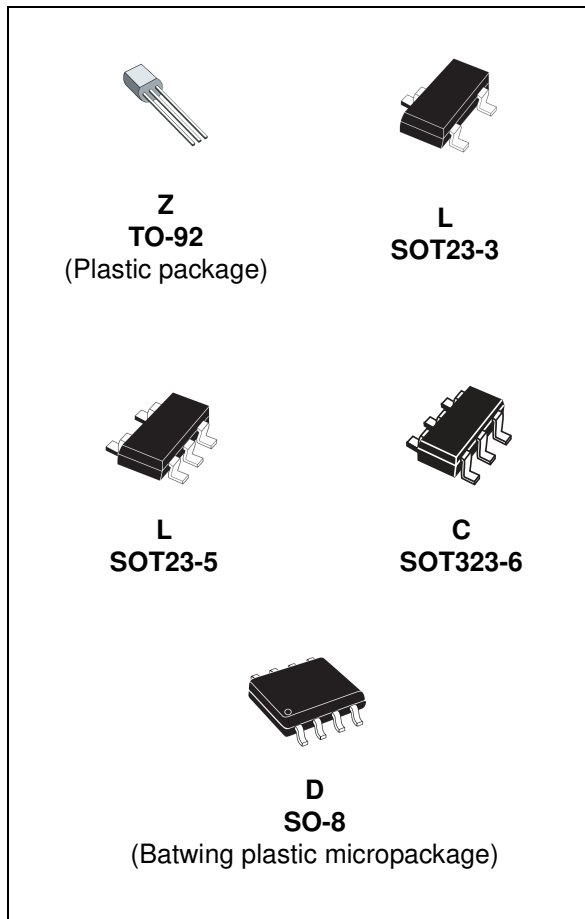


Automotive adjustable voltage reference

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
- 0.5% voltage precision only on the TL431B version
- 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)

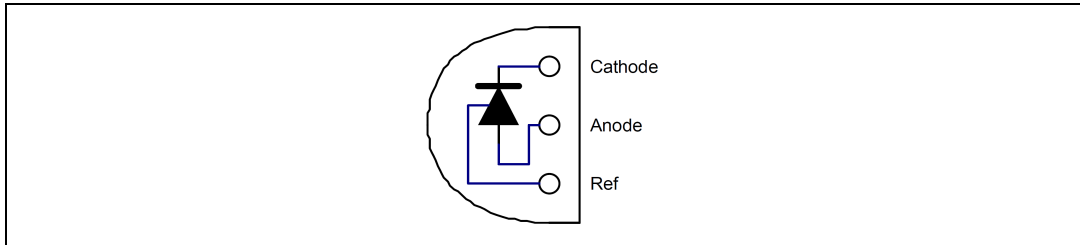


Figure 2. SO-8 batwing pin connections (top view)

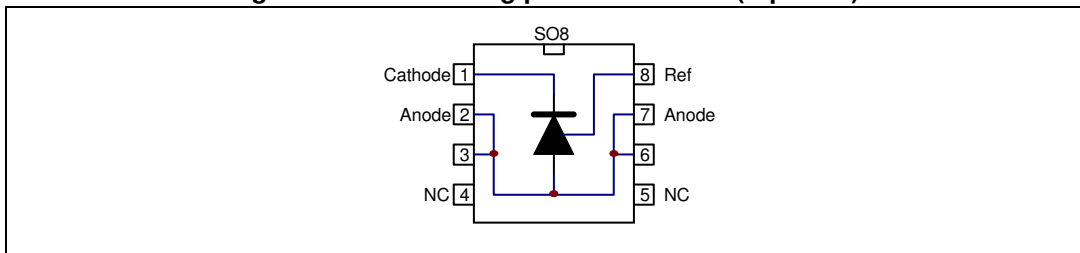


Figure 3. SOT23-5 and SOT23-3 pin connections (top view)

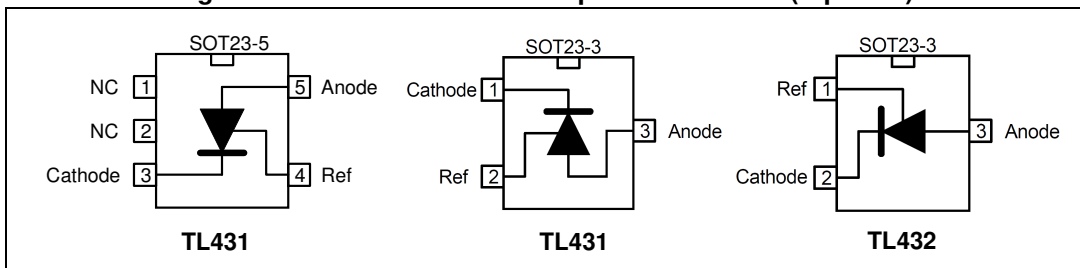


Figure 4. SOT323-6 pin connections (top view)

