TL431

Programmable voltage reference

Features

- 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

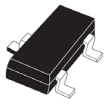
Applications

- Power supply
- Industrial
- Automotive

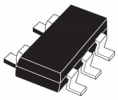
Description

The TL431 is a programmable shunt voltage reference with guaranteed temperature stability over the entire operating temperature range. The device's 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 operates with a wide current range from 1 to 100 mA with a typical dynamic impedance of 0.22 Ω.

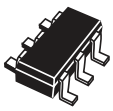
Z
TO-92
(Plastic package)



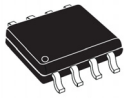
L
SOT23-3



L
SOT23-5



C
SOT323-6



D
SO-8
(Batwing plastic micropackage)

Contents

1 Schematic diagrams

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

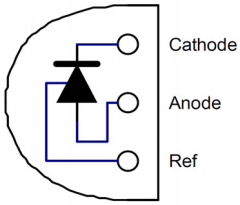


Figure 2. SO-8 batwing pin connections (top view)

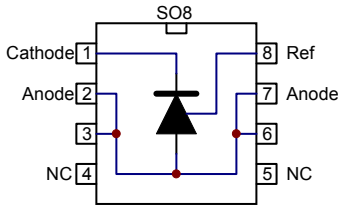


Figure 3. SOT23-5 and SOT23-3 pin connections (top view)

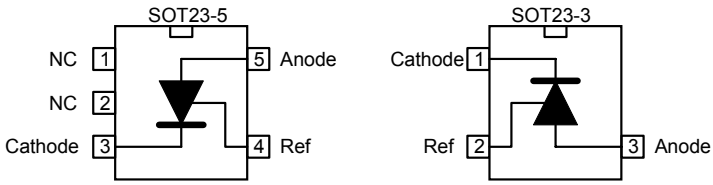


Figure 4. SOT323-6 pin connections (top view)

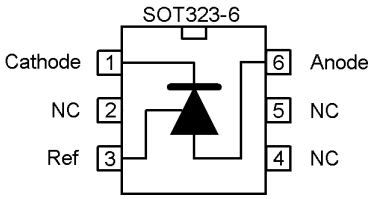
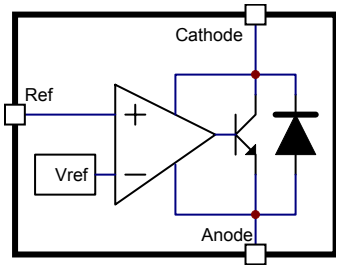


Figure 5. TL431 block diagram



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_{thja}	Thermal resistance junction to ambient(1) TO-92 SO-8 batwing SOT23-3L SOT23-5L SOT323-6L	 200 85 248 157 221	°C/W
R_{thjc}	Thermal resistance junction to case (1) SO-8 batwing SOT23-3L SOT23-5L SOT323-6L	 30 136 67 110	°C/W
T_{stg}	Storage temperature range	-65 to +150	°C
T_J	Junction temperature	150	°C
ESD	TL431IY TL431AIY: HBM: human body model (2) TL431: HBM: human body model MM: machine model (3) CDM: charged device model (4)	3000 2000 200 1500	V

1. Short-circuits can cause excessive heating. These values are typical.
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 TL431C/AC TL431I/AI TL431IY/AIY	 0 to +70 -40 to +105 -40 to +125	°C

3 Electrical characteristics

Table 3. TL431C: 0° C to 70° C (T_{amb} = 25° 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 mA, T_{amb} = 25° 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 over temperature range (1) $V_{KA} = V_{ref}$, I_k = 10 mA, $T_{min} \leq T_{amb} \leq T_{max}$		3	17		3	15	mV
$\frac{\Delta Vref}{\Delta Vka}$	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 $T_{min} \leq T_{amb} \leq T_{max}$		1.8	4 5.2		1.8	4 5.2	µA
ΔI_{ref}	Reference input current deviation over temperature range I_k = 10 mA, R1 = 10 kΩ, R2 =∞ $T_{min} \leq T_{amb} \leq T_{max}$		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
$\lvert ZKA \rvert$	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 3.1: Reference input voltage deviation over temperature range*.
2. The dynamic impedance is defined as $\lvert ZKA \rvert = \frac{\Delta V_{KA}}{\Delta I_k}$

