

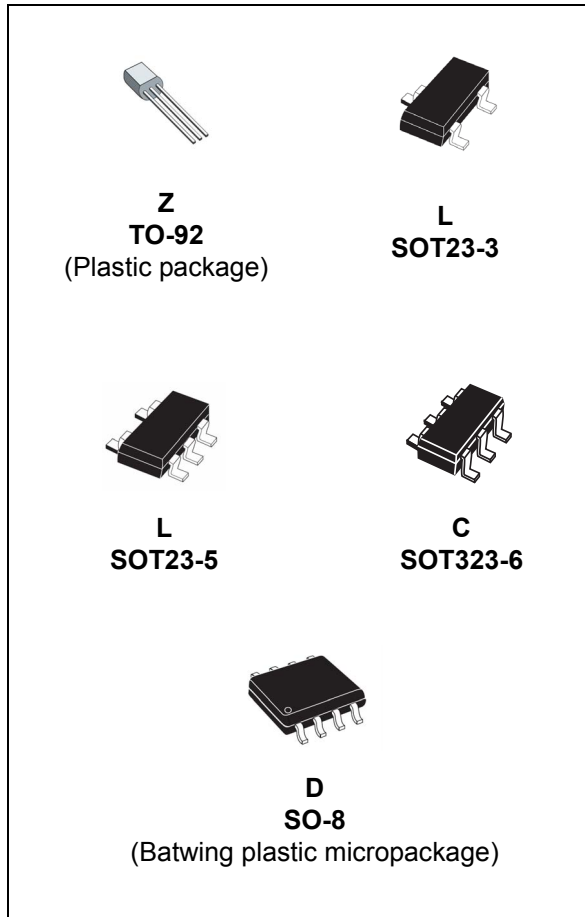


# THE DATASHEET OF TL431CZ-AP



**Automotive adjustable voltage reference**

Datasheet - production data

**Applications**

- Power supply
- Industrial
- Automotive

**Description**

The TL431 and TL432 are adjustable shunt voltage references with guaranteed temperature stability over the entire operating temperature range. The device 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 and TL432 operate with a wide current range from 1 to 100 mA with a typical dynamic impedance of 0.22 Ω.

**Features**

- AEC-Q100 qualified
- 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 temp. range -40 °C to +125 °C

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# 1 Schematic diagrams

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

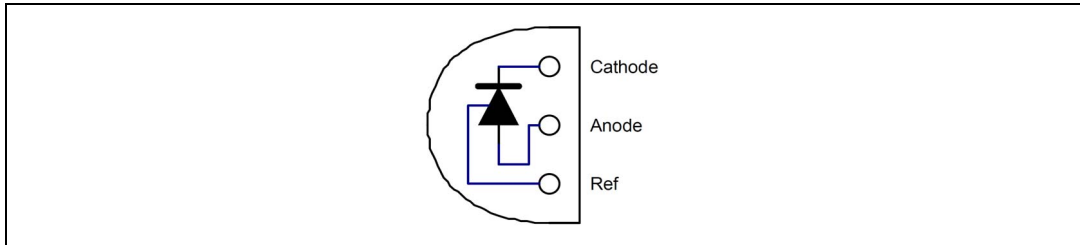


Figure 2. SO-8 batwing pin connections (top view)

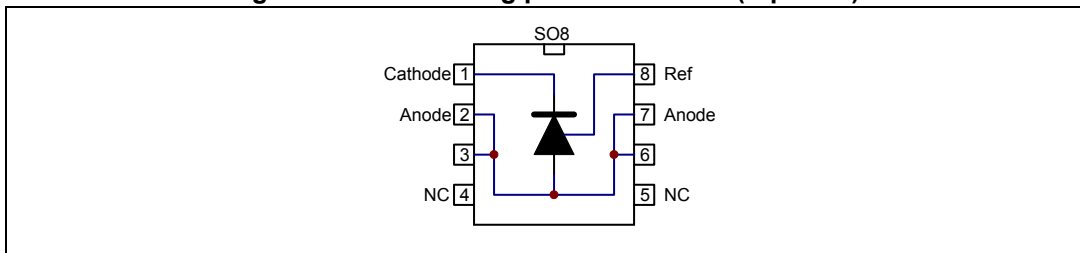


Figure 3. SOT23-5 and SOT23-3 pin connections (top view)

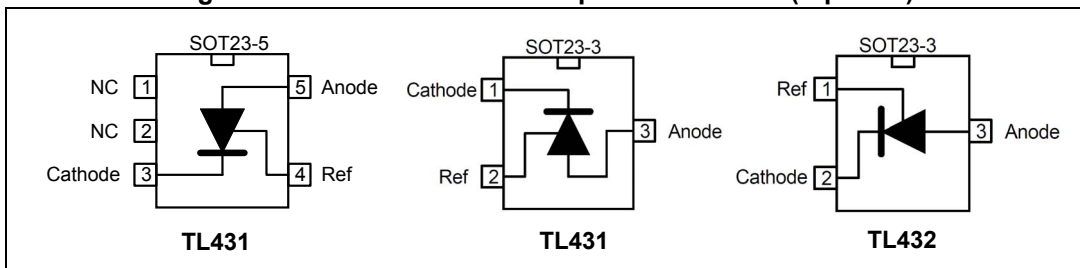


Figure 4. SOT323-6 pin connections (top view)

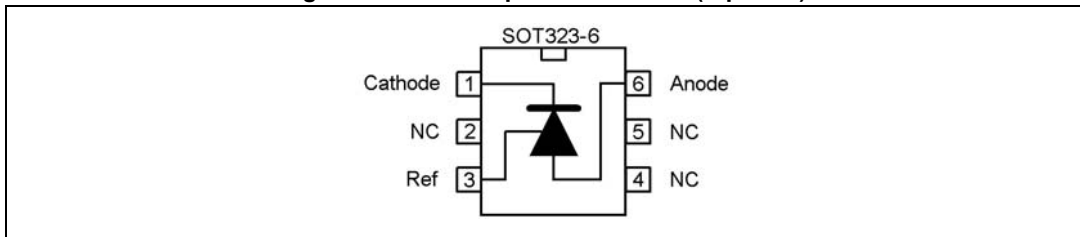
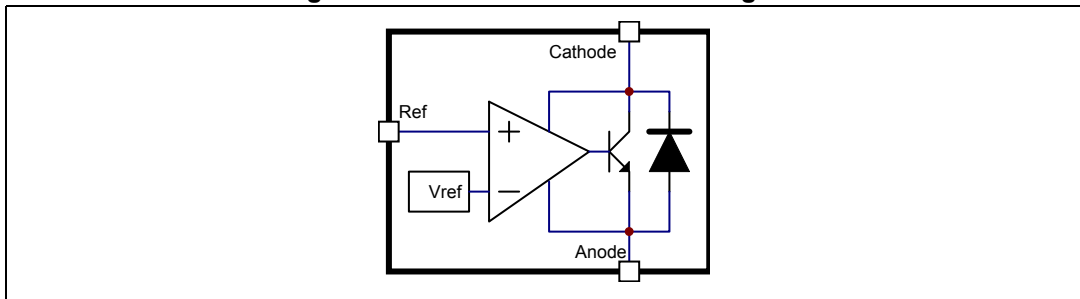