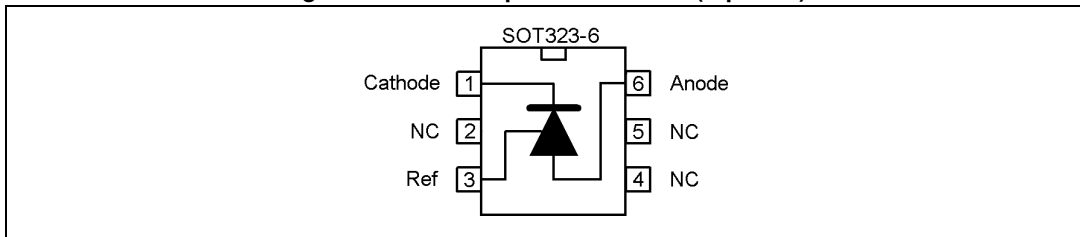
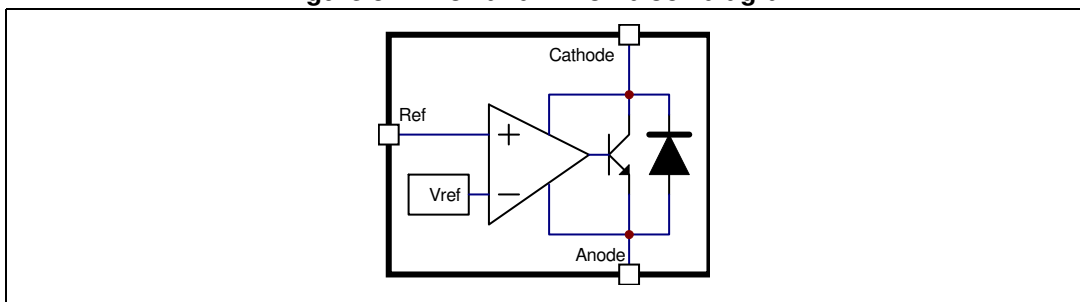


Figure 5. TL431 and TL432 block diagram



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) ⁽¹⁾	3000	V
	TL431-TL432: HBM (human body model)	2000	
	MM: machine model ⁽²⁾	200	
	CDM: charged device model ⁽³⁾	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	-40 to +105	
	TL431B	-40 to +125	
	TL431IY/AIY	-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
ΔV_{ref}	Reference input voltage deviation overtemperature 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 $I_k = 10\text{ mA}$, $R1 = 10\text{ k}\Omega$, $R2 = \infty$ $T_{amb} = 25\text{ °C}$ $T_{min} \leq T_{amb} \leq T_{max}$	- -	1.8 -	4 5.2	- -	1.8 -	4 5.2	μA
ΔI_{ref}	Reference input current deviation 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	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
$ ZKA $	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 : Reference input voltage deviation overtemperature range](#).

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

Table 4. TL431B, TL432B ($T_{amb} = 25\text{ °C}$ unless otherwise specified)

Symbol	Parameter	TL431B, TL432B			Unit
		Min.	Typ.	Max.	
V_{ref}	Reference input voltage $V_{KA} = V_{ref}$, $I_k = 10\text{ mA}$, $T_{amb} = 25\text{ °C}$ $T_{min} \leq T_{amb} \leq T_{max}$	2.483 2.453	2.495 -	2.507 2.537	V
ΔV_{ref}	Reference input voltage deviation overtemperature range ⁽¹⁾ $V_{KA} = V_{ref}$, $I_k = 10\text{ mA}$, $T_{min} \leq T_{amb} \leq T_{max}$	-	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 V	-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	μA
ΔI_{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	μA
I_{min}	Minimum cathode current for regulation $V_{KA} = V_{ref}$	-	0.45	0.6	mA
I_{off}	Off-state cathode current	-	180	500	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	Ω

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 5. TL431I/TL432I (T_{amb} = 25 °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 mA, T _{amb} = 25 °C 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 overtemperature 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} 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 _{amb} = 25 °C T _{min} ≤ T _{amb} ≤ T _{max}	- -	1.8 -	4 6.5	- -	1.8 -	4 6.5	μA
ΔI _{ref}	Reference input current deviation overtemperature 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	0.7	mA
I _{off}	Off-state cathode current	-	2.6	1000	-	2.6	1000	nA
ZKA	Dynamic impedance ⁽²⁾ V _{KA} = V _{ref} , Δ I _k = 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 $|ZKA| = \frac{\Delta V_{KA}}{\Delta I_k}$

Table 6. TL431IY (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 overtemperature 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 overtemperature 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
ZKA	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 : Reference input voltage deviation overtemperature range](#) below.

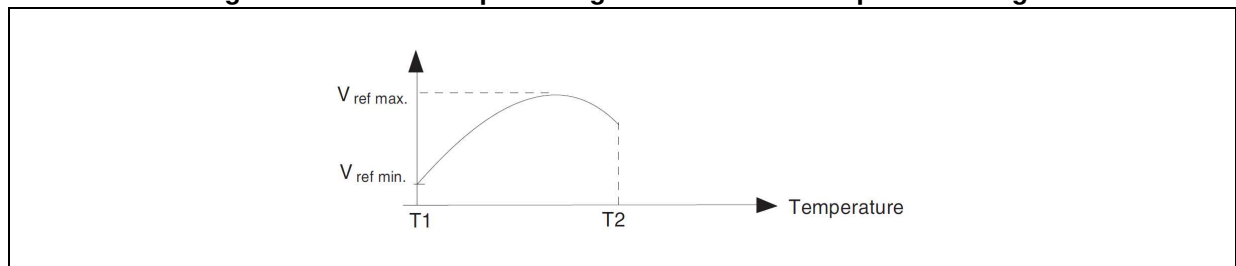
2. The dynamic impedance is defined as $|ZKA| = \frac{\Delta V_{KA}}{\Delta I_k}$