Table 4. TL431I: -40° C to 105° C, T_{amb} = 25°C (unless otherwise specified)

Symbol	Parameter	TL431I			TL431AI			Unit
		Min.	Typ.	Max.	Min.	Typ.	Max.	
V_{ref}	Reference input voltage $V_{KA} = V_{ref}$, I_k = 10 mA, T_{amb} = 25° C $T_{min} \leq T_{amb} \leq T_{max}$	2.44 2.41	2.495	2.55 2.58	2.47 2.44	2.495	2.52 2.55	V
ΔV_{ref}	Reference input voltage deviation over temperature range (1) $V_{KA} = V_{ref}$, I_k =10 mA, $T_{min} \leq T_{amb} \leq T_{max}$		7	30		7	30	mV
$\frac{\Delta Vref}{\Delta Vka}$	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 $T_{min} \leq T_{amb} \leq T_{max}$		1.8	4 6.5		1.8	4 6.5	µA
ΔI_{ref}	Reference input current deviation over temperature range I_k = 10 mA, R1 = 10 kΩ, R2 = ∞ $T_{min} \leq T_{amb} \leq T_{max}$		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
$\lvert ZKA \rvert$	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 3.1: Reference input voltage deviation over temperature range* below.
2. The dynamic impedance is defined as $\lvert ZKA \rvert = \frac{\Delta V_{KA}}{\Delta I_k}$

Table 5. TL431IY: -40° C to 125° C, 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 $T_{min} \leq T_{amb} \leq T_{max}$	2.44 2.41	2.495	2.55 2.58	2.47 2.44	2.495	2.52 2.55	V
ΔV_{ref}	Reference input voltage deviation over temperature range (1) $V_{KA} = V_{ref}$, I_k = 10 mA, $T_{min} \leq T_{amb} \leq T_{max}$		7	30		7	30	mV
$\frac{\Delta Vref}{\Delta Vka}$	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 = ∞ $T_{min} \leq T_{amb} \leq T_{max}$		1.8	4 6.5		1.8	4 6.5	µA
ΔI_{ref}	Reference input current deviation over temperature range I_k = 10 mA, R1 = 10 kΩ, R2 = ∞, $T_{min} \leq T_{amb} \leq T_{max}$		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 $T_{min} \leq T_{amb} \leq T_{max}$		2.6	1000 3000		2.6	1000 3000	nA
$\lvert ZKA \rvert$	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 3.1: Reference input voltage deviation over temperature range* below.
2. The dynamic impedance is defined as $\lvert ZKA \rvert = \frac{\Delta V_{KA}}{\Delta I_k}$

3.1 Reference input voltage deviation over temperature 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 over temperature range

