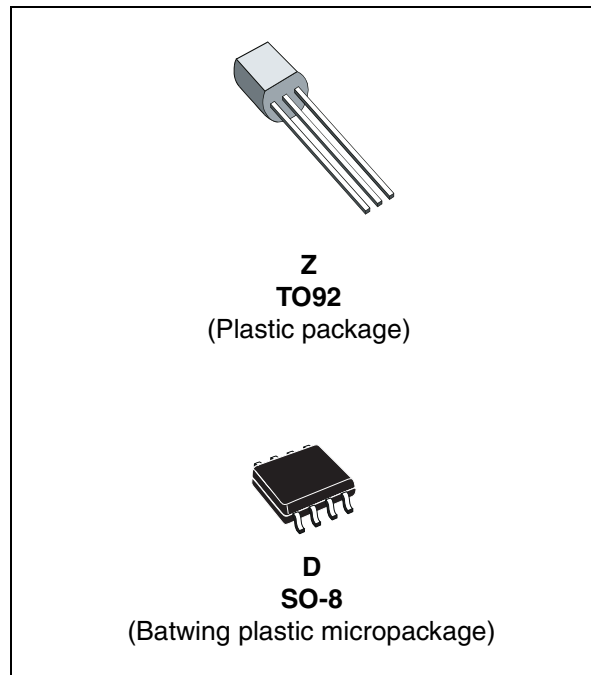
- Adjustable output voltage:  $V_{REF}$  to 36 V
- Sink current capability: 1 to 100 mA
- Typical output impedance: 0.22  $\Omega$
- 0.4% and 0.25% voltage precision
- Automotive temp. range - 40 °C to +125 °C

**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  $\Omega$ .



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# 1 Schematic diagrams

Figure 1. T092 pin connections (top view)

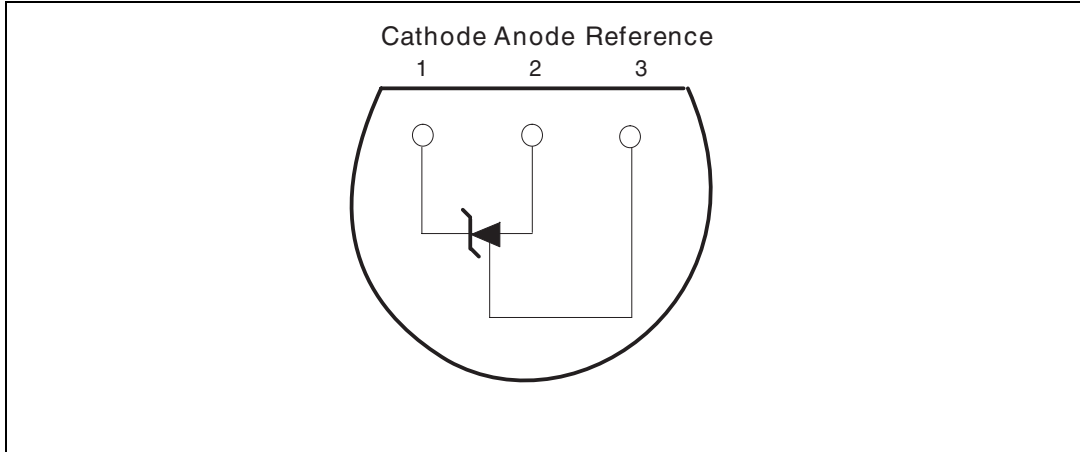


Figure 2. SO-8 pin connections (top view)

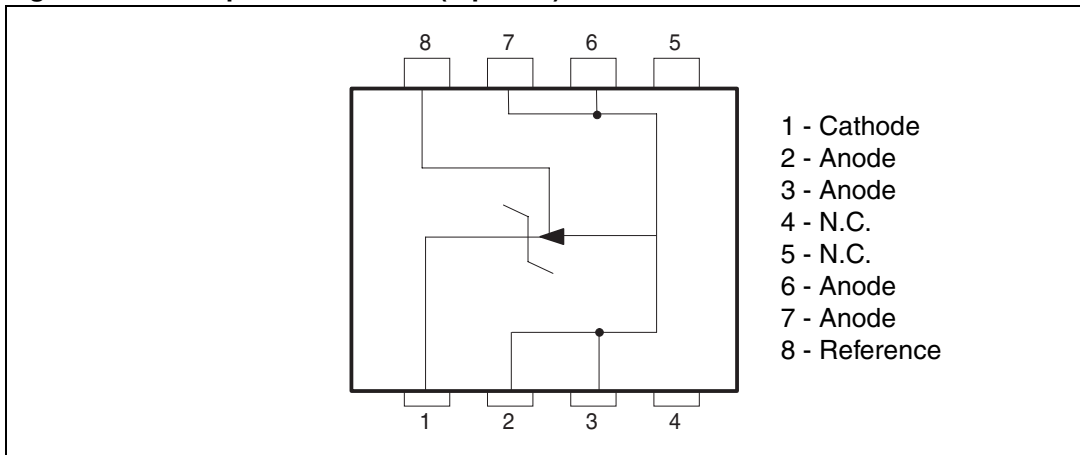
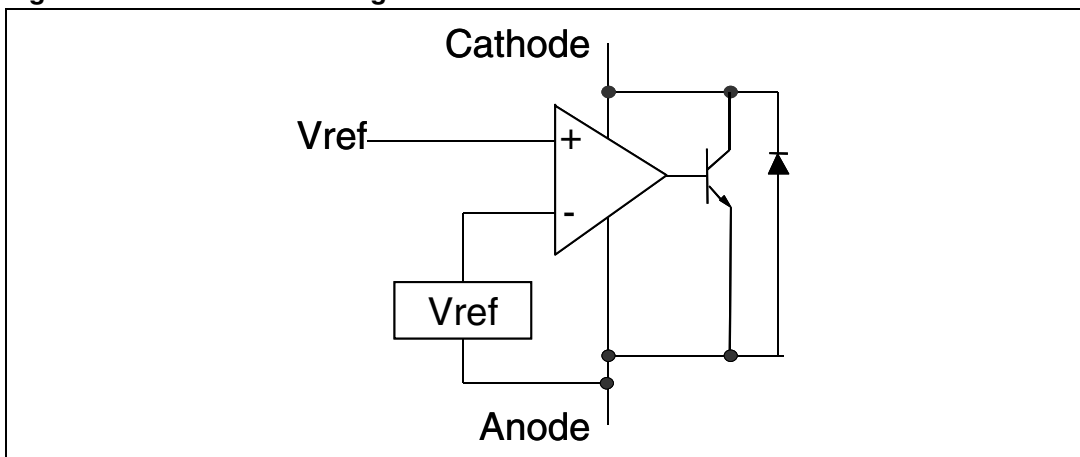