Figure 5. TL431 and TL432 block diagram



## 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
$R_{thjc}$	Thermal resistance junction to case		
	TO-92	57	°C/W
	SO-8 batwing	30	
	SOT23-3L	136	
	SOT23-5L	67	
SOT323-6L	110		
$R_{thja}$	Thermal resistance junction to ambient		
	TO-92	200	°C/W
	SO-8 batwing	85	
	SOT23-3L	248	
	SOT23-5L	157	
SOT323-6L	221		
$T_{stg}$	Storage temperature range	-65 to +150	°C
$T_J$	Junction temperature	150	°C
ESD	TL431IY, TL431AIY-T: HBM (human body model) <sup>(1)</sup>	3000	V
	TL431-TL432: HBM (human body model)	2000	
	MM: machine model <sup>(2)</sup>	200	
	CDM: charged device model <sup>(3)</sup>	1500	

- 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		°C
	TL431C/AC	0 to +70	
	TL431I/AI - TL432I/AI TL431IY/AIY	-40 to +105 -40 to +125	

### 3 Electrical characteristics

Table 3. TL431C ( $T_{amb} = 25\text{ °C}$  unless otherwise specified)

Symbol	Parameter	TL431C			TL431AC			Unit
		Min.	Typ.	Max.	Min.	Typ.	Max.	
$V_{ref}$	Reference input voltage $V_{KA} = V_{ref}$ , $I_k = 10\text{ mA}$ , $T_{amb} = 25\text{ °C}$ $T_{min} \leq T_{amb} \leq T_{max}$	2.44 2.423	2.495 -	2.55 2.567	2.47 2.453	2.495 -	2.52 2.537	V
$\Delta V_{ref}$	Reference input voltage deviation overtemperature range <sup>(1)</sup> $V_{KA} = V_{ref}$ , $I_k = 10\text{ mA}$ , $T_{min} \leq T_{amb} \leq T_{max}$	-	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 $10\text{ V}$	-2.7 -2	-1.4 -1	- -	-2.7 -2	-1.4 -1	- -	mV/V
$I_{ref}$	Reference input current $I_k = 10\text{ mA}$ , $R1 = 10\text{ k}\Omega$ , $R2 = \infty$ $T_{amb} = 25\text{ °C}$ $T_{min} \leq T_{amb} \leq T_{max}$	- -	1.8 -	4 5.2	- -	1.8 -	4 5.2	$\mu\text{A}$
$\Delta I_{ref}$	Reference input current deviation overtemperature 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	$\mu\text{A}$
$I_{min}$	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 <sup>(2)</sup> $V_{KA} = V_{ref}$ , $\Delta I_k = 1$ to $100\text{ mA}$ , $f \leq 1\text{ kHz}$	-	0.22	0.5	-	0.22	0.5	$\Omega$

1. See definition of [Section : Reference input voltage deviation overtemperature range](#).

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

Table 4. TL431I/TL432I ( $T_{amb} = 25\text{ °C}$  unless otherwise specified)

Symbol	Parameter	TL431I/TL432I			TL431AI/TL432AI			Unit
		Min.	Typ.	Max.	Min.	Typ.	Max.	
$V_{ref}$	Reference input voltage $V_{KA} = V_{ref}$ , $I_k = 10\text{ mA}$ , $T_{amb} = 25\text{ °C}$ $T_{min} \leq T_{amb} \leq T_{max}$	2.44 2.41	2.495 -	2.55 2.58	2.47 2.44	2.495 -	2.52 2.55	V
$\Delta V_{ref}$	Reference input voltage deviation overtemperature range <sup>(1)</sup> $V_{KA} = V_{ref}$ , $I_k = 10\text{ mA}$ , $T_{min} \leq T_{amb} \leq T_{max}$	-	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 $I_k = 10\text{ mA}$ , $R1 = 10\text{ k}\Omega$ , $R2 = \infty$ $T_{amb} = 25\text{ °C}$ $T_{min} \leq T_{amb} \leq T_{max}$	- -	1.8 -	4 6.5	- -	1.8 -	4 6.5	$\mu\text{A}$
$\Delta I_{ref}$	Reference input current deviation overtemperature 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	$\mu\text{A}$
$I_{min}$	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 <sup>(2)</sup> $V_{KA} = V_{ref}$ , $\Delta I_k = 1\text{ to } 100\text{ mA}$ , $f \leq 1\text{ kHz}$	-	0.22	0.5	-	0.22	0.5	$\Omega$

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

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

Table 5. TL431IY (T<sub>amb</sub> = 25 °C unless otherwise specified)

