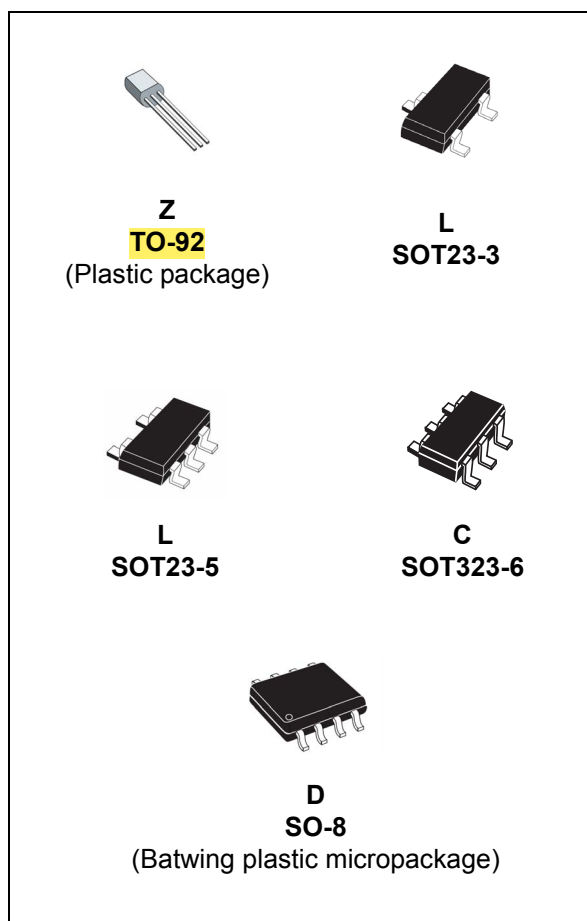


## Automotive adjustable voltage reference

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  $\Omega$ .

### Features



- AEC-Q100 qualified
- Adjustable output voltage: 2.5 to 36 V
- Sink current capability: 1 to 100 mA
- Typical output impedance: 0.22  $\Omega$
- 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)

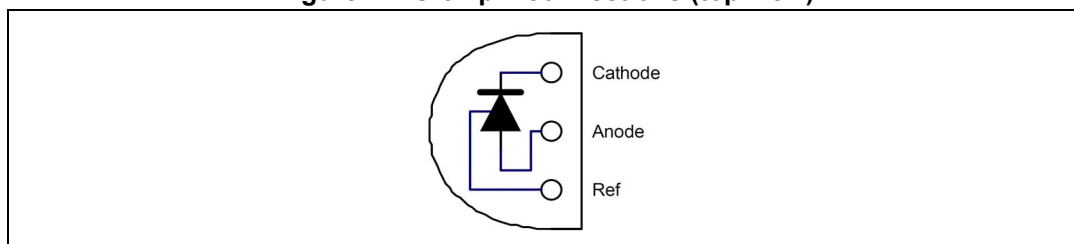


Figure 2. SO-8 batwing pin connections (top view)

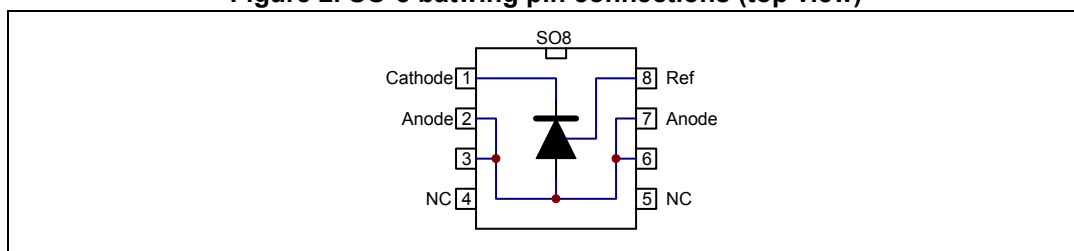


Figure 3. SOT23-5 and SOT23-3 pin connections (top view)

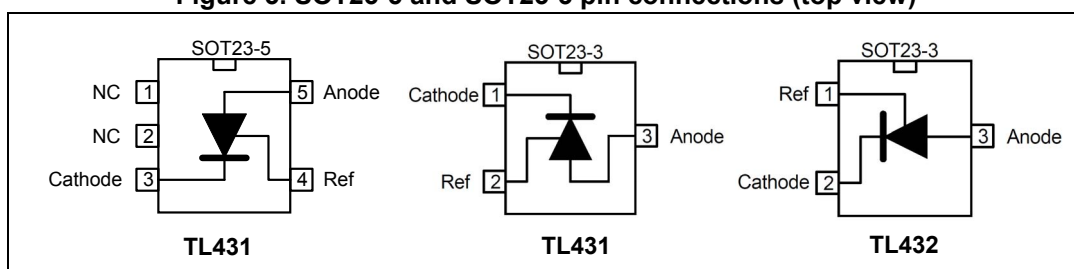


Figure 4. SOT323-6 pin connections (top view)