Figure 3. TL1431 block diagram



## 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 <sup>(1)</sup>		
	TO92 SO-8 batwing	625 960	mW
$T_{stg}$	Storage temperature range	-65 to +150	°C
ESD	HBM: human body model <sup>(2)</sup>	2000	V
	MM: machine model <sup>(3)</sup>	200	
	CDM: charged device model <sup>(4)</sup>	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 kΩ 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	-20 to +70	
	TL1431I/AI TL1431IY/AIY	-40 to +105 -40 to +125	
$R_{thja}$	Thermal resistance junction to ambient		°C/W
	SO-8 batwing TO92	130 200	

### 3 Electrical characteristics

$T_{amb} = 25\text{ °C}$  (unless otherwise specified).

**Table 3. Electrical characteristics for TL1431C, TL1431AC**

Symbol	Parameter	TL1431C			TL1431AC			Unit
		Min.	Typ.	Max.	Min.	Typ.	Max.	
$V_{ref}$	Reference input voltage - see <a href="#">Figure 4</a> $V_{KA} = V_{ref}$ , $I_k = 10\text{ mA}$	2.490	2.500	2.510	2.493	2.500	2.507	V
$\Delta V_{ref}$	Reference input voltage deviation over temperature range <sup>(1)</sup> - see <a href="#">Figure 4</a> $V_{KA} = V_{ref}$ , $I_k = 10\text{ mA}$ , $T_{min} \leq T_{amb} \leq T_{max}$		3	20		3	20	mV
$\frac{\Delta V_{ref}}{\Delta T}$	Temperature coefficient of reference input voltage <sup>(2)</sup> $V_{KA} = V_{ref}$ , $I_k = 10\text{ mA}$ , $T_{min} \leq T_{amb} \leq T_{max}$		$\pm 13$	$\pm 90$		$\pm 13$	$\pm 90$	ppm/°C
$\frac{\Delta V_{ref}}{\Delta V_{ka}}$	Ratio of change in reference input voltage to change in cathode to anode voltage - see <a href="#">Figure 5</a> $I_k = 10\text{ mA}$ - $\Delta V_{KA} = 36\text{ V}$ to $3\text{ V}$	-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	$\mu\text{A}$
$\Delta I_{ref}$	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	$\mu\text{A}$
$I_{min}$	Minimum cathode current for regulation - <a href="#">Figure 4</a> $V_{KA} = V_{ref}$		0.5	1		0.5	0.6	mA
$I_{off}$	Off-state cathode current - see <a href="#">Figure 6</a>		180	500		180	500	nA
$ Z_{KA} $	Dynamic impedance <sup>(3)</sup> $V_{KA} = V_{ref}$ , $\Delta I_k = 1\text{ to }100\text{ mA}$ , $f \leq 1\text{ kHz}$		0.2	0.5		0.2	0.5	$\Omega$

1. See [Reference input voltage deviation over temperature range](#) in [Section 4: Parameter definitions on page 11](#).

2. See [Temperature coefficient of reference input voltage](#) in [Section 4: Parameter definitions on page 11](#).

3. See [Dynamic impedance](#) in [Section 4: Parameter definitions on page 11](#).

$T_{amb} = 25\text{ °C}$  (unless otherwise specified).