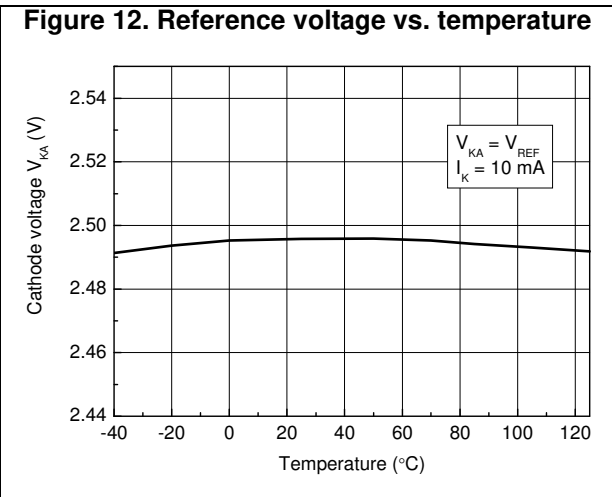
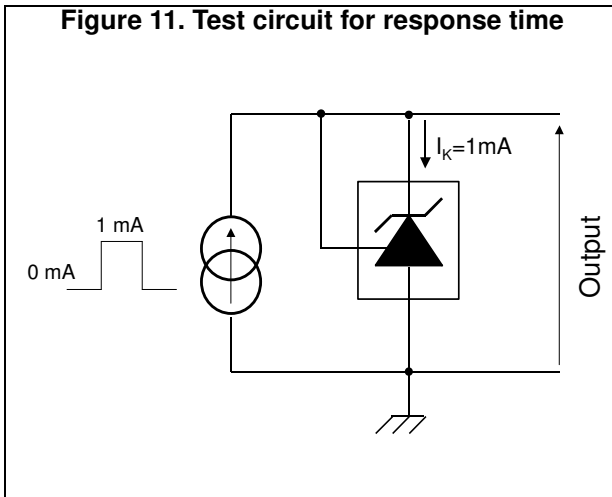
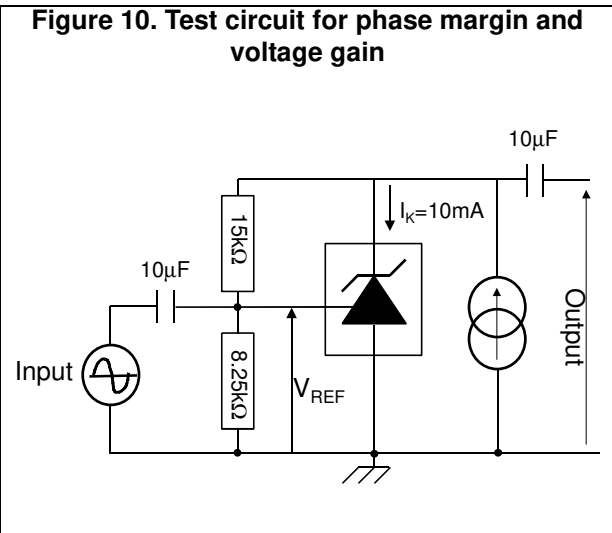
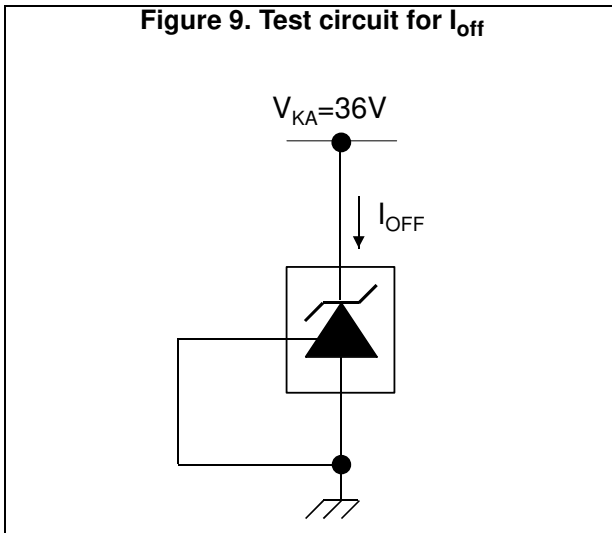
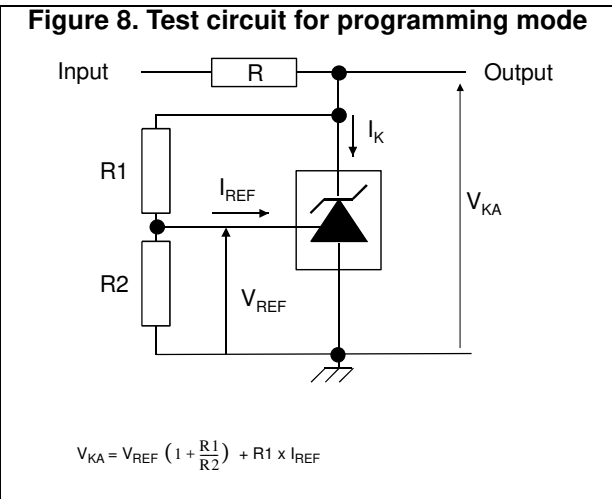
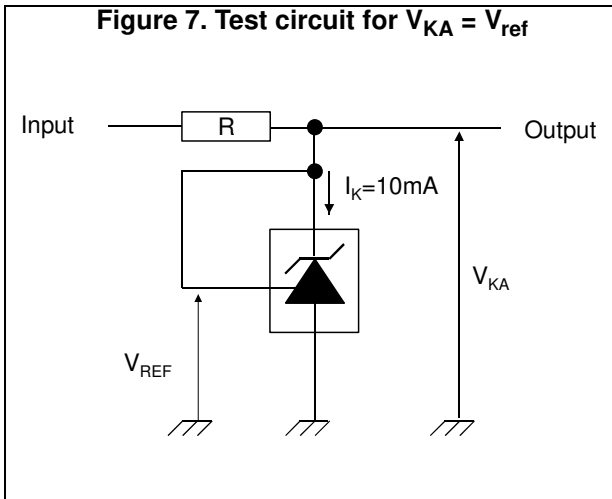
Reference input voltage deviation overtemperature range