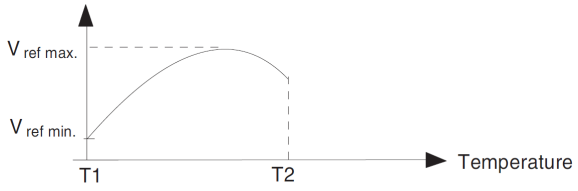


Figure 7. Test circuit for $V_{KA} = V_{ref}$

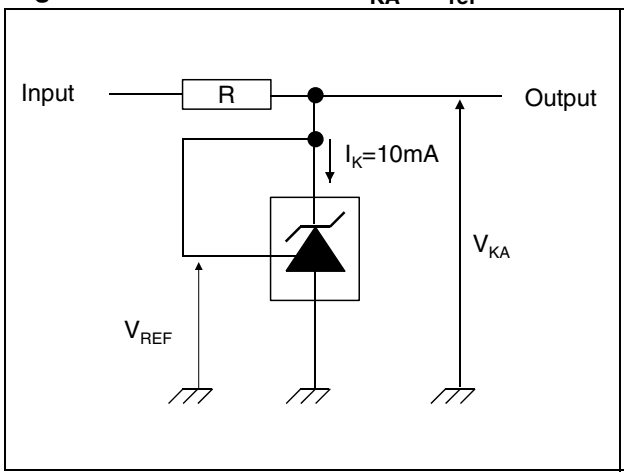


Figure 8. Test circuit for programming mode

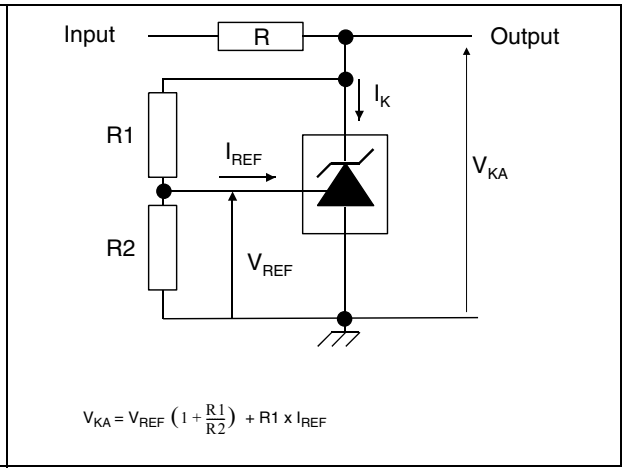


Figure 9. Test circuit for I_{off}

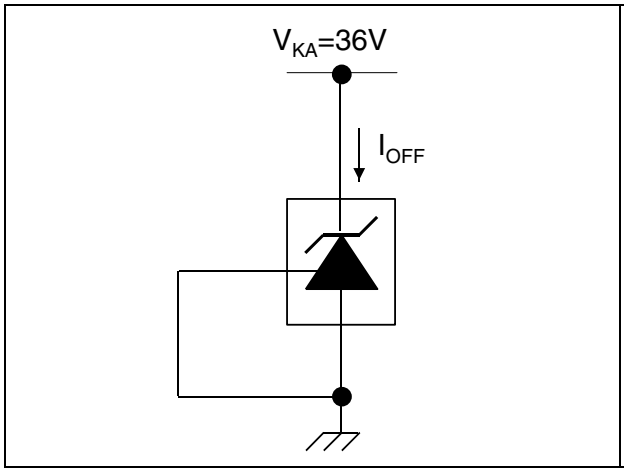


Figure 10. Test circuit for phase margin and voltage gain