**Table 4. Electrical characteristics for TL1431I, TL1431AI**

Symbol	Parameter	TL1431I			TL1431AI			Unit
		Min.	Typ.	Max.	Min.	Typ.	Max.	
$V_{ref}$	Reference input voltage - see <a href="#">Figure 4</a> $V_{KA} = V_{ref}$ , $I_k = 10\text{ mA}$	2.490	2.500	2.510	2.493	2.500	2.507	V
$\Delta V_{ref}$	Reference input voltage deviation over temperature range <sup>(1)</sup> - see <a href="#">Figure 4</a> $V_{KA} = V_{ref}$ , $I_k = 10\text{ mA}$ , $T_{min} \leq T_{amb} \leq T_{max}$		7	30		7	30	mV
$\frac{\Delta V_{ref}}{\Delta T}$	Temperature coefficient of reference input voltage <sup>(2)</sup> $V_{KA} = V_{ref}$ , $I_k = 10\text{ mA}$ , $T_{min} \leq T_{amb} \leq T_{max}$		$\pm 22$	$\pm 100$		$\pm 22$	$\pm 100$	ppm/°C
$\frac{\Delta V_{ref}}{\Delta V_{ka}}$	Ratio of change in reference input voltage to change in cathode to anode voltage - see <a href="#">Figure 5</a> $I_k = 10\text{ mA}$ , $\Delta V_{KA} = 36\text{V to } 3\text{V}$	-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	$\mu\text{A}$
$\Delta I_{ref}$	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	$\mu\text{A}$
$I_{min}$	Minimum cathode current for regulation - see <a href="#">Figure 4</a> $V_{KA} = V_{ref}$		0.5	1		0.5	0.7	mA
$I_{off}$	Off-state cathode current - see <a href="#">Figure 6</a>		180	500		180	500	nA
$ Z_{KA} $	Dynamic impedance <sup>(3)</sup> $V_{KA} = V_{ref}$ , $\Delta I_k = 1\text{ to } 100\text{ mA}$ , $f \leq 1\text{ kHz}$		0.2	0.5		0.2	0.5	$\Omega$

1. See [Reference input voltage deviation over temperature range](#) in [Section 4: Parameter definitions on page 11](#).
2. See [Temperature coefficient of reference input voltage](#) in [Section 4: Parameter definitions on page 11](#).
3. See [Dynamic impedance](#) in [Section 4: Parameter definitions on page 11](#).

$T_{amb} = 25\text{ °C}$  (unless otherwise specified).

**Table 5. Electrical characteristics for TL1431IY, TL1431AIY**

Symbol	Parameter	TL1431IY			TL1431AIY			Unit
		Min.	Typ.	Max.	Min.	Typ.	Max.	
$V_{ref}$	Reference input voltage - see <a href="#">Figure 4</a> $V_{KA} = V_{ref}$ , $I_k = 10\text{ mA}$	2.490	2.500	2.510	2.493	2.500	2.507	V
$\Delta V_{ref}$	Reference input voltage deviation over temperature range <sup>(1)</sup> - see <a href="#">Figure 4</a> $V_{KA} = V_{ref}$ , $I_k = 10\text{ mA}$ , $T_{min} \leq T_{amb} \leq T_{max}$		7	30		7	30	mV
$\frac{\Delta V_{ref}}{\Delta T}$	Temperature coefficient of reference input voltage <sup>(2)</sup> $V_{KA} = V_{ref}$ , $I_k = 10\text{ mA}$ , $T_{min} \leq T_{amb} \leq T_{max}$		$\pm 22$	$\pm 100$		$\pm 22$	$\pm 100$	ppm/°C
$\frac{\Delta V_{ref}}{\Delta V_{ka}}$	Ratio of change in reference input voltage to change in cathode to anode voltage - see <a href="#">Figure 5</a> $I_k = 10\text{ mA}$ , $\Delta V_{KA} = 36\text{V to } 3\text{V}$	-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	$\mu\text{A}$
$\Delta I_{ref}$	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	$\mu\text{A}$
$I_{min}$	Minimum cathode current for regulation - see <a href="#">Figure 4</a> $V_{KA} = V_{ref}$		0.5	1		0.5	0.7	mA
$I_{off}$	Off-state cathode current - see <a href="#">Figure 6</a>		180	500		180	500	nA
$ Z_{KA} $	Dynamic impedance <sup>(3)</sup> $V_{KA} = V_{ref}$ , $\Delta I_k = 1\text{ to } 100\text{ mA}$ , $f \leq 1\text{ kHz}$		0.2	0.5		0.2	0.5	$\Omega$

1. See [Reference input voltage deviation over temperature range](#) in [Section 4: Parameter definitions on page 11](#).
2. See [Temperature coefficient of reference input voltage](#) in [Section 4: Parameter definitions on page 11](#).
3. See [Dynamic impedance](#) in [Section 4: Parameter definitions on page 11](#).