ΔV_{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 6. Reference input voltage deviation overtemperature range





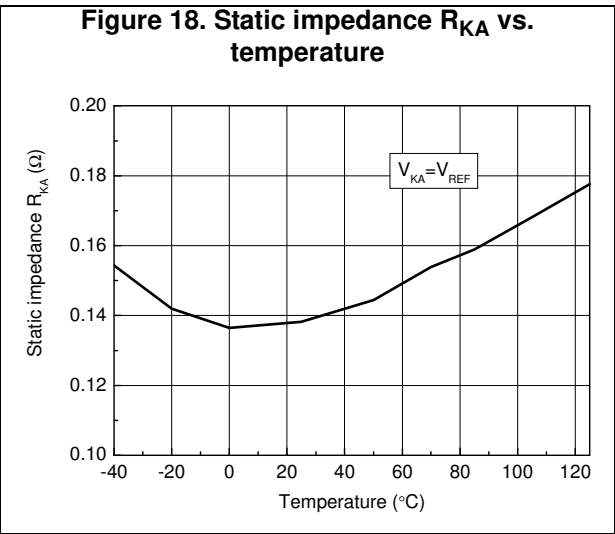
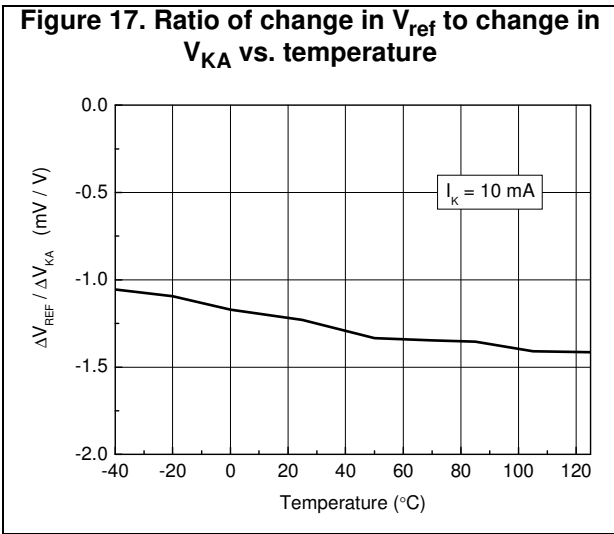
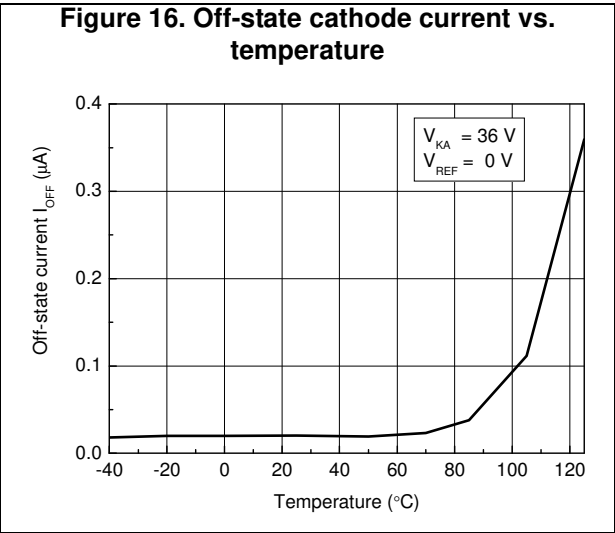
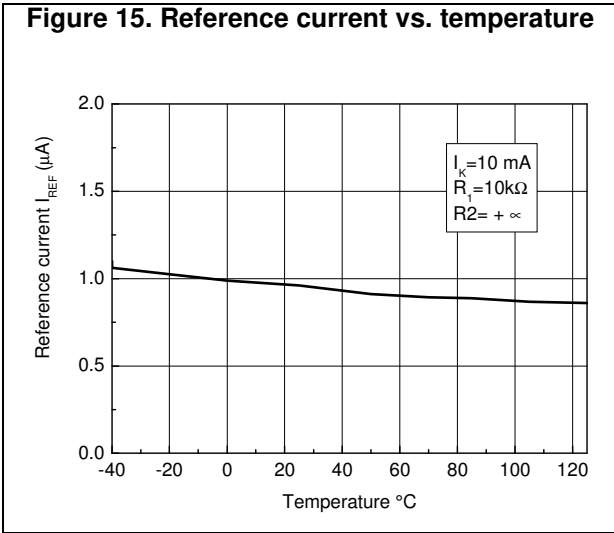
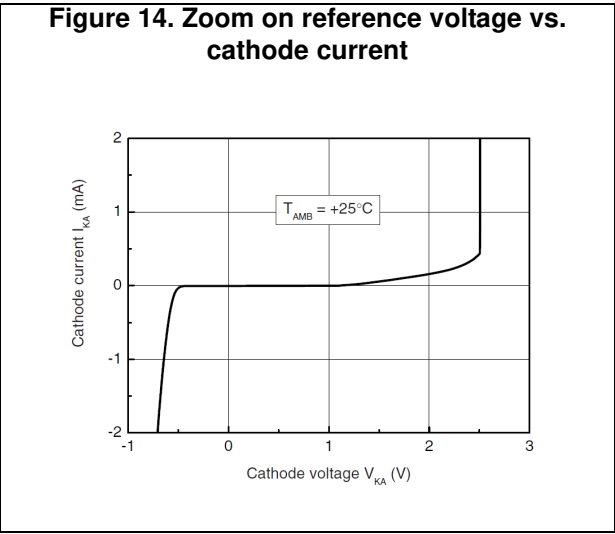
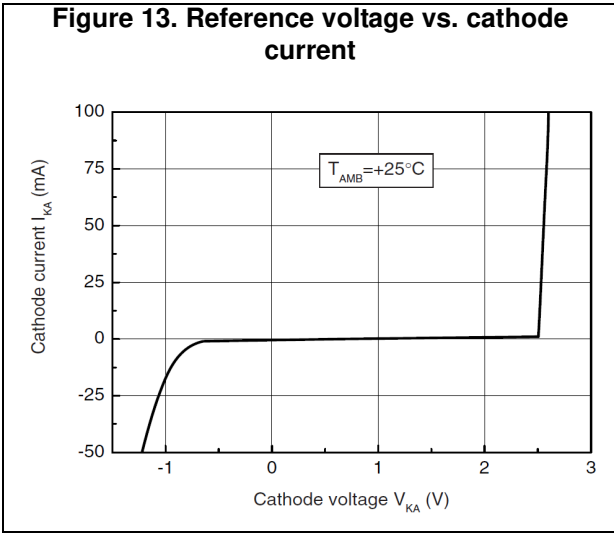