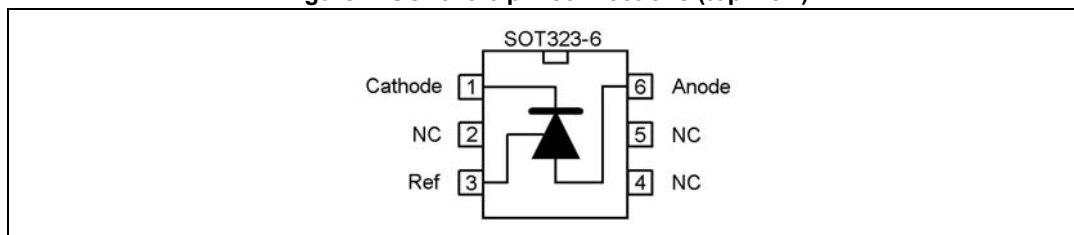
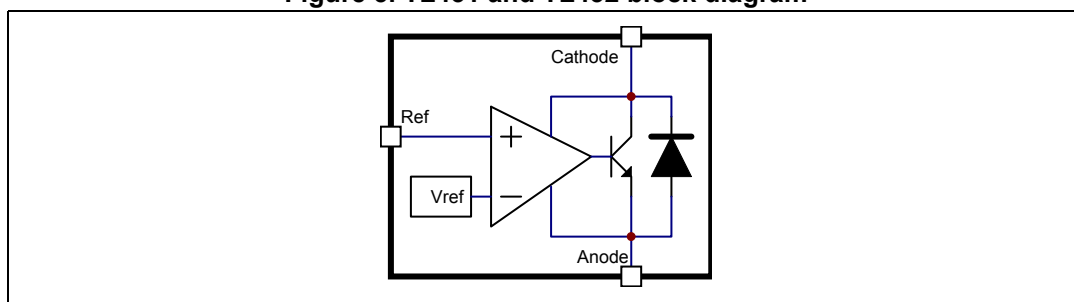


Figure 5. TL431 and TL432 block diagram



## 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	

1. Human body model: a 100 pF capacitor is charged to the specified voltage, then discharged through a 1.5 k $\Omega$  resistor between two pins of the device. This is done for all couples of connected pin combinations while the other pins are floating.
2. 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  $\Omega$ ). This is done for all couples of connected pin combinations while the other pins are floating.
3. 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		
	TL431C/AC	0 to +70	°C
	TL431I/AI - TL432I/AI	-40 to +105	
	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
$\Delta V_{ref}$	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> $V_{KA} = V_{ref}$ , $\Delta I_k = 1\text{ to }100\text{ mA}$ , $f \leq 1\text{ kHz}$	-	0.22	0.5	-	0.22	0.5	$\Omega$

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

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

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

Symbol	Parameter	TL431I/TL432I			TL431AI/TL432AI			Unit
		Min.	Typ.	Max.	Min.	Typ.	Max.	
$V_{ref}$	Reference input voltage $V_{KA} = V_{ref}$ , $I_k = 10\text{ mA}$ , $T_{amb} = 25\text{ }^{\circ}\text{C}$ $T_{min} \leq T_{amb} \leq T_{max}$	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 $I_k = 10\text{ mA}$ , $R1 = 10\text{ k}\Omega$ , $R2 = \infty$ $T_{amb} = 25\text{ }^{\circ}\text{C}$ $T_{min} \leq T_{amb} \leq T_{max}$	- -	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 ( $T_{amb} = 25\text{ °C}$  unless otherwise specified)

Symbol	Parameter	TL431IY			TL431AIY			Unit
		Min.	Typ.	Max.	Min.	Typ.	Max.	
$V_{ref}$	Reference input voltage $V_{KA} = V_{ref}$ , $I_k = 10\text{ mA}$ $T_{min} \leq T_{amb} \leq T_{max}$	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 $I_k = 10\text{ mA}$ , $\Delta V_{KA} = 10\text{ V to } V_{ref}$ $I_k = 10\text{ mA}$ , $\Delta V_{KA} = 36\text{ V to } 10\text{ V}$	-2.7 -2	-1.4 -1	- -	-2.7 -2	-1.4 -1	- -	mV/V
$I_{ref}$	Reference input current $I_k = 10\text{ mA}$ , $R1 = 10\text{ k}\Omega$ , $R2 = \infty$ $T_{min} \leq T_{amb} \leq T_{max}$	- -	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	0.6	mA
$I_{off}$	Off-state cathode current $T_{min} \leq T_{amb} \leq T_{max}$	- -	2.6	1000 3000	- -	2.6	1000 3000	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  $|Z_{KA}| = \frac{\Delta V_{KA}}{\Delta I_k}$

## Reference input voltage deviation overtemperature 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 6. Reference input voltage deviation overtemperature range