Symbol	Parameter	TL431IY			TL431AIY			Unit
		Min.	Typ.	Max.	Min.	Typ.	Max.	
V <sub>ref</sub>	Reference input voltage 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>	2.44 2.41	2.495 -	2.55 2.58	2.47 2.44	2.495 -	2.52 2.55	V
ΔV <sub>ref</sub>	Reference input voltage deviation overtemperature range <sup>(1)</sup> 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 I <sub>k</sub> = 10 mA, ΔV <sub>KA</sub> = 10 V to V <sub>ref</sub> I <sub>k</sub> = 10 mA, ΔV <sub>KA</sub> = 36 V to 10 V	-2.7 -2	-1.4 -1	- -	-2.7 -2	-1.4 -1	- -	mV/V
I <sub>ref</sub>	Reference input current I <sub>k</sub> = 10 mA, R1 = 10 kΩ, R2 = ∞ T <sub>min</sub> ≤ T <sub>amb</sub> ≤ T <sub>max</sub>	- -	1.8 -	4 6.5	- -	1.8 -	4 6.5	μA
ΔI <sub>ref</sub>	Reference input current deviation overtemperature range I <sub>k</sub> = 10 mA, R1 = 10 kΩ, R2 = ∞, 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 V <sub>KA</sub> = V <sub>ref</sub>	-	0.5	1	-	0.5	0.6	mA
I <sub>off</sub>	Off-state cathode current T <sub>min</sub> ≤ T <sub>amb</sub> ≤ T <sub>max</sub>	- -	2.6	1000 3000	- -	2.6	1000 3000	nA
ZKA	Dynamic impedance <sup>(2)</sup> V <sub>KA</sub> = V <sub>ref</sub> , ΔI <sub>k</sub> = 1 to 100 mA, F ≤ 1 kHz	-	0.22	0.5	-	0.22	0.5	Ω

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

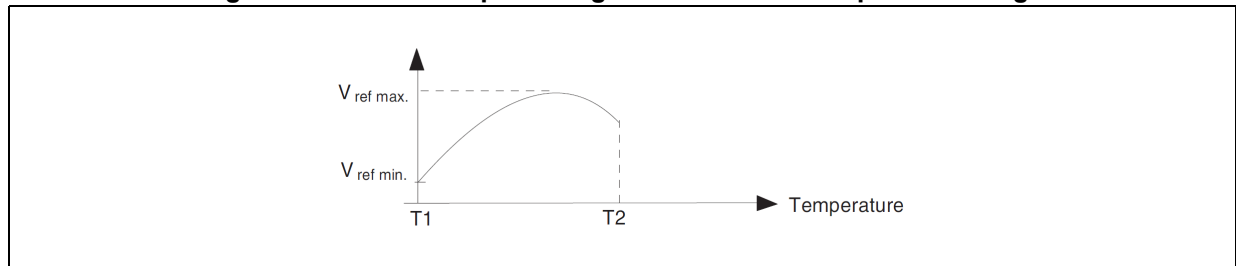
2. The dynamic impedance is defined as  $|ZKA| = \frac{\Delta V_{KA}}{\Delta I_k}$

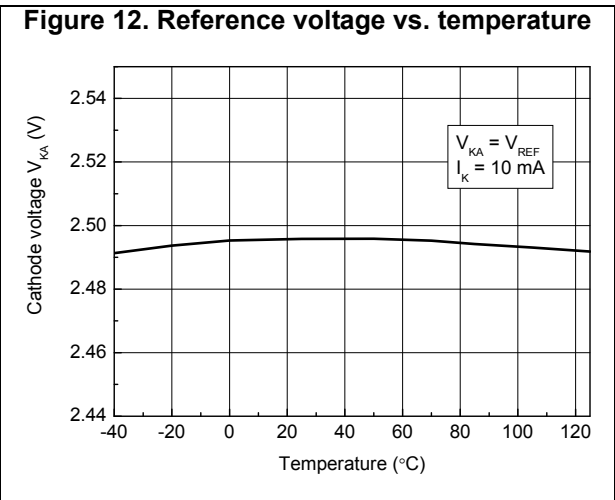
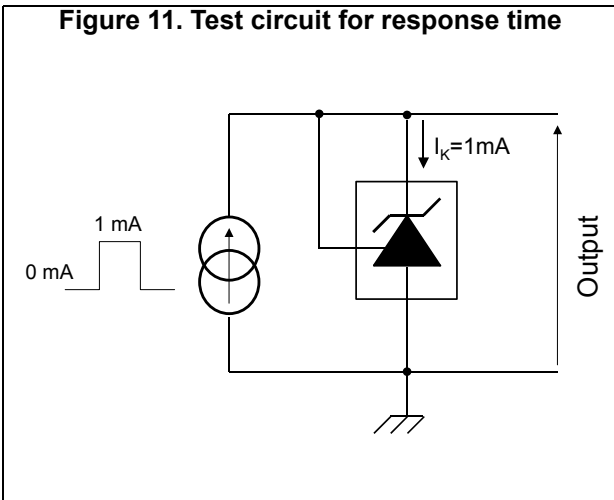
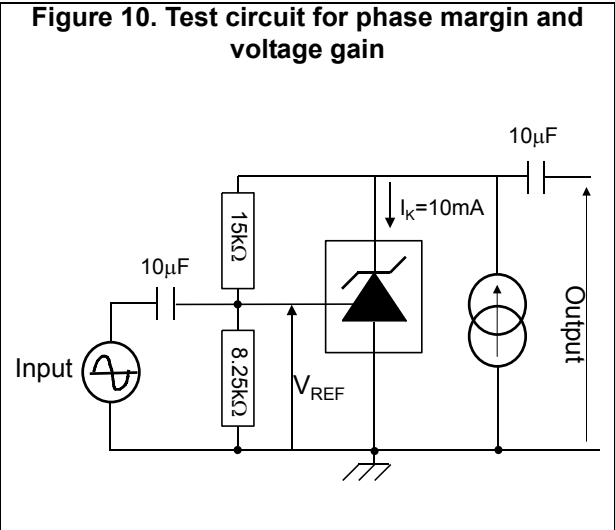
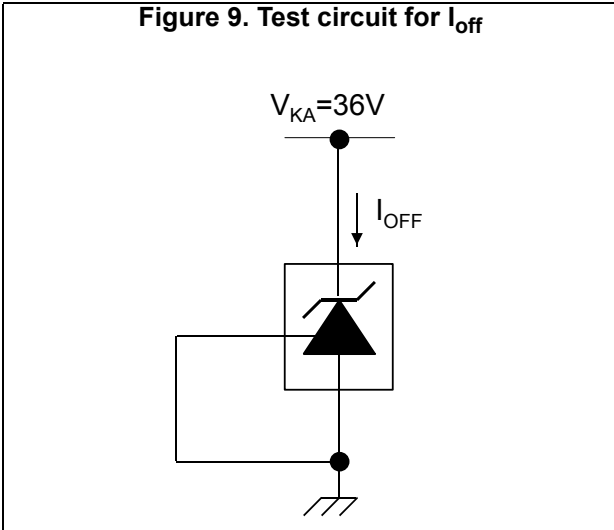
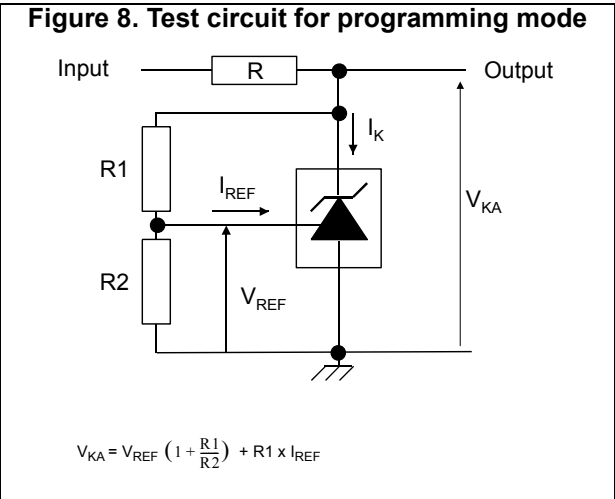
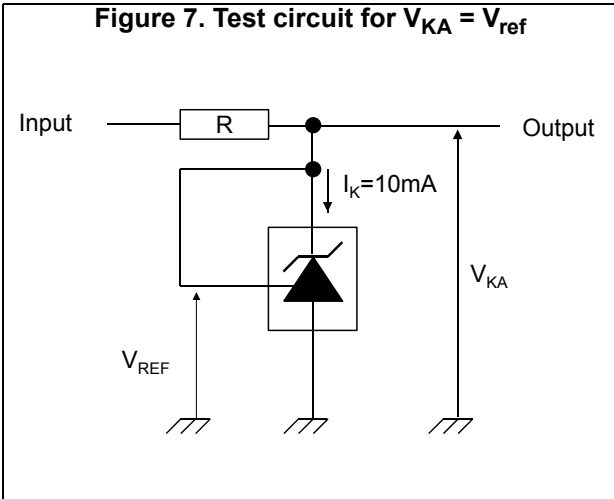
### Reference input voltage deviation overtemperature range