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

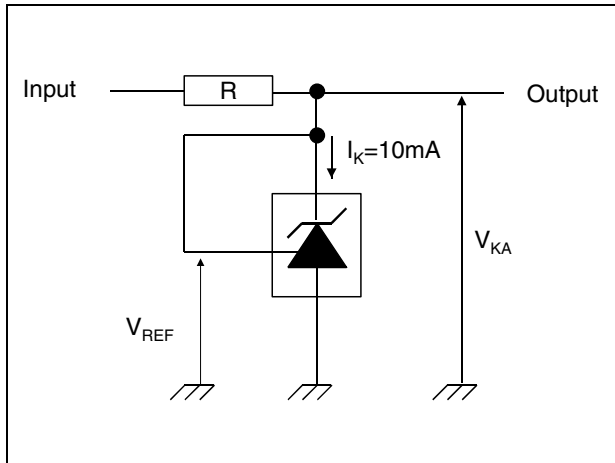


Figure 5. Test circuit for  $V_{KA} > V_{REF}$

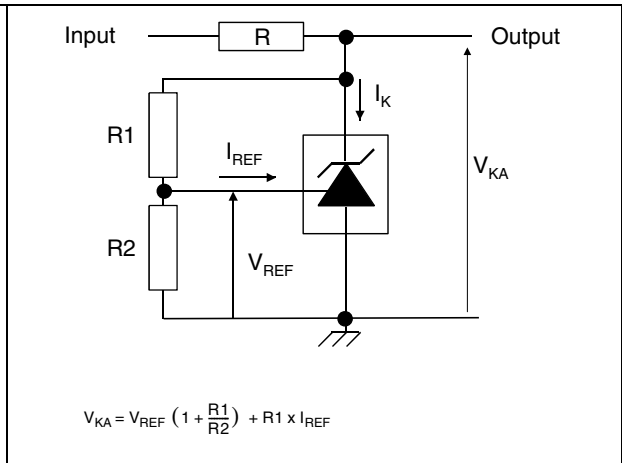


Figure 6. Test circuit for  $I_{OFF}$

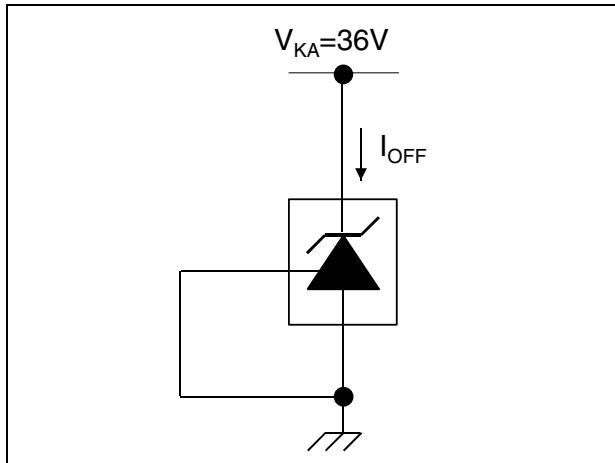


Figure 7. Test circuit for phase margin and voltage gain

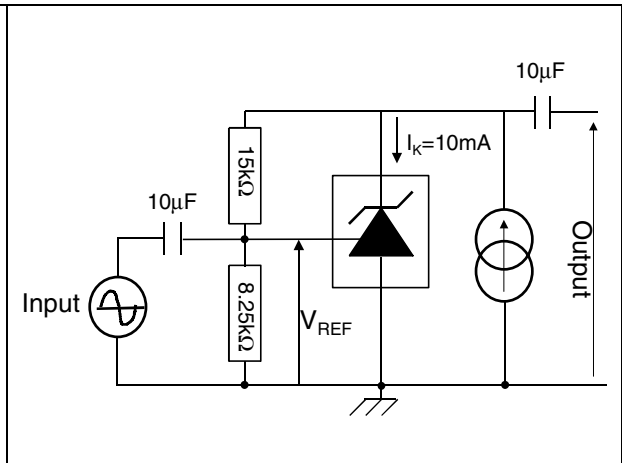


Figure 8. Test circuit for response time

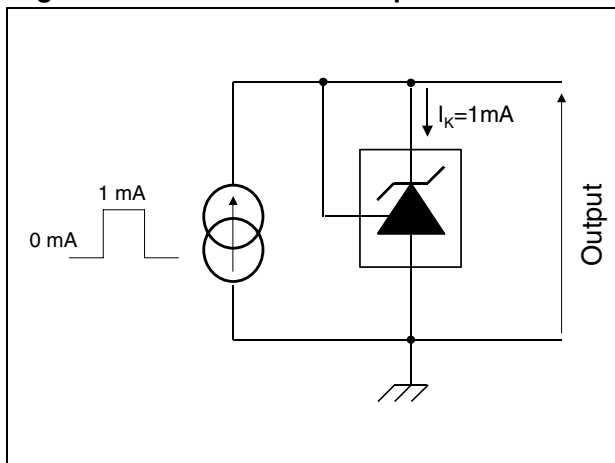


Figure 9. Reference voltage vs. temperature

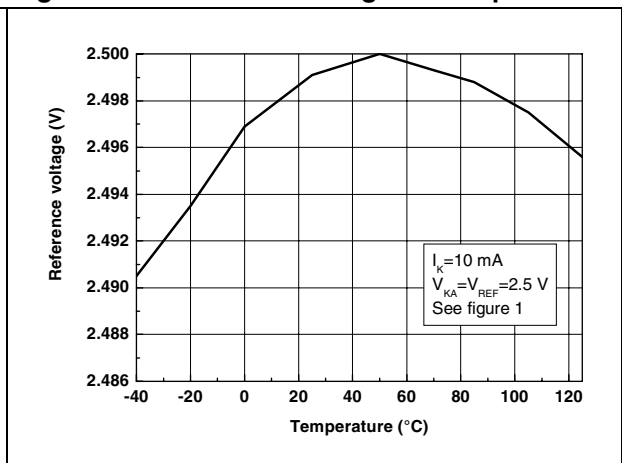




Figure 10. Reference voltage vs. cathode current

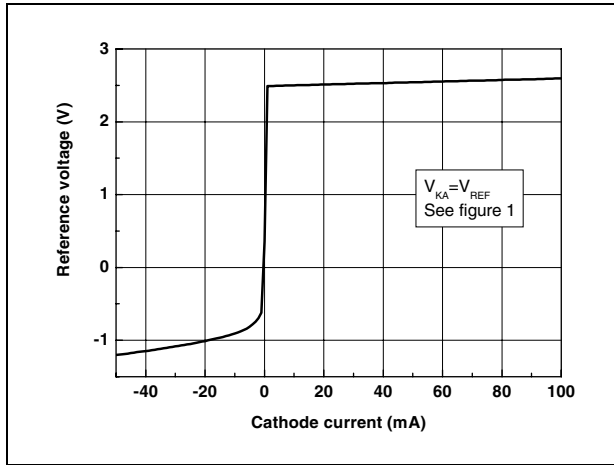


Figure 11. Reference voltage vs. cathode current ( $I_K = 0$  to 1 mA)