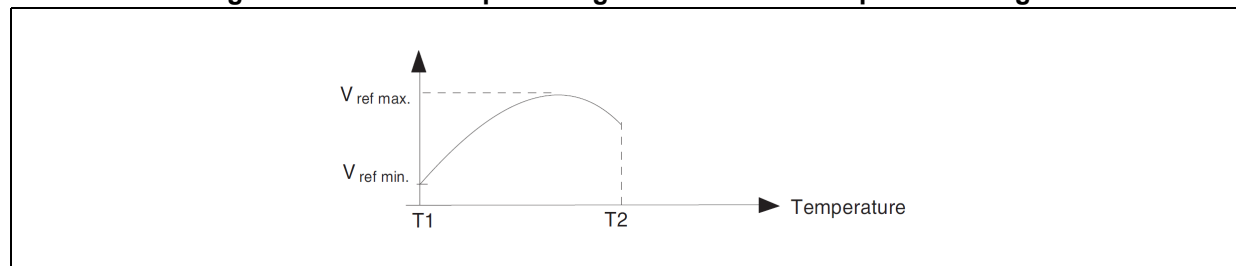


Figure 7. Test circuit for  $V_{KA} = V_{ref}$

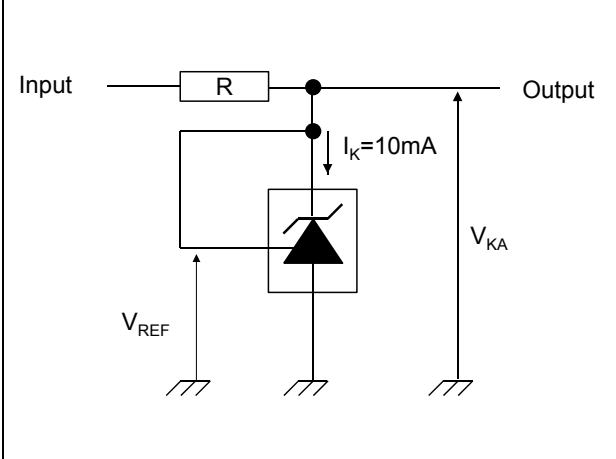


Figure 8. Test circuit for programming mode

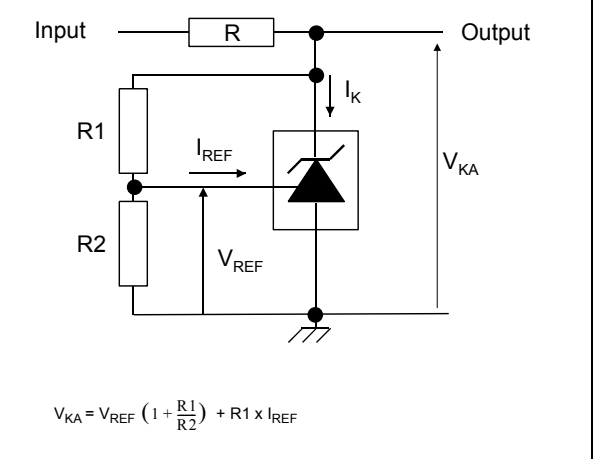


Figure 9. Test circuit for  $I_{off}$

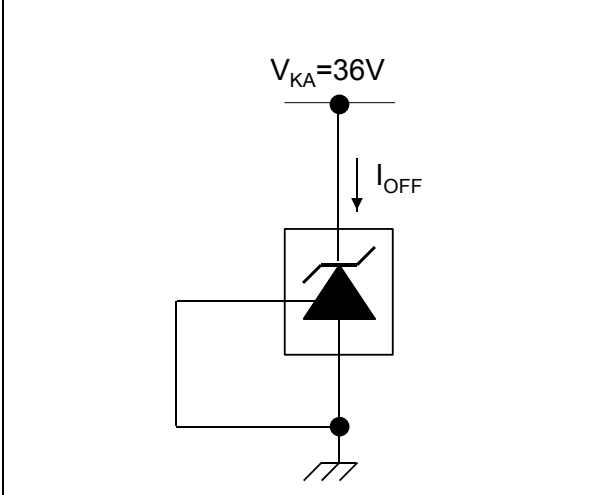


Figure 10. Test circuit for phase margin and voltage gain

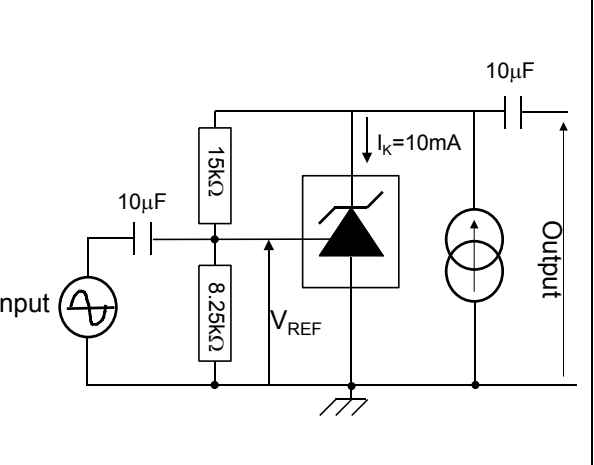


Figure 11. Test circuit for response time

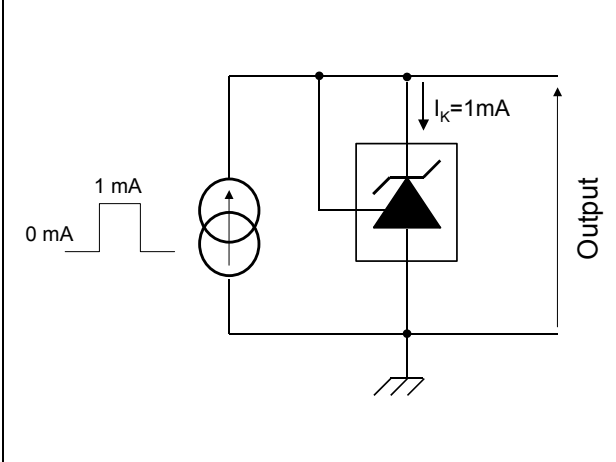
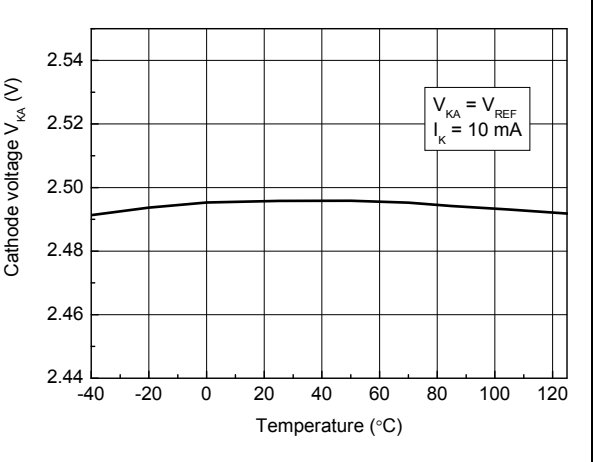


Figure 12. Reference voltage vs. temperature