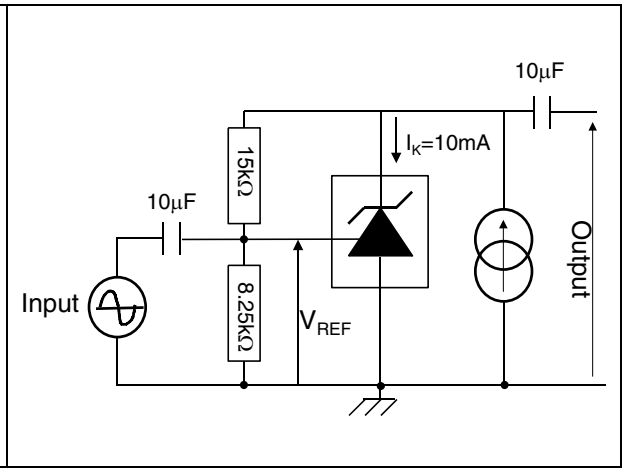


Figure 11. Test circuit for response time

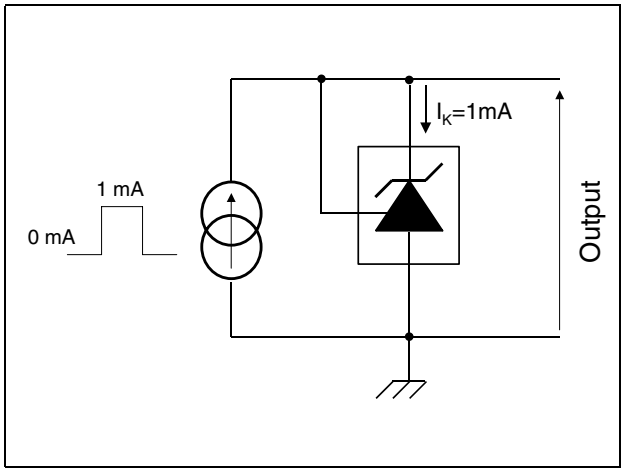


Figure 12. Reference voltage vs. temperature

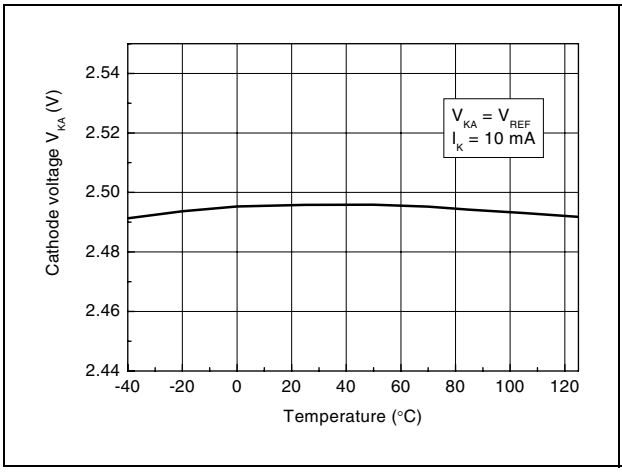


Figure 13. Reference voltage vs. cathode current

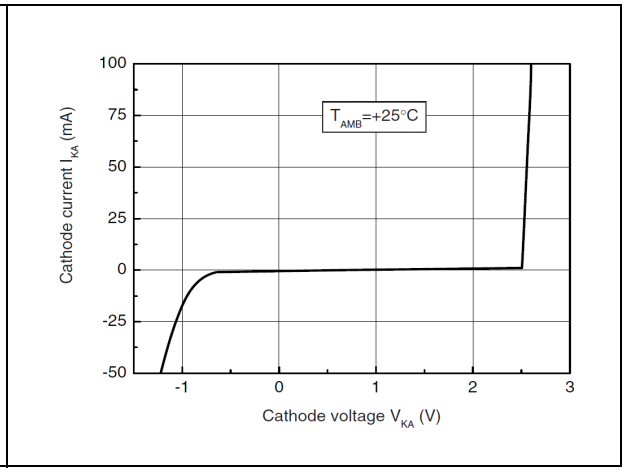


Figure 14. Zoom on reference voltage vs. cathode current

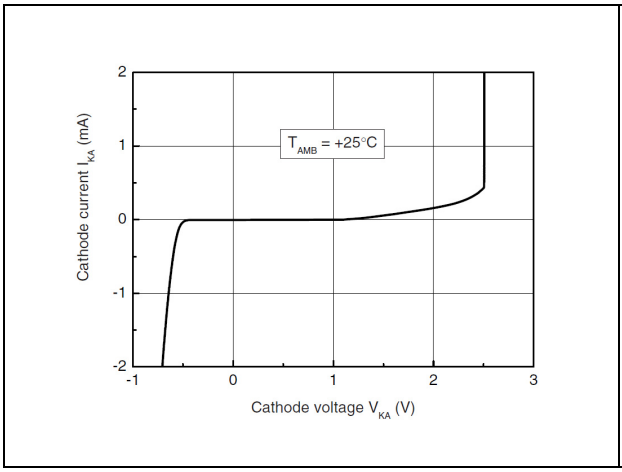