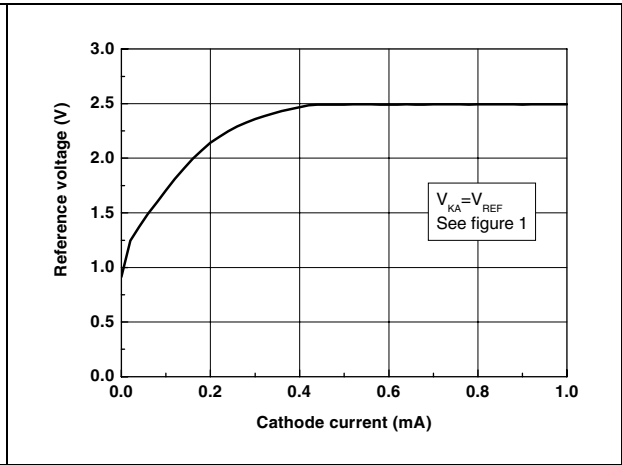


Figure 12. Reference current vs. temperature

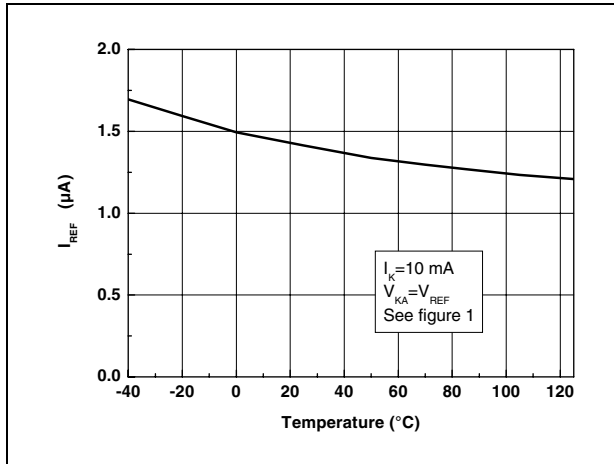


Figure 13. Off-state cathode current vs. temperature

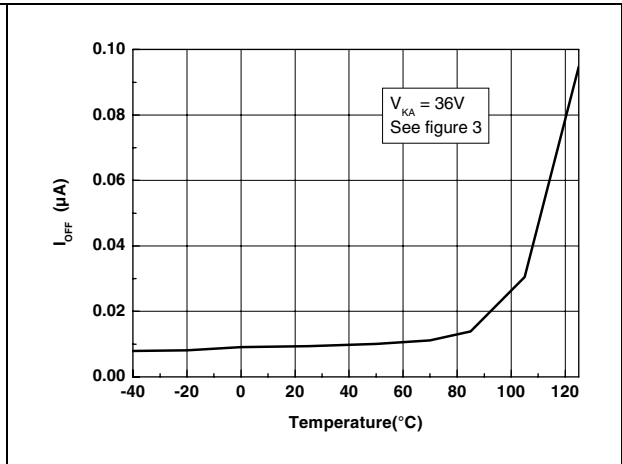


Figure 14. Ratio of change in  $V_{REF}$  to change in  $V_{KA}$  vs. temperature