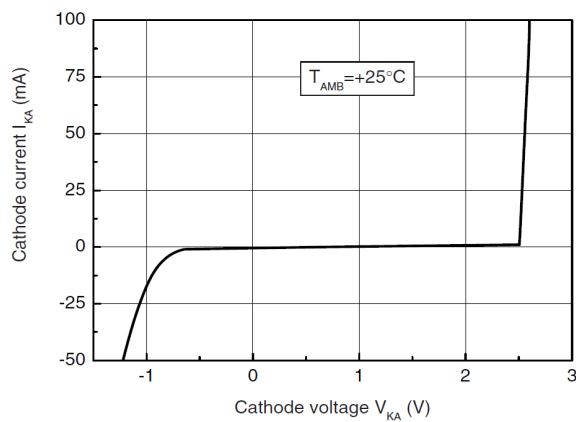
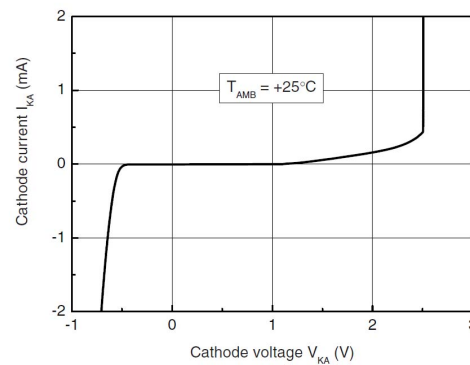
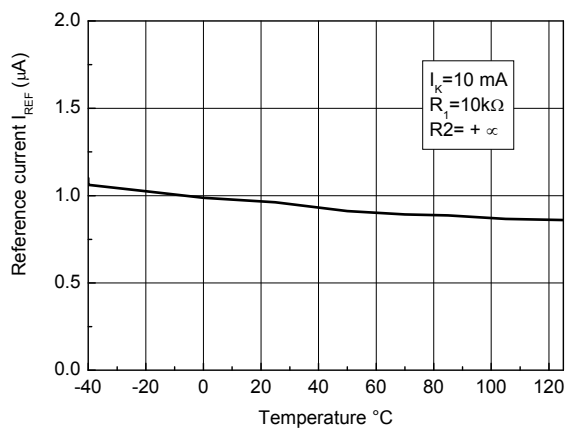
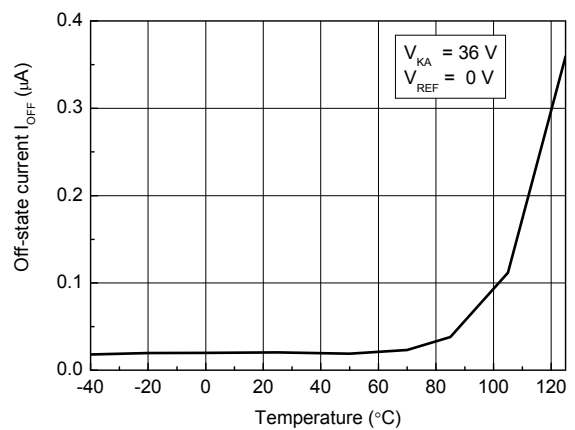
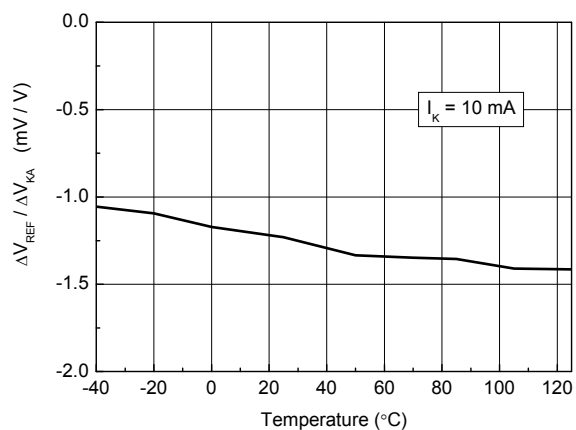
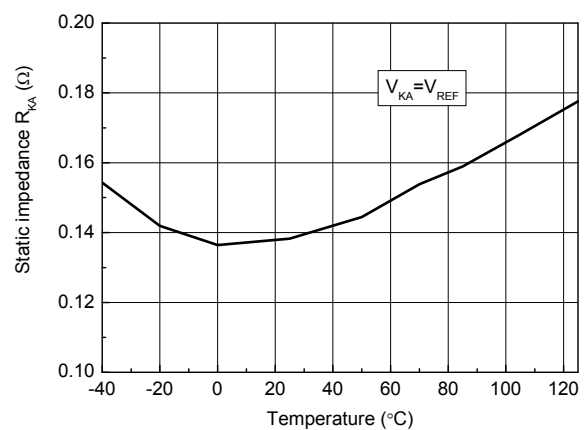
**Figure 13. Reference voltage vs. cathode current****Figure 14. Zoom on reference voltage vs. cathode current****Figure 15. Reference current vs. temperature****Figure 16. Off-state cathode current vs. temperature****Figure 17. Ratio of change in  $V_{REF}$  to change in  $V_{KA}$  vs. temperature****Figure 18. Static impedance  $R_{KA}$  vs. temperature**