ΔV<sub>ref</sub> is defined as the difference between the maximum and minimum values obtained over the full temperature range.

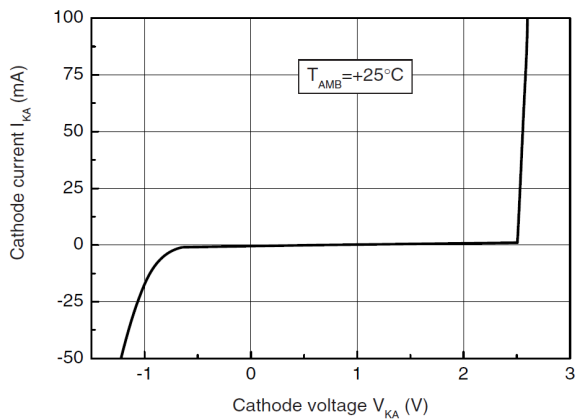
$$\Delta V_{ref} = V_{ref\ max} - V_{ref\ min}$$

Figure 6. Reference input voltage deviation overtemperature range

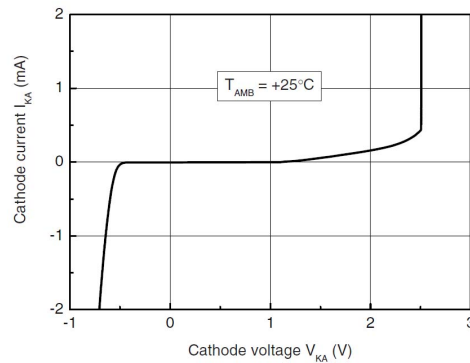




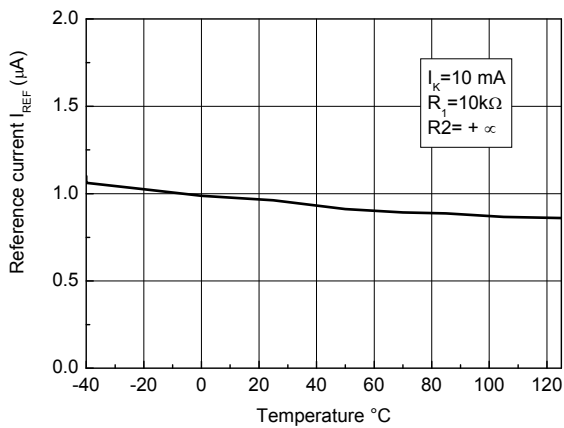
**Figure 13. Reference voltage vs. cathode current**



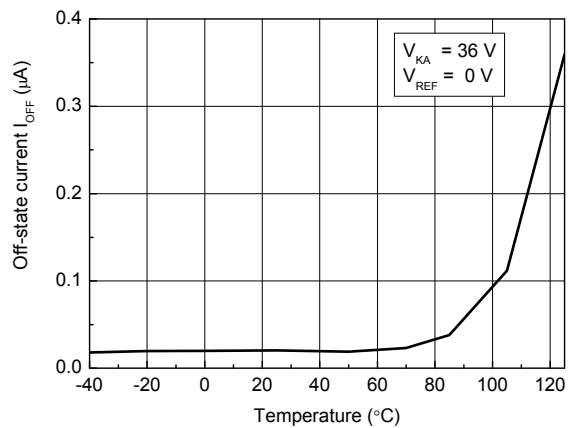
**Figure 14. Zoom on reference voltage vs. cathode current**



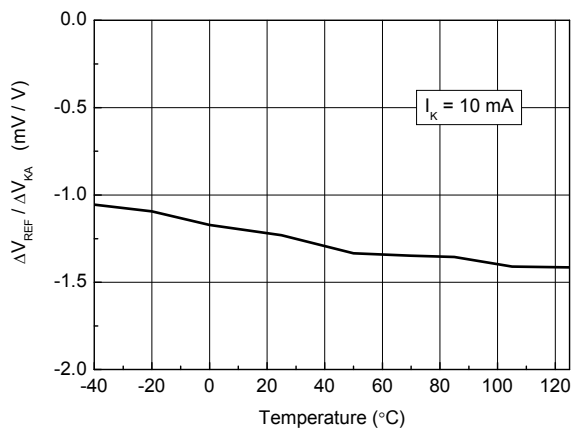
**Figure 15. Reference current vs. temperature**