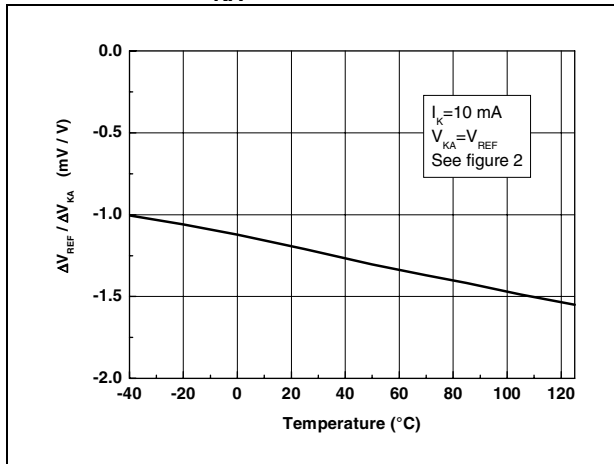


Figure 15. Drift of  $R_{KA}$  vs. temperature

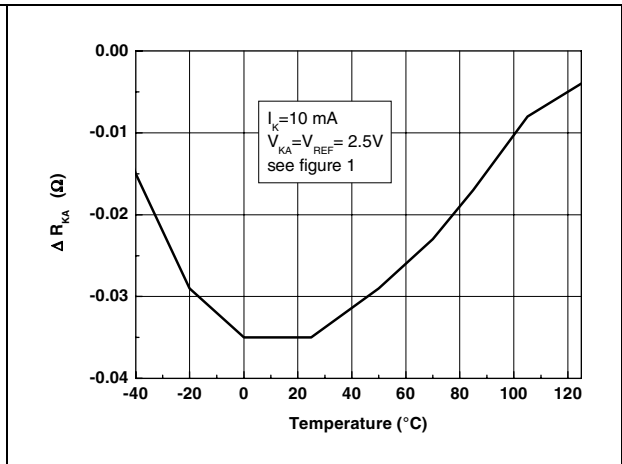


Figure 16. Maximum operating current vs. temperature

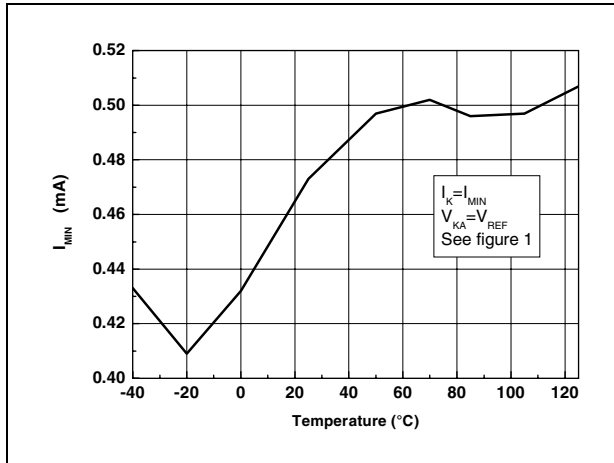


Figure 17. Gain and phase vs. frequency

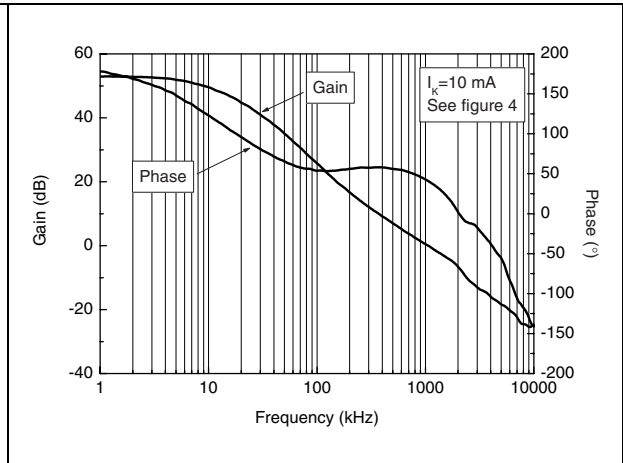


Figure 18. Stability behavior with capacitive loads

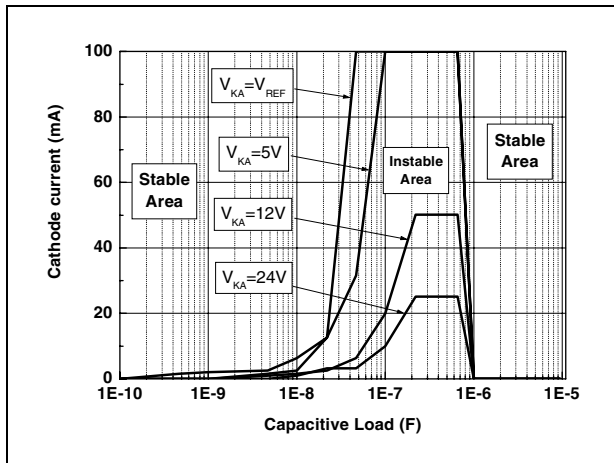


Figure 19. Maximum power dissipation

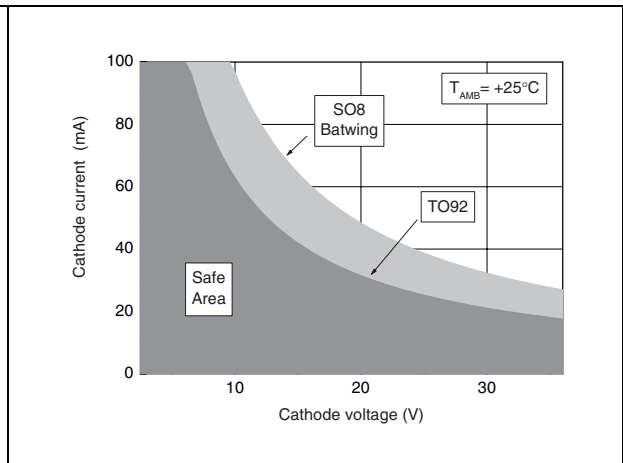
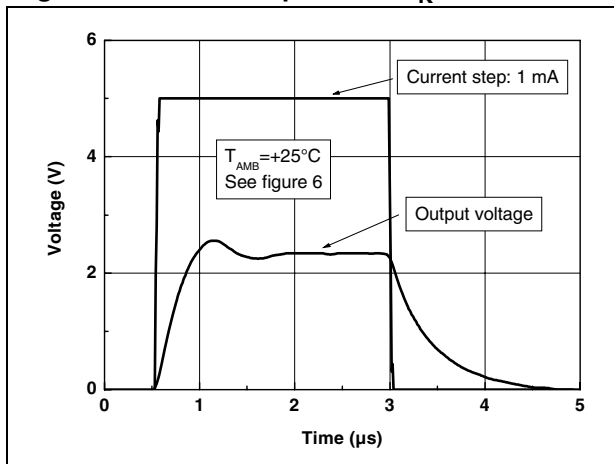