Figure 19. Minimum operating current vs. temperature

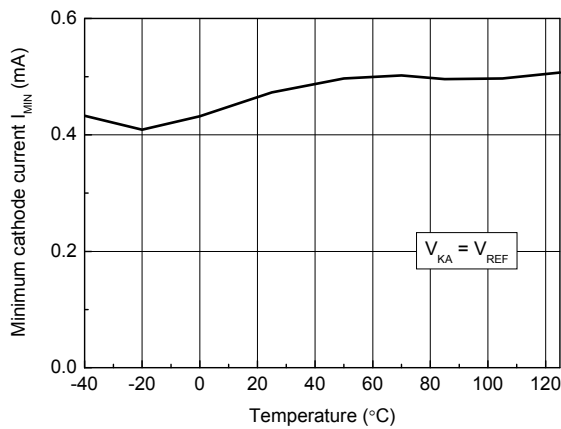


Figure 20. Gain and phase vs. frequency

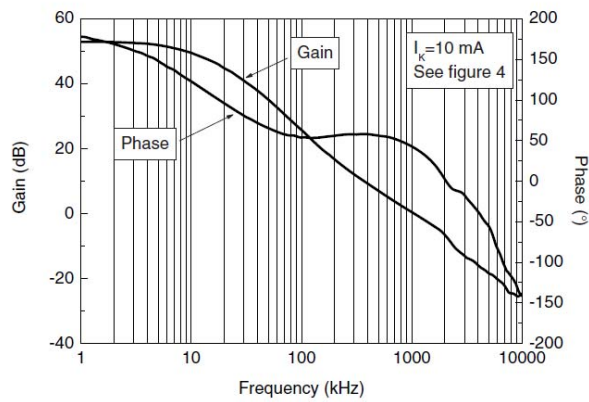


Figure 21. Stability behavior with capacitive loads

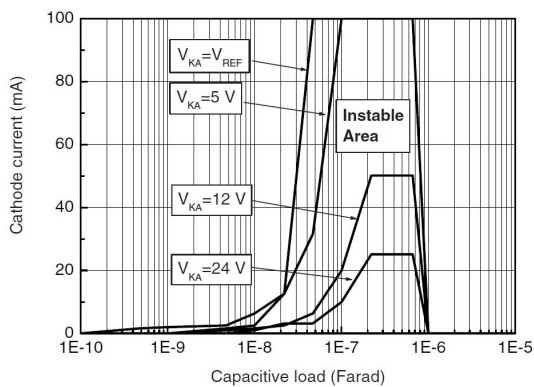


Figure 22. Maximum power dissipation

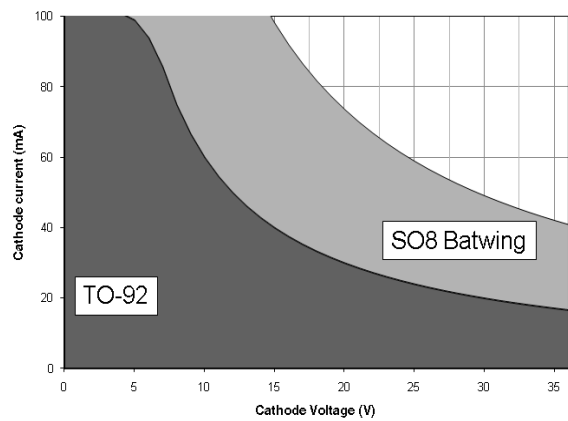
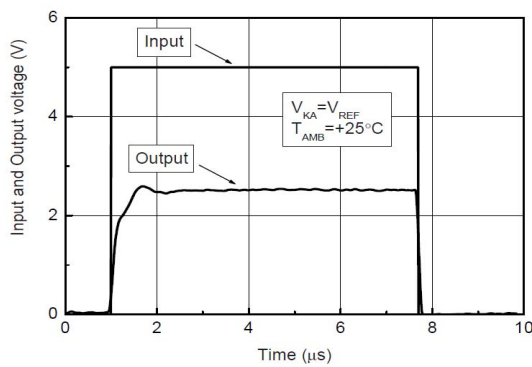