Figure 19. Minimum operating current vs. temperature

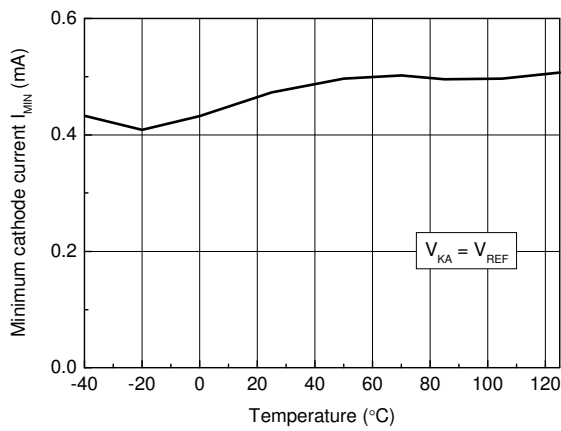


Figure 20. Gain and phase vs. frequency

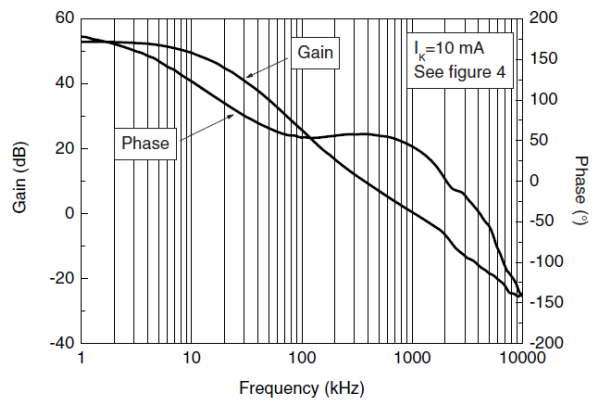


Figure 21. Stability behavior with capacitive loads

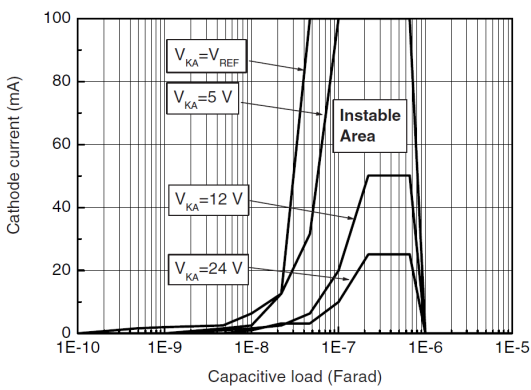


Figure 22. Maximum power dissipation

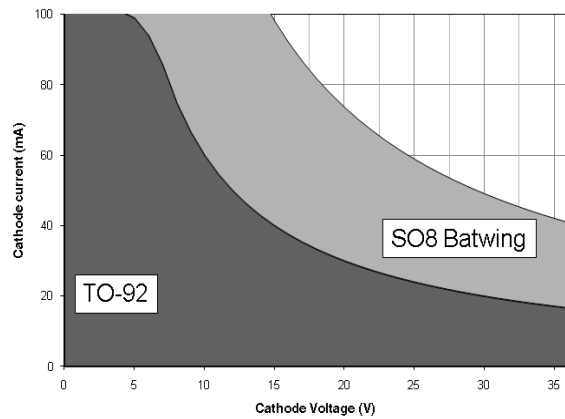
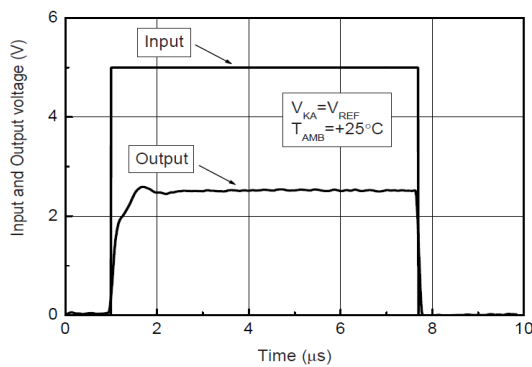