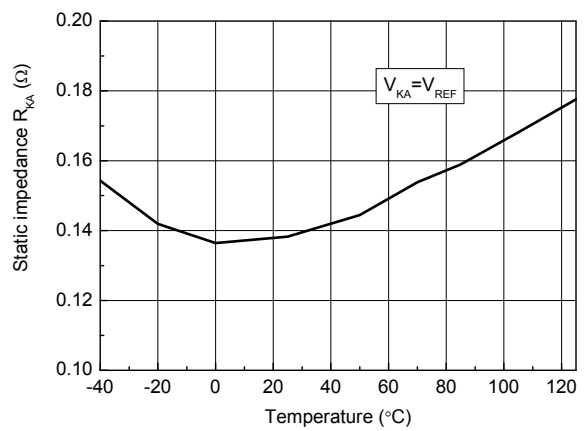
**Figure 16. Off-state cathode current vs. temperature**



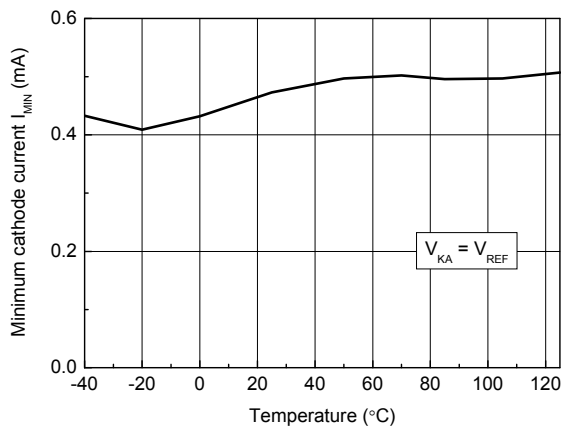
**Figure 17. Ratio of change in  $V_{REF}$  to change in  $V_{KA}$  vs. temperature**



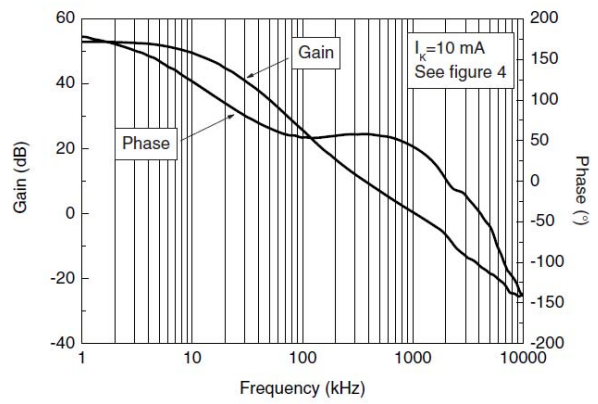
**Figure 18. Static impedance  $R_{KA}$  vs. temperature**



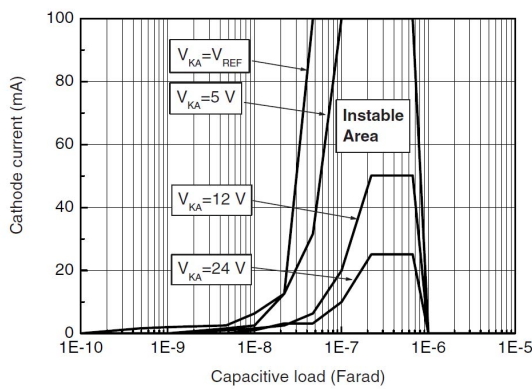
**Figure 19. Minimum operating current vs. temperature**



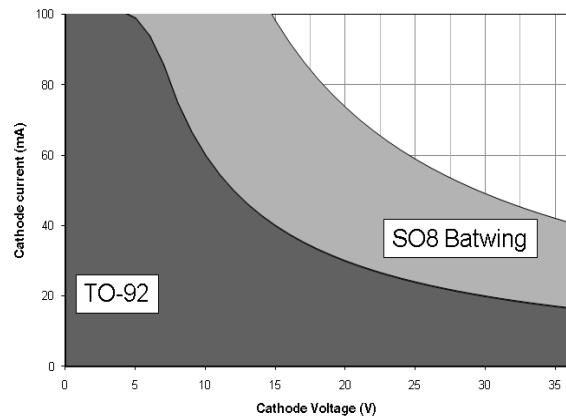
**Figure 20. Gain and phase vs. frequency**



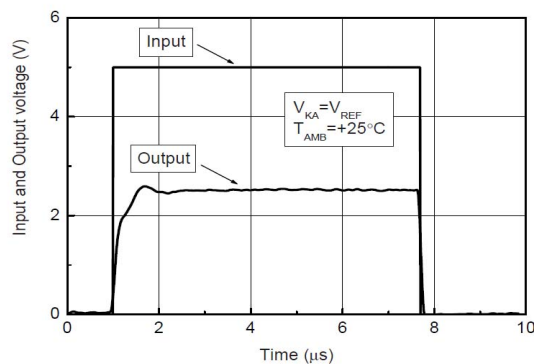
**Figure 21. Stability behavior with capacitive loads**



**Figure 22. Maximum power dissipation**



**Figure 23. 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<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.