Figure 23. Pulse response for  $I_K = 1 \text{ mA}$



## 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

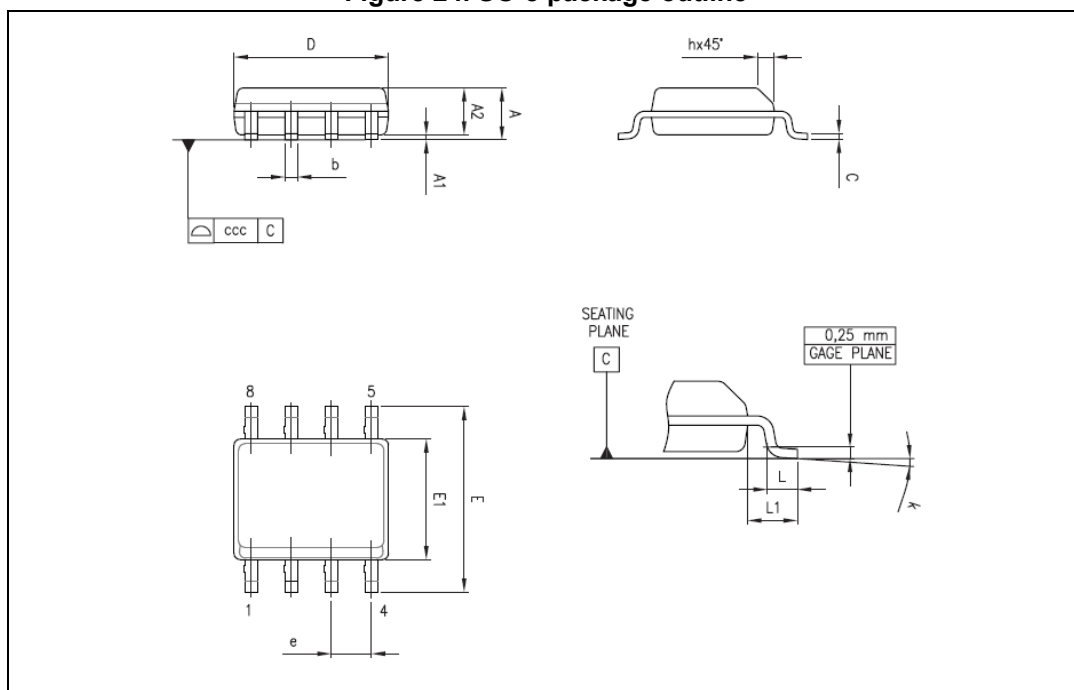


Table 6. SO-8 package mechanical data

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

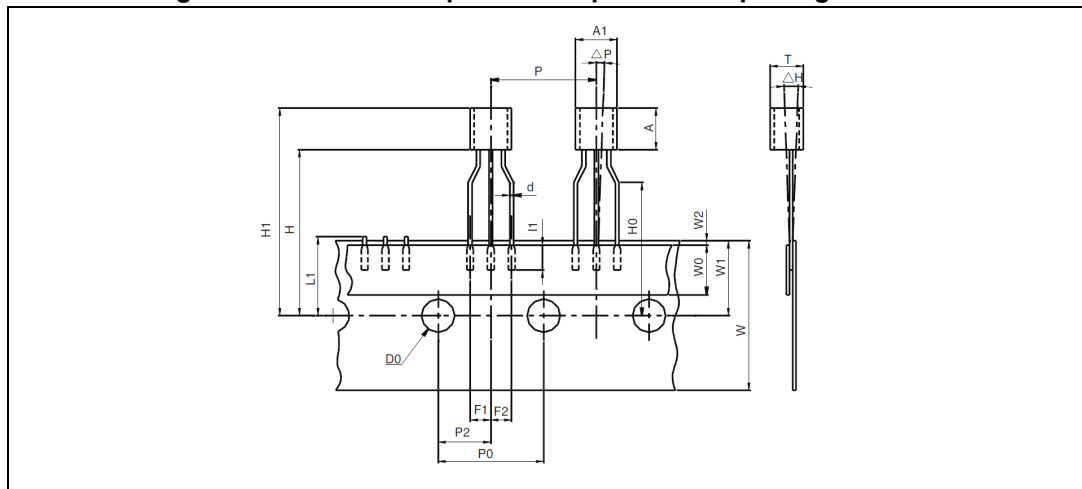


Table 7. TO-92 ammopack and tape and reel package mechanical data

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	-
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
$\Delta h$	-1	0	1	-0.039	0	0.039
$\Delta P$	-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