Figure 23. Pulse response for $I_K = 1 \text{ mA}$



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 24. SO-8 package outline

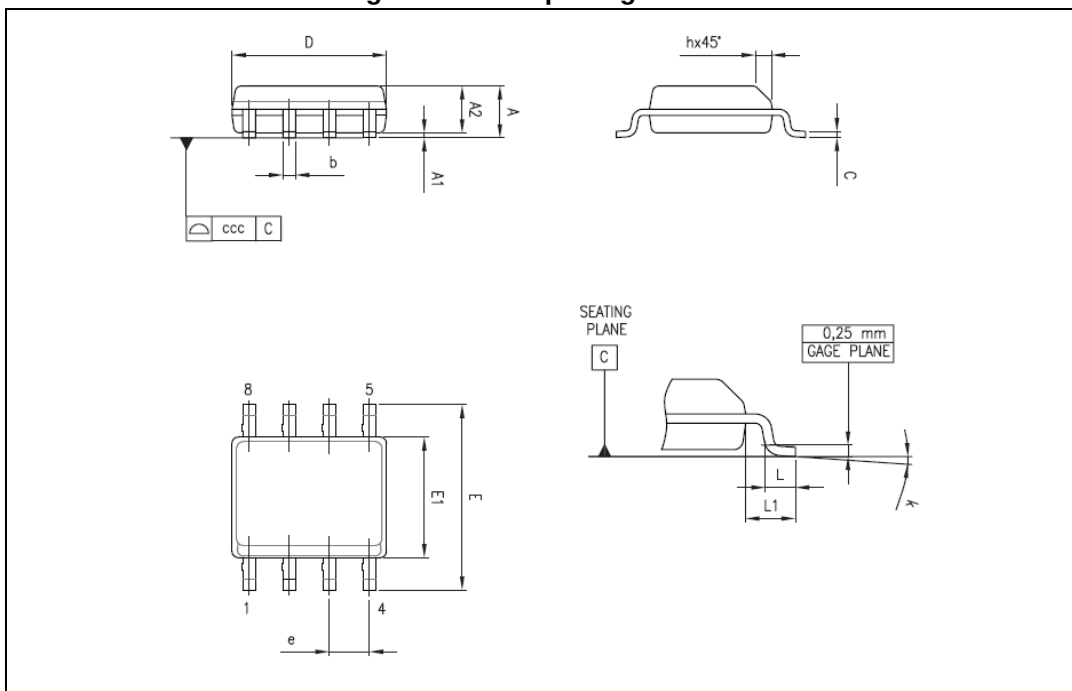


Table 7. SO-8 package mechanical data

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

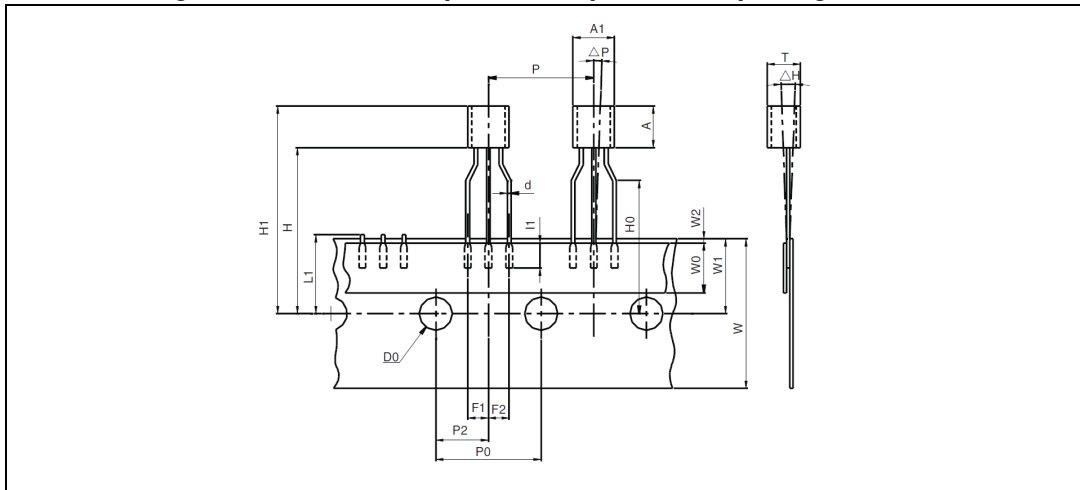


Table 8. TO-92 ammopack and tape and reel package mechanical data

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	-
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 26. TO-92 bulk package outline