### 4.1 SO-8 package information

Figure 24. SO-8 package outline

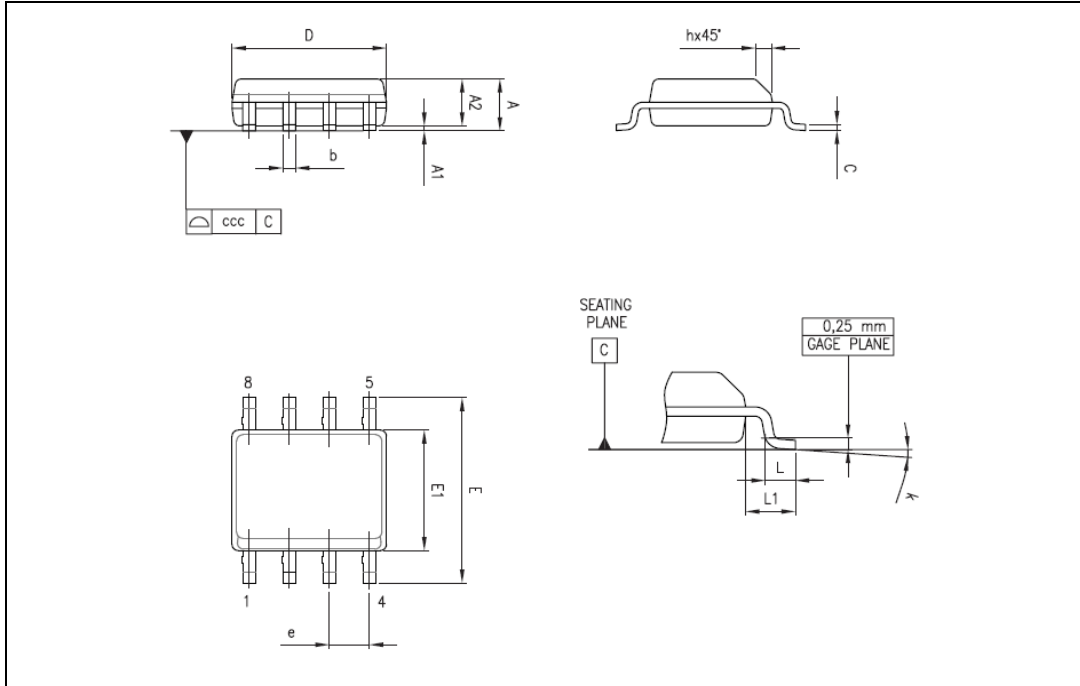


Table 6. SO-8 package mechanical data

Symbol	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	0°	-	8°	0°	-	8°
ccc	-	-	0.10	-	-	0.004

## 4.2 TO-92 ammopack and tape and reel package information

Figure 25. TO-92 ammopack and tape and reel package outline

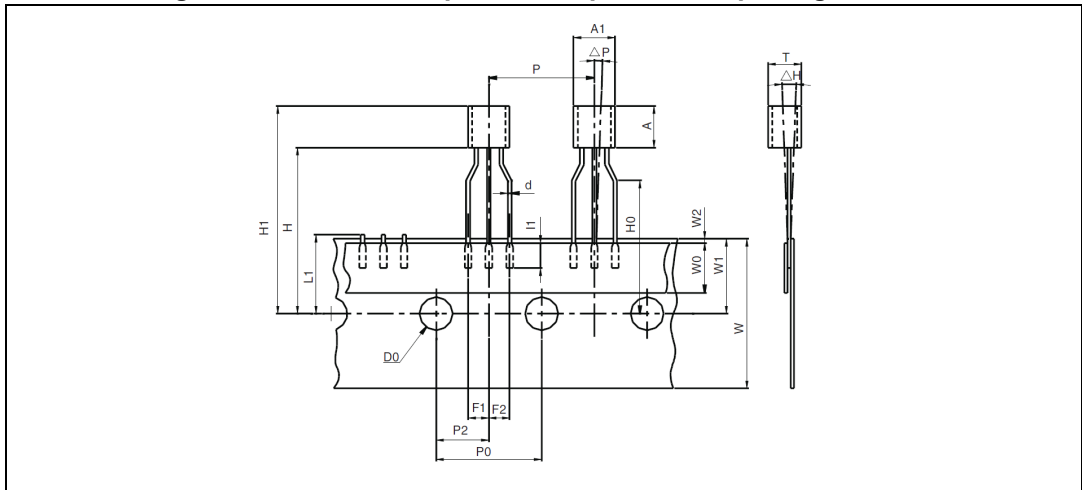


Table 7. TO-92 ammopack and tape and reel package mechanical data

Symbol	Dimension (millimeters)			Dimension (Inches)		
	Min.	Typ.	Max.	Min.	Typ.	Max.
A1	-	-	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

### 4.3 TO-92 (bulk) package information

Figure 26. TO-92 bulk package outline

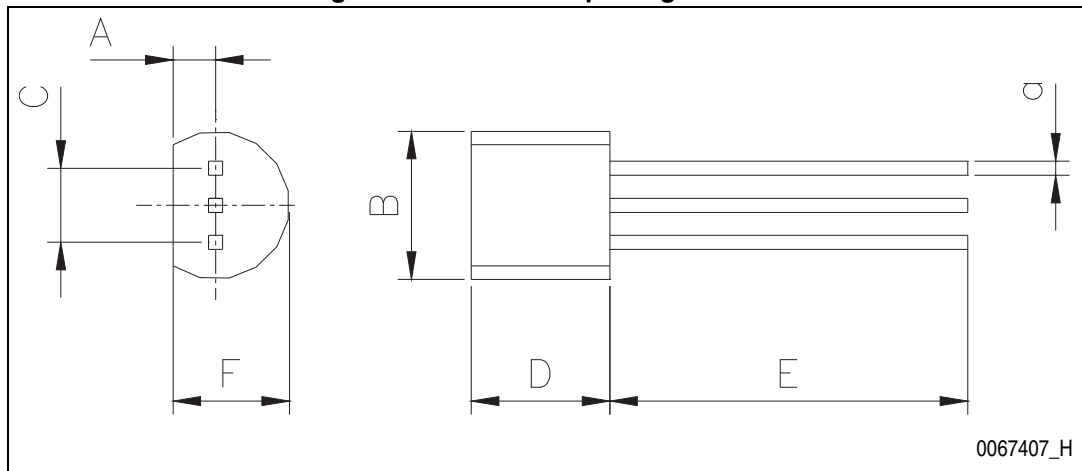


Table 8. TO-92 bulk package mechanical data

Symbol	Dimension (millimeters)			Dimension (Inches)		
	Min.	Typ.	Max.	Min.	Typ.	Max.
A	-	1.35	-	-	0.053	-
B	-	-	4.70	-	-	0.185
C	-	2.54	-	-	0.100	-
D	4.40	-	-	0.173	-	-
E	12.70	-	-	0.500	-	-
F	-	-	3.70	-	-	0.146
a	-	-	0.5	-	-	0.019