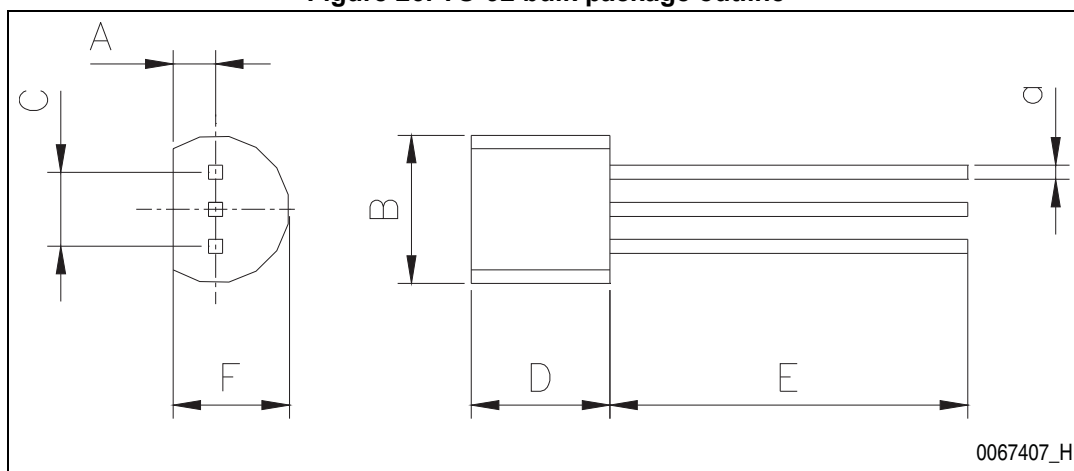


Table 8. TO-92 bulk package mechanical data

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

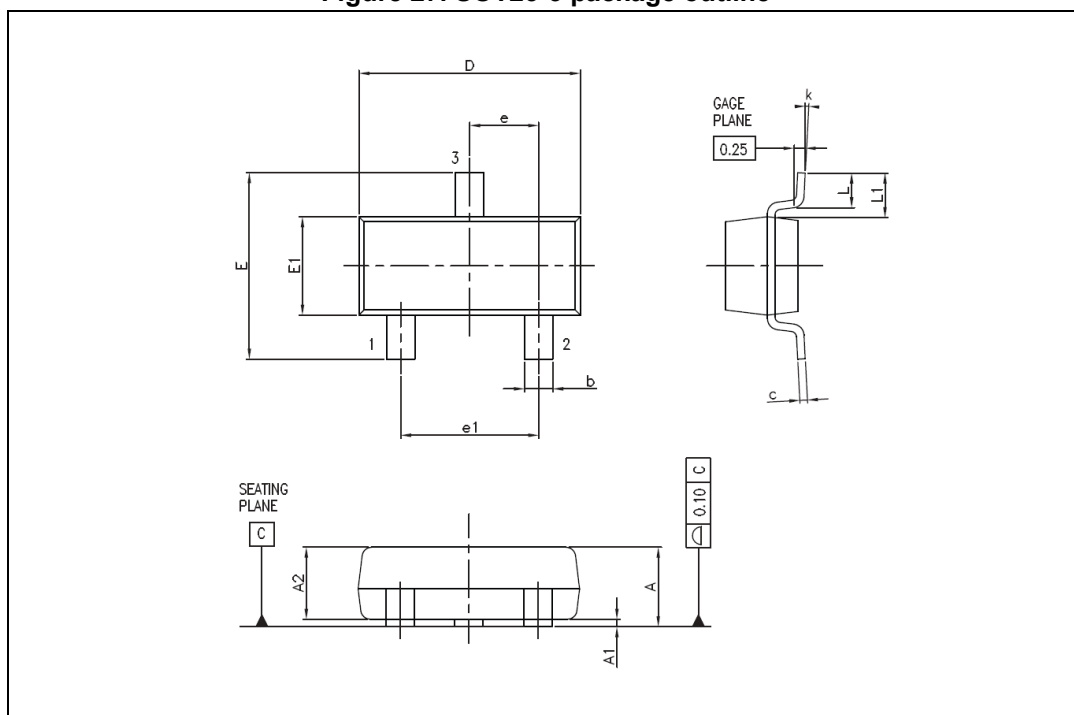


Table 9. SOT23-3 package mechanical data

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

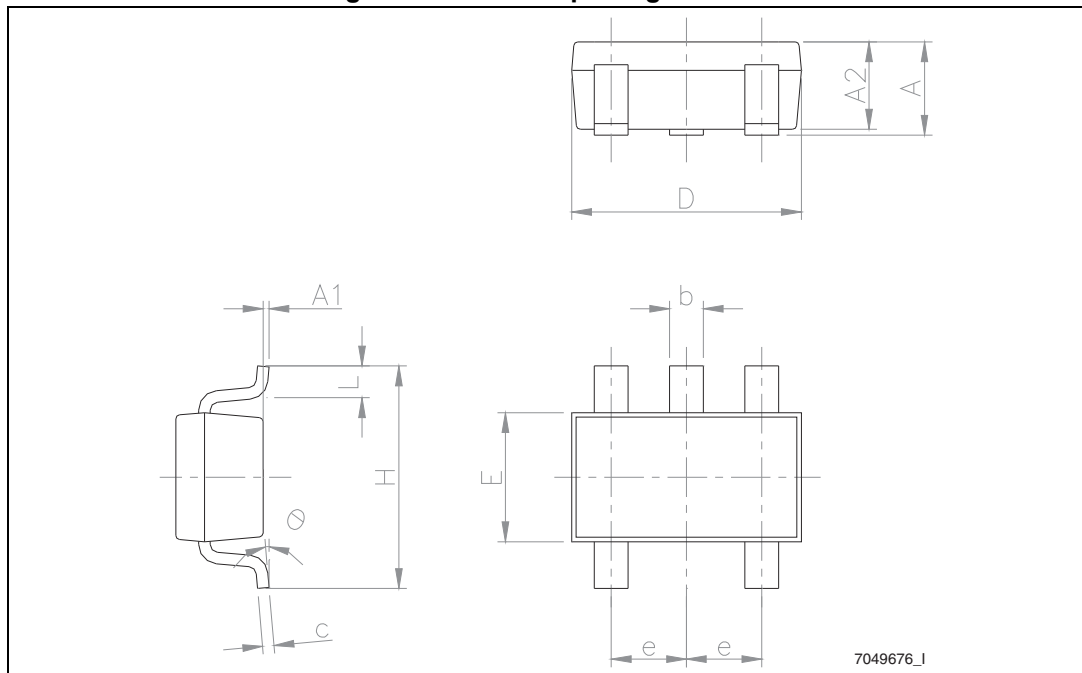


Table 10. SOT23-5 package mechanical data

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