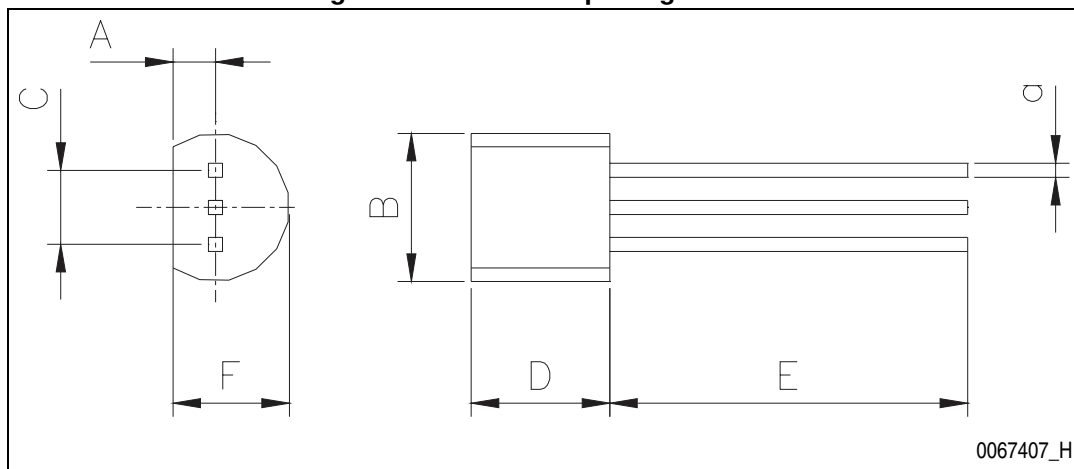


Table 9. TO-92 bulk package mechanical data

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

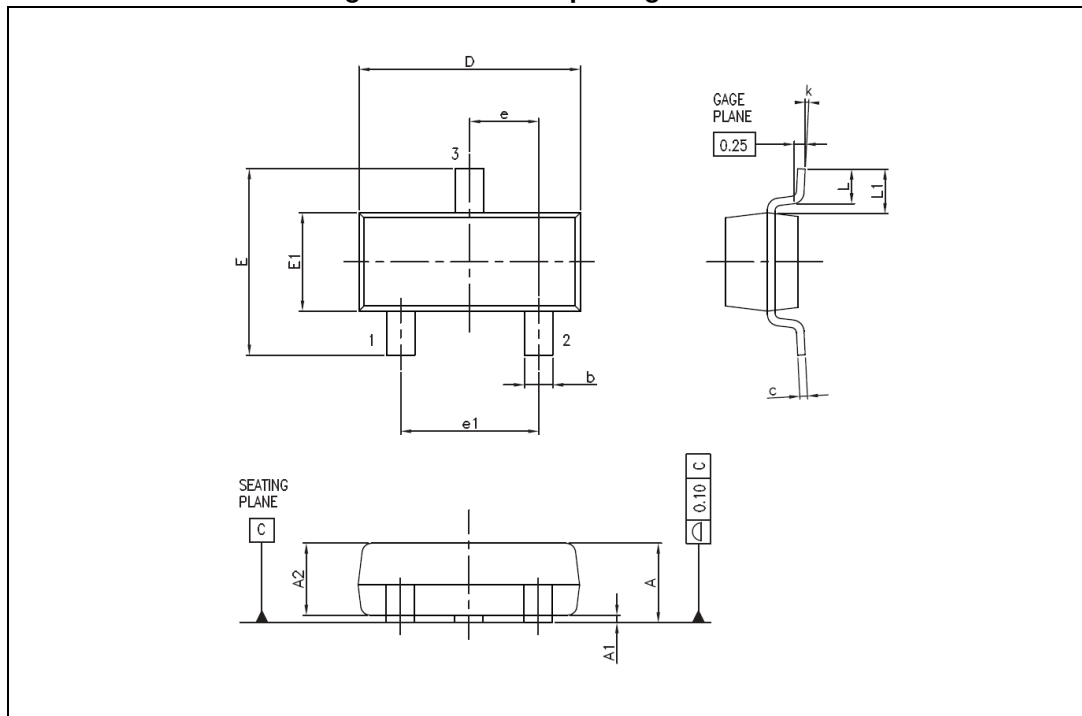


Table 10. SOT23-3 package mechanical data

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

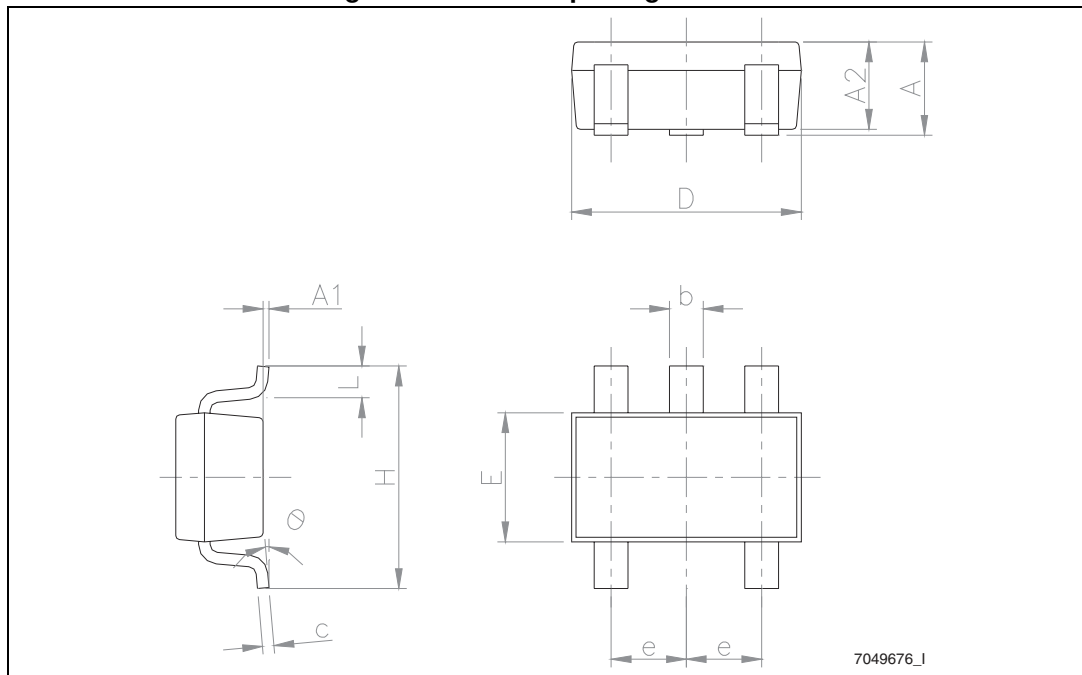
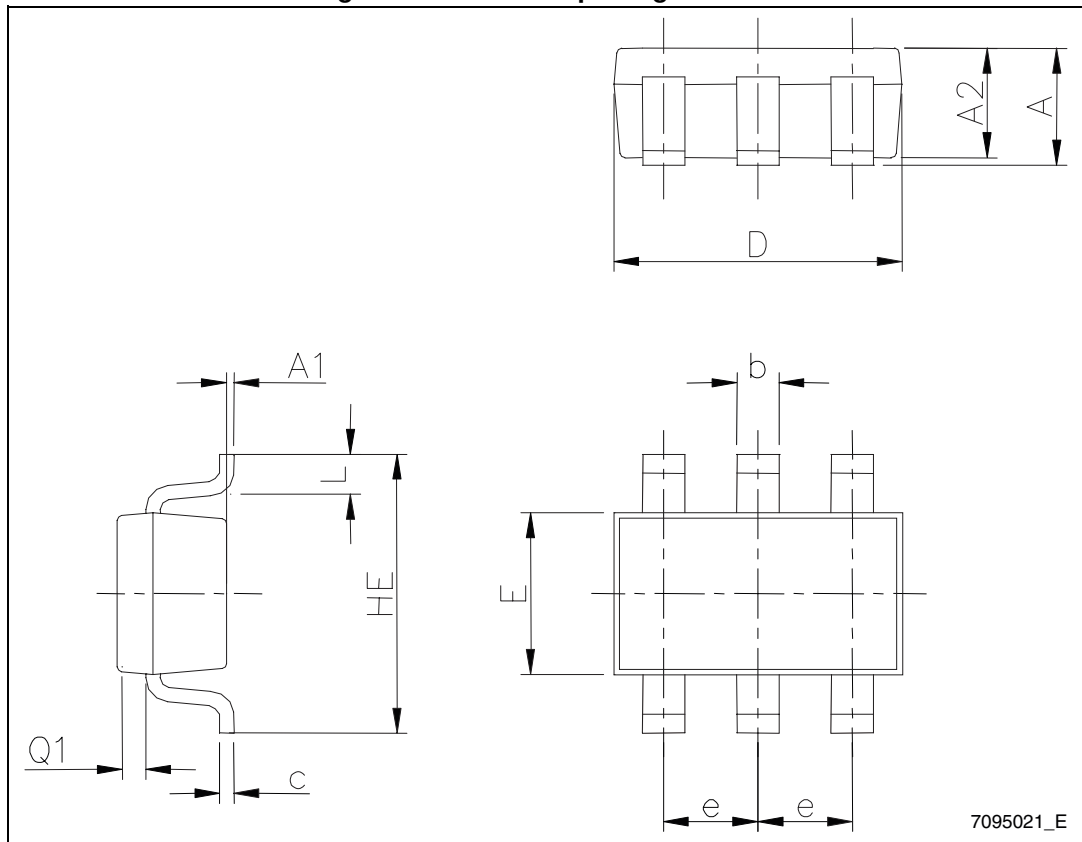


Table 11. SOT23-5 package mechanical data

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
θ	0 degrees	-	10 degrees	-	-	-

4.6 SOT323-6 package information

Figure 29. SOT323-6 package outline



7095021_E

Table 12. 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 13. 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	431CH	
TL431ACD TL431ACDT	1				431ACH	
TL431CZ TL431CZT TL431CZ-AP	2		TO-92	Bulk or Tape or Ammopack	TL431C	
TL431ACZ TL431ACZT TL431ACZ-AP	1				TL431AC	
TL431CL3T	2		-40 °C to +105 °C	SOT23-3	Tape	L19
TL431ACL3T	1			SOT23-5		L18
TL431CL5T	2					SOT323-6
TL431ACL5T	1			L18		
TL431CCT	2			31C		
TL431ACCT	1			31C		
TL431ID TL431IDT	2	-40 °C to +105 °C	SO-8	Tube or tape and reel	431IH	
TL431AID TL431AIDT	1				431AIH	
TL431IZ TL431IZT TL431IZ-AP	2		TO-92	Bulk or Tape or Ammopack	TL431I	