Figure 15. Reference current vs. temperature

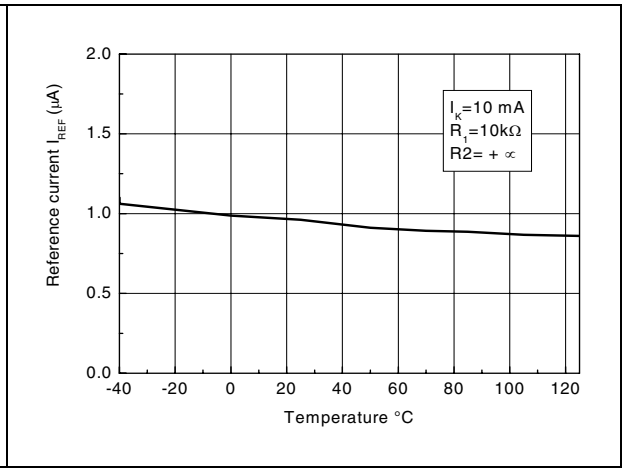


Figure 16. Off-state cathode current vs. temperature

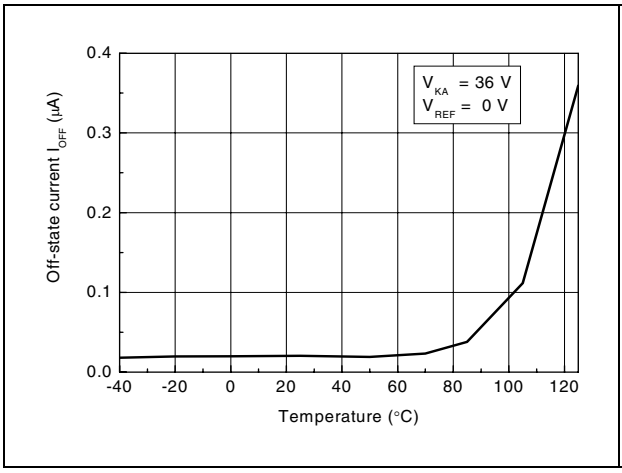


Figure 17. Ratio of change in V_{ref} to change in V_{KA} vs. temperature

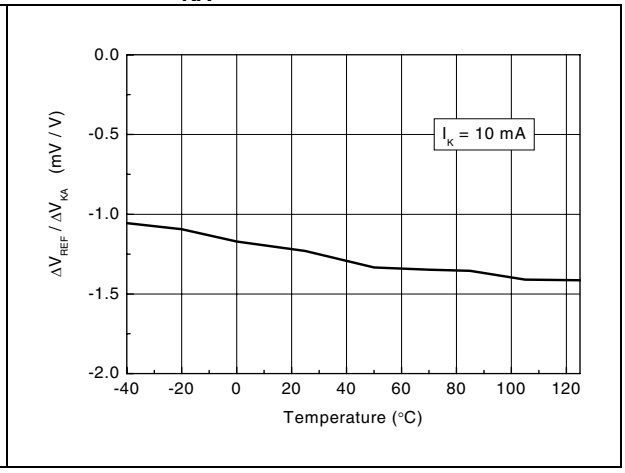


Figure 18. Static impedance R_{KA} vs. temperature