θ	0 degrees	-	10 degrees	-	-	-



## 4.6 SOT323-6 package information

Figure 29. SOT323-6 package outline

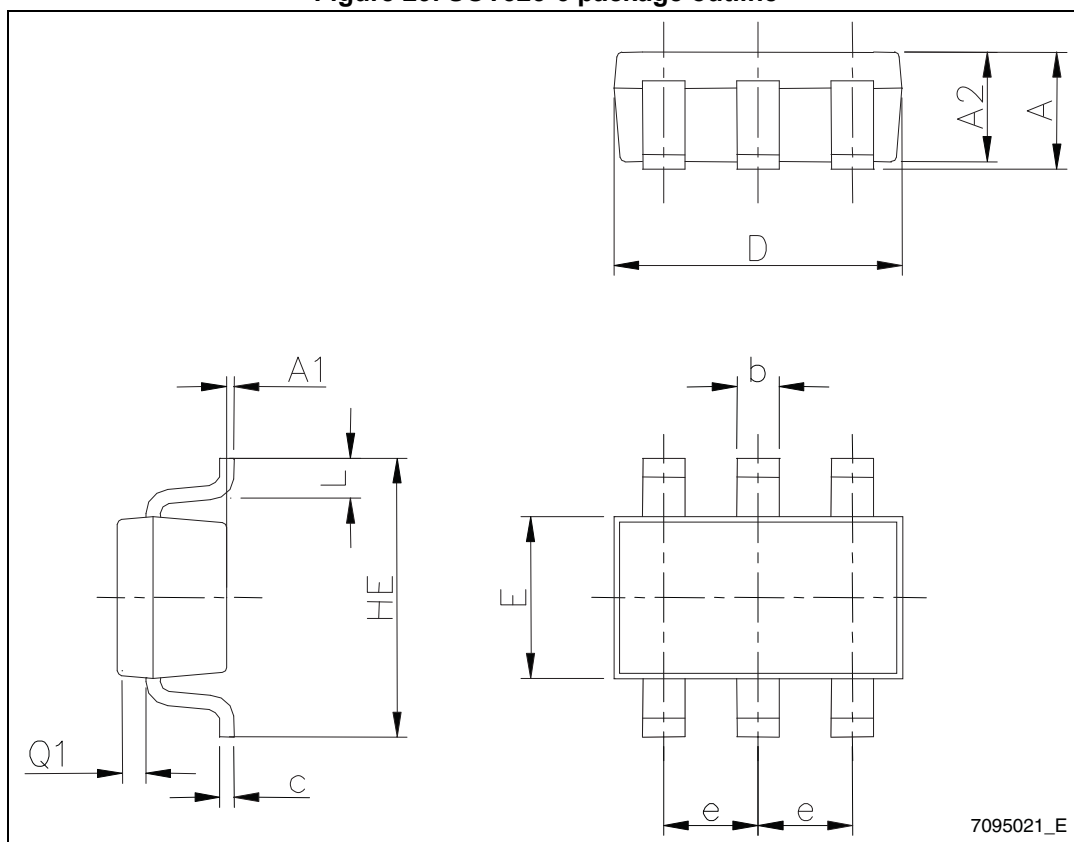


Table 11. SOT323-6 package mechanical data

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		SOT23-5		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			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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