TL431AIZ TL431AIZT TL431AIZ-AP	1				TL431AI	
TL431IL3T	2		-40 °C to +125 °C	SOT23-3	Tape	L17
TL431AIL3T	1			SOT23-3		L16
TL432IL3T	2					SOT23-5
TL432AIL3T	1			32AI		
TL431IL5T	2			SOT323-6		L17
TL431AIL5T	1					L16
TL431ICT	2	31I				
TL431AICT	1	31I				
TL431BL3T	0.5	-40 °C to +125 °C	SOT23-3		1B	
TL432BL3T	0.5	-40 °C to +125 °C	SOT23-3		2B	

Table 13. Order codes (continued)

Order code	Accuracy (%)	Temperature range	Package	Packing	Marking
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 and Q 002 or equivalent.

6 Revision history

Table 14. 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 on <i>page 1</i> and <i>Section : Features on page 1</i> , (added "automotive" - AEC-Q100 qualified). Updated <i>Table 1 on page 4</i> (updated R_{thja} and R_{thjc}). Minor modifications throughout document.
10-Sep-2020	13	Added the part number TL431B and all its occurrences throughout the document.
23-Sep-2020	14	Updated <i>Table 4: TL431B</i> ($T_{amb} = 25\text{ °C}$ unless otherwise specified).
08-Feb-2021	15	Updated <i>Table 13: Order codes</i> .
14-Feb-2022	16	Added new order code TL432BL3T and updated Marking in <i>Table 13</i> .

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