Figure 20. Pulse response for I\_K = 1 mA



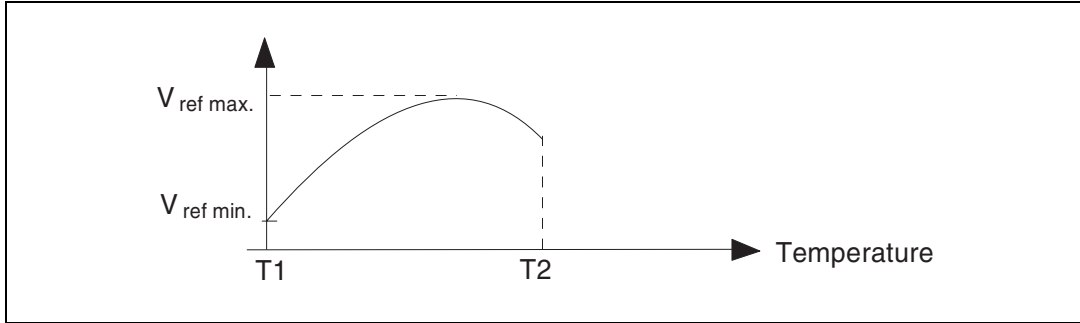
## 4 Parameter definitions

### 4.1 Reference input voltage deviation over temperature range

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

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

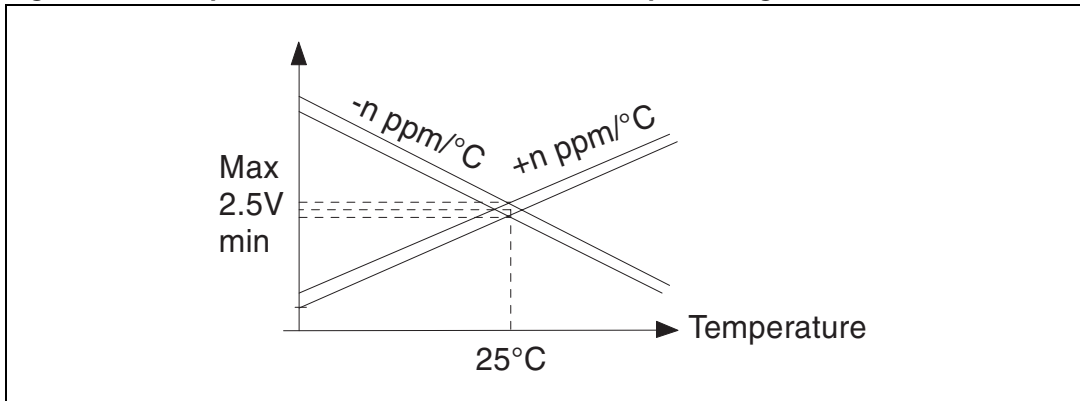
Figure 21. Reference input voltage deviation over temperature range