### 4.4 SOT23-3 package information

Figure 27. SOT23-3 package outline

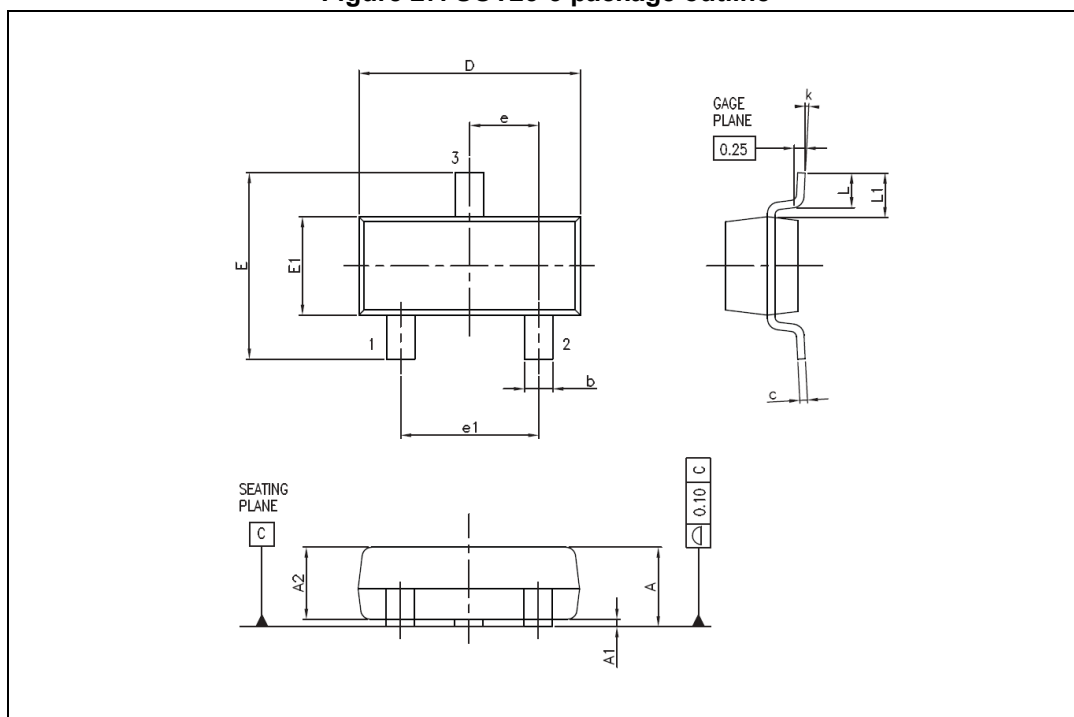


Table 9. SOT23-3 package mechanical data

Symbol	Dimensions					
	Millimeters			Inches		
	Min.	Typ.	Max.	Min.	Typ.	Max.
A	0.89	-	1.12	0.035	-	0.044
A1	0.01	-	0.10	0.0004	-	0.004
A2	0.88	0.95	1.02	0.035	0.037	0.040
b	0.30	-	0.50	0.012	-	0.020
c	0.08	-	0.20	0.003	-	0.008
D	2.80	2.90	3.04	0.110	0.114	0.120
E	2.10	-	2.64	0.083	-	0.104
E1	1.20	1.30	1.40	0.047	0.051	0.055
e	-	0.95	-	-	0.037	-
e1	-	1.90	-	-	0.075	-
L	0.40	0.50	0.60	0.016	0.020	0.024
L1	-	0.54	-	-	0.021	-
k	0d	-	8d	-	-	-

### 4.5 SOT23-5 package information

Figure 28. SOT23-5 package outline

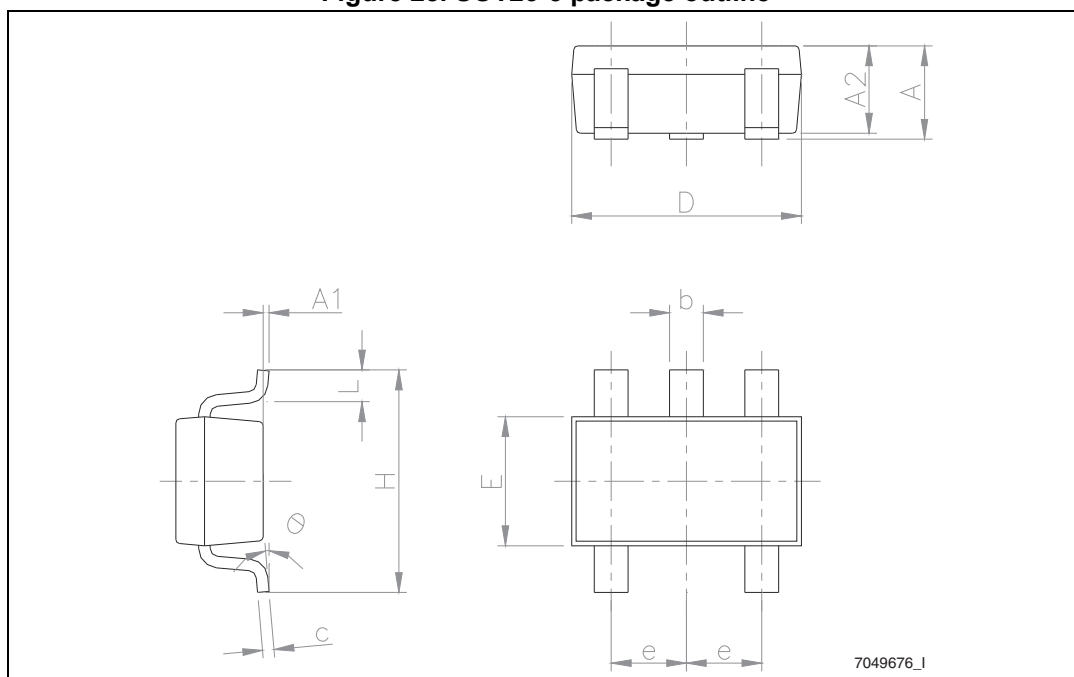


Table 10. SOT23-5 package mechanical data

Symbol	Dimensions					
	Millimeters			Inches		
	Min.	Typ.	Max.	Min.	Typ.	Max.
A	0.90	-	1.45	0.035	-	0.057
A1	-	-	0.15	-	-	0.006
A2	0.90	-	1.30	0.035	-	0.051
b	0.35	-	0.50	0.014	-	0.020
c	0.09	-	0.20	0.004	-	0.008
D	2.80	-	3.05	0.110	-	0.120
E	1.50	-	1.75	0.059	-	0.069
e	-	0.95	-	-	0.037	-
H	2.60	-	3.00	0.102	-	0.118
L	0.10	-	0.60	0.004	-	0.024
$\theta$	0 degrees	-	10 degrees	-	-	-