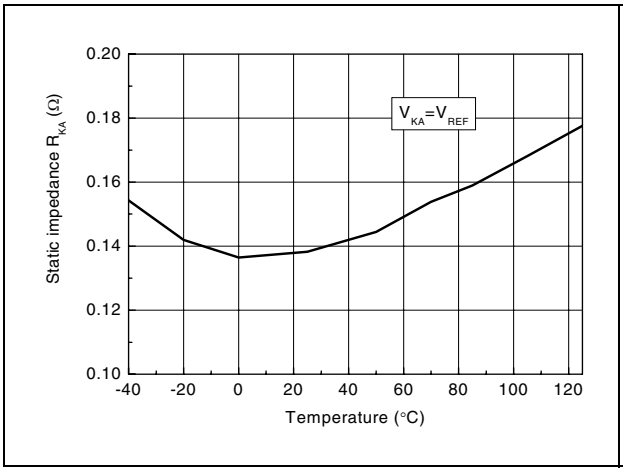


Figure 19. Minimum operating current vs. temperature

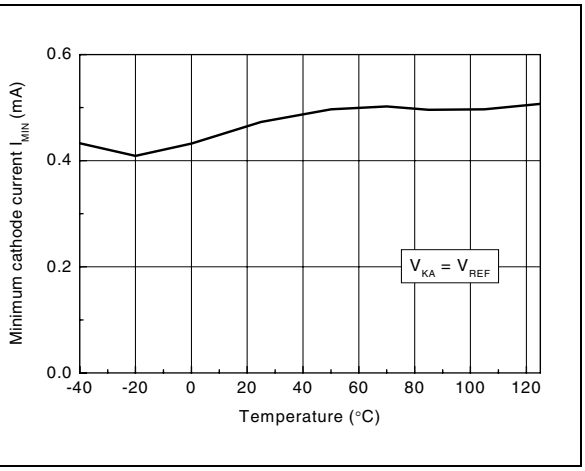


Figure 20. Gain and phase vs. frequency

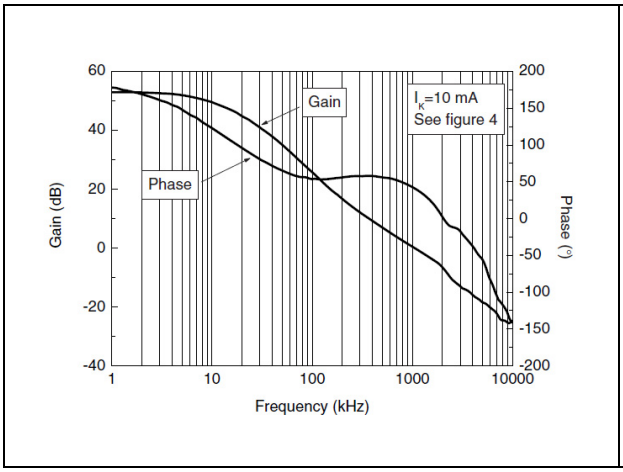


Figure 21. Stability behavior with capacitive loads

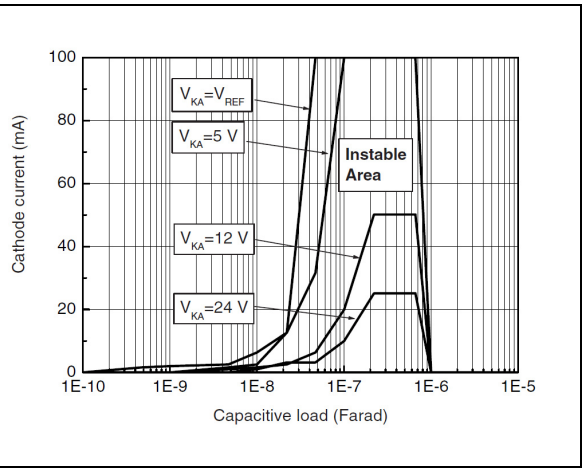


Figure 22. Maximum power dissipation

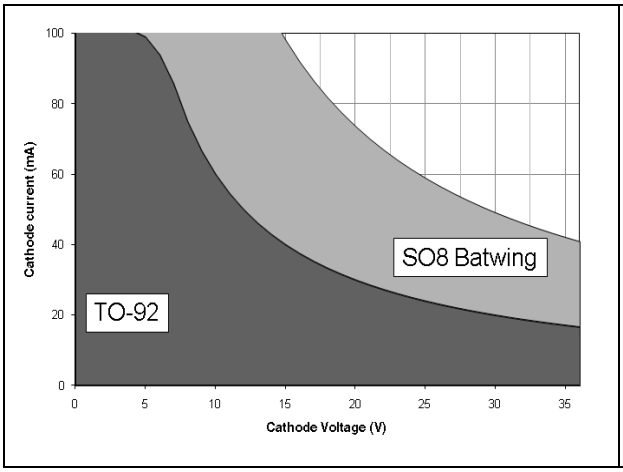