### 4.2 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



### 4.3 Dynamic impedance

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

## 5 Package mechanical data

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

Figure 23. SO-8 batwing package mechanical drawing

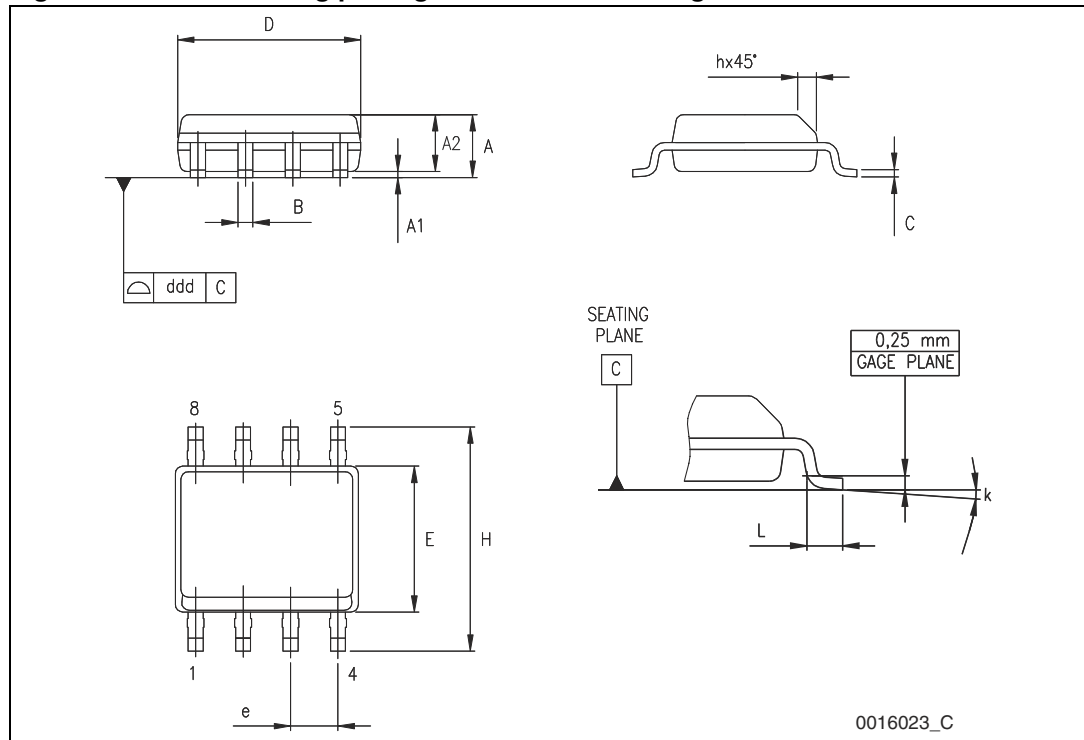


Table 6. SO-8 batwing package mechanical data

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

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

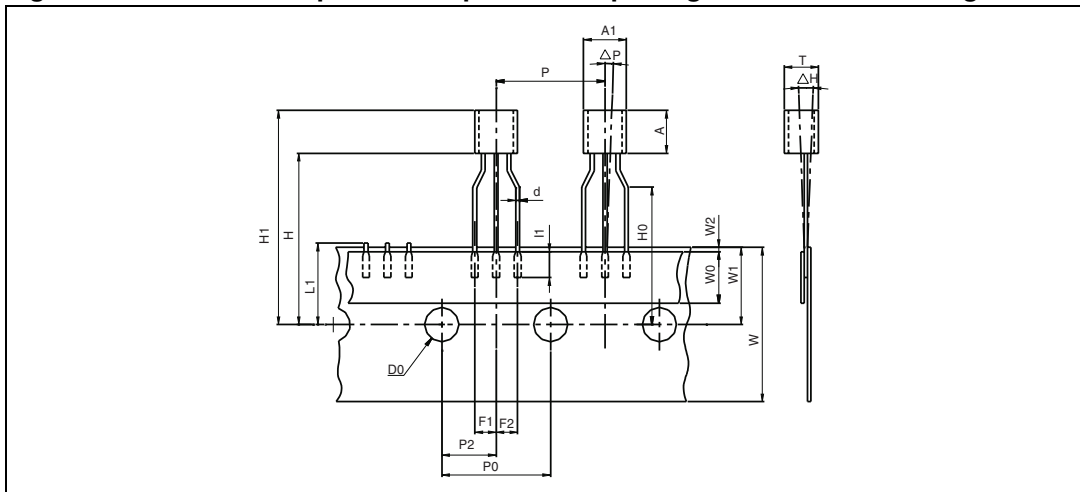


Table 7. TO-92 ammpack and tape and reel package mechanical data

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

Figure 25. TO-92 bulk package mechanical drawing

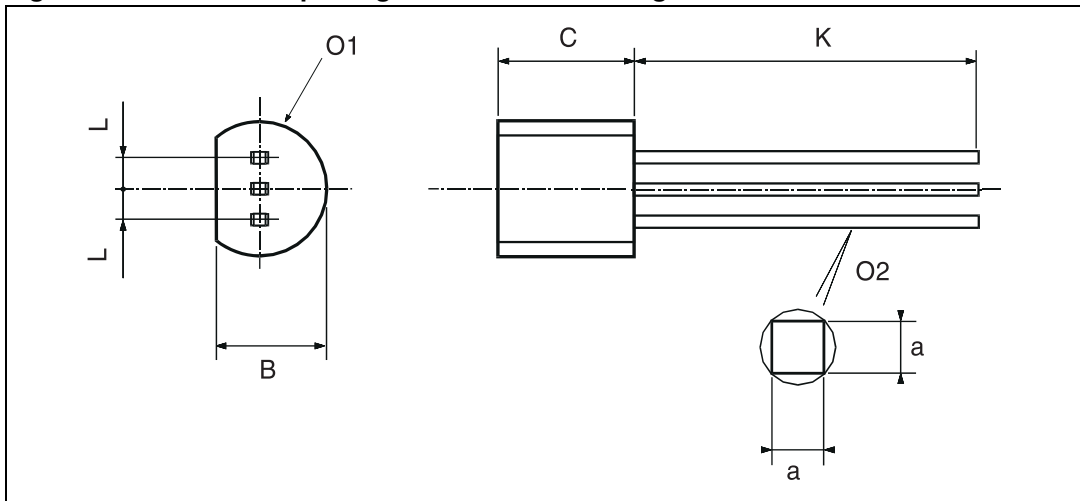


Table 8. TO-92 bulk package mechanical data

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		

## 6 Ordering information

**Table 9. Order codes**

Order codes	Accuracy (%)	Temperature range	Package	Packing	Marking
TL1431CD TL1431CDT	0.4	- 20°C, +70°C	SO-8	Tube or tape and reel	1431C
TL1431ACD TL1431ACDT	0.25				1431AC
TL1431CZ TL1431CZT TL1431CZ-AP	0.4		TO92	Bulk or Tape or Ammopack	TL1431C
TL1431ACZ TL1431ACZT TL1431ACZ-AP	0.25				TL1431AC
TL1431ID TL1431IDT	0.4	-40°C, + 105°C	SO-8	Tube or tape and reel	1431I
TL1431AID TL1431AIDT	0.25				1431AI
TL1431IZ TL1431IZT TL1431IZ-AP	0.4		TO92	Bulk or Tape or Ammopack	TL1431I
TL1431AIZ TL1431AIZT TL1431AIZ-AP	0.25				TL1431AI
TL1431IYDT <sup>(1)</sup>	0.4	-40°C, + 125°C	SO-8 (Automotive grade)	tape and reel	1431IY
TL1431AIYDT <sup>(1)</sup>	0.25				1431AIY

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



## 7 Revision history

**Table 10. Document revision history**

Date	Revision	Changes
01-Mar-2002	1	Initial release.
01-Nov-2005	2	PPAP references inserted in the datasheet see <a href="#">Table 9: Order codes on page 16</a> .
25-Apr-2007	3	<p>Minimum value for temperature range updated in <a href="#">Table 2: Operating conditions</a>.</p> <p>Minimum values added and maximum values deleted for <math>\frac{\Delta V_{ref}}{\Delta V_{ka}}</math> parameter in <a href="#">Table 4</a> in <a href="#">Section 3: Electrical characteristics</a>.</p> <p>Package information for TO92 tape and reel updated, see <a href="#">Section 5: Package mechanical data</a>.</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>
11-Sep-2012	5	<p>Added: feature <a href="#">Automotive temp. range - 40 °C to +125 °C on page 1</a>.</p> <p>Updated: <a href="#">Table 9 on page 16</a>.</p>

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