### 4.6 SOT323-6 package information

Figure 29. SOT323-6 package outline

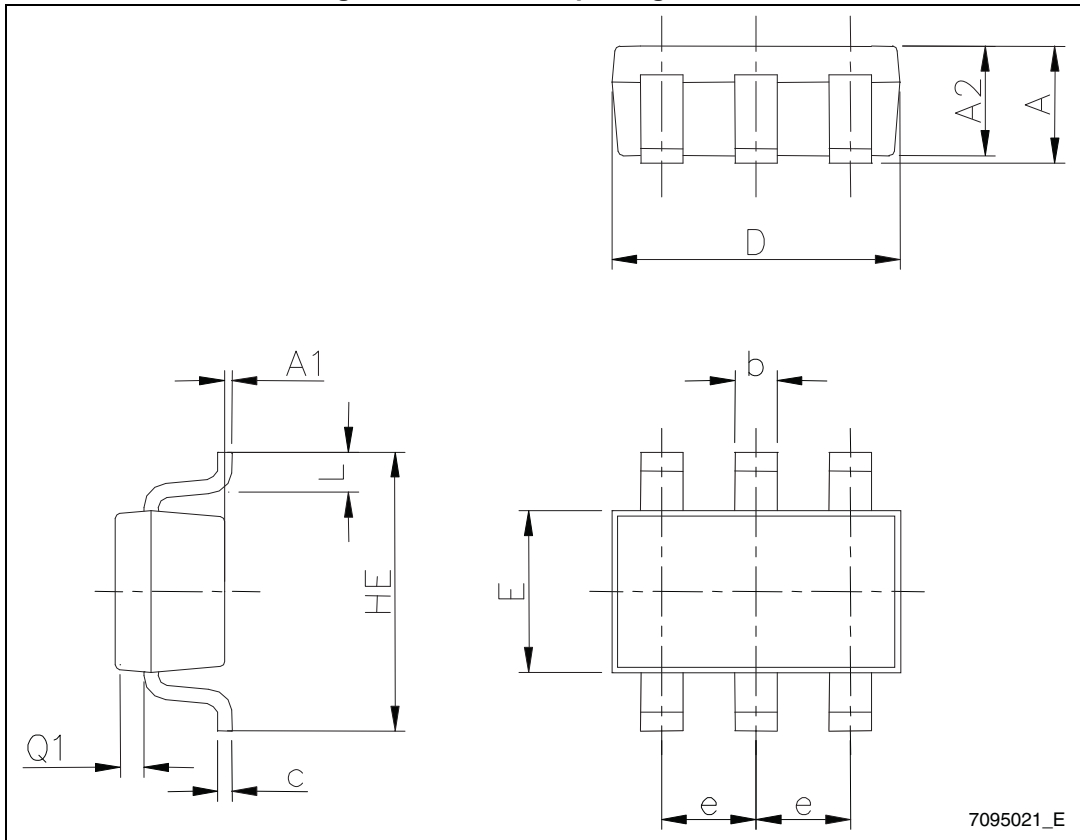


Table 11. SOT323-6 package mechanical data

Symbol	Dimensions					
	Millimeters			Inches		
	Min.	Typ.	Max.	Min.	Typ.	Max.
A	0.80	-	1.10	0.031	-	0.043
A1	0	-	0.10	-	-	0.004
A2	0.80	-	1.00	0.031	-	0.039
b	0.15	-	0.30	0.006	-	0.012
c	0.10	-	0.18	0.004	-	0.007
D	1.80	-	2.20	0.071	-	0.087
E	1.15	-	1.35	0.045	-	0.053
e	-	0.65	-	-	0.026	-
HE	1.80	-	2.40	0.071	-	0.094
L	0.10	-	0.40	0.004	-	0.016
Q1	0.10	-	0.40	0.004	-	0.016

## 5 Ordering information

Table 12. 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
TL431CL3T	2		SOT23-3	Tape	L19
TL431ACL3T	1				L18
TL431CL5T	2				L19
TL431ACL5T	1				L18
TL431CCT	2		SOT323-6		31C
TL431ACCT	1				31C
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
TL431IL3T	2		SOT23-3	Tape	L17
TL431AIL3T	1				L16
TL432IL3T	2		SOT23-3		32I
TL432AIL3T	1				32AI
TL431IL5T	2		SOT23-5	Tape	L17
TL431AIL5T	1				L16
TL431ICT	2	SOT323-6			31I
TL431AICT	1				31I

Table 12. Order codes (continued)

Order code	Accuracy (%)	Temperature range	Package	Packing	Marking
TL431IYD <sup>(1)</sup> TL431IYDT <sup>(1)</sup>	2	-40 °C to + 125 °C	SO-8 (Automotive grade level)	Tube or tape and reel	431IY
TL431AIYD <sup>(1)</sup> TL431AIYDT <sup>(1)</sup>	1				431AIY

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

## 6 Revision history

**Table 13. 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 <i>Figure 7</i> and of <i>Figure 18</i> . Added footnote to <i>Table 8: TO-92 bulk package mechanical data</i> .
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 <i>Table 3</i> and <i>Table 4</i> . Increased temperature range to 125°C in temperature curves. Added <i>Table 5</i> , dedicated to automotive version. Increased high temperature for automotive range up to +125 °C in <i>Table 5</i> and in <i>Table 12: Order codes</i> . Inserted accuracy column in <i>Table 12</i> .
09-Jun-2009	7	Corrected minor error in package column in <i>Table 12</i> .
14-Mar-2011	8	Added <i>Figure 3 on page 3</i> , <i>Section 4.4 on page 15</i> and <i>Section 4.5 on page 16</i> .
07-Oct-2011	9	Added new package mechanical data <i>Table 11 on page 17</i> and <i>Figure 29 on page 17</i> . Updated <i>Table 12 on page 18</i> .
17-Nov-2011	10	Added new part number TL432, new order code <i>Table 12 on page 18</i> and pin connection for TL432 <i>Figure 3 on page 3</i> .
03-Dec-2012	11	Removed temperature range in title <i>Table 3 on page 5</i> , <i>Table 4 on page 6</i> and <i>Table 5 on page 7</i> .
07-Dec-2017	12	Updated main title <a href="#">on page 1</a> and <a href="#">Section : Features on page 1</a> , (added "automotive" - AEC-Q100 qualified). Updated <a href="#">Table 1 on page 4</a> (updated $R_{thja}$ and $R_{thjc}$ ). Minor modifications throughout document.

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