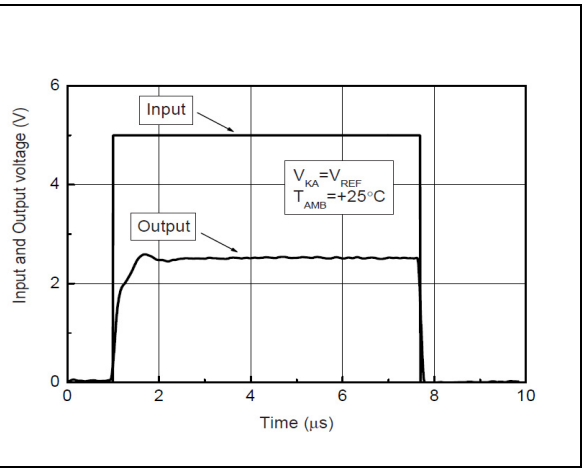


Figure 23. Pulse response for I_k = 1 mA



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 mechanical drawing

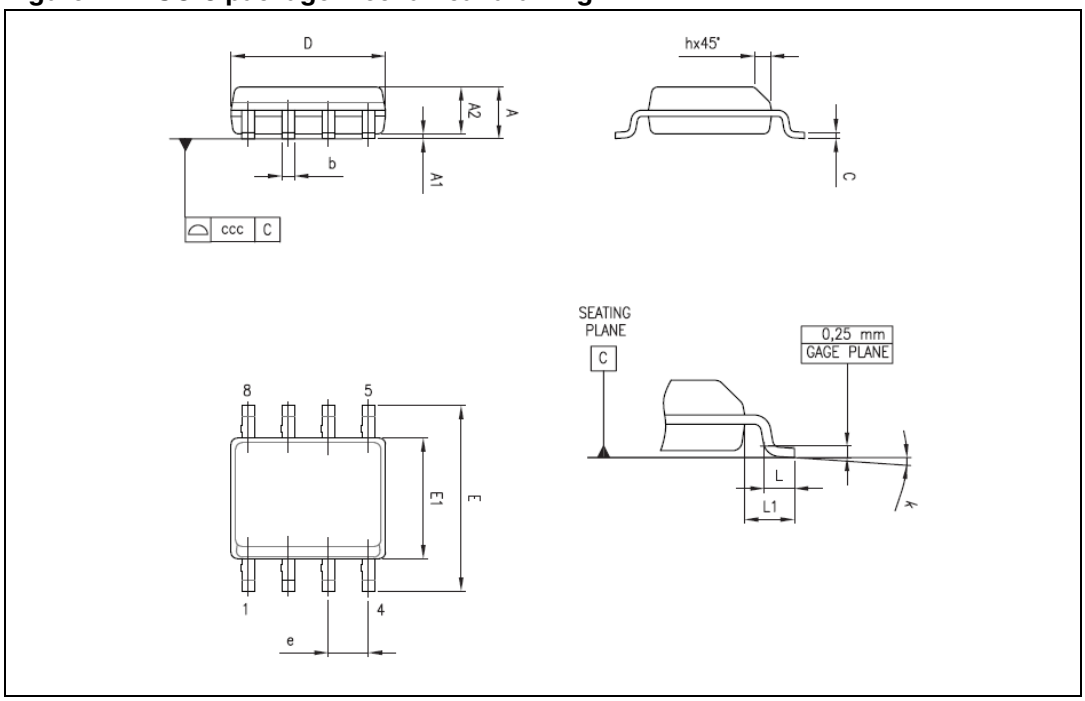


Table 6. SO-8 package mechanical data

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
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 mechanical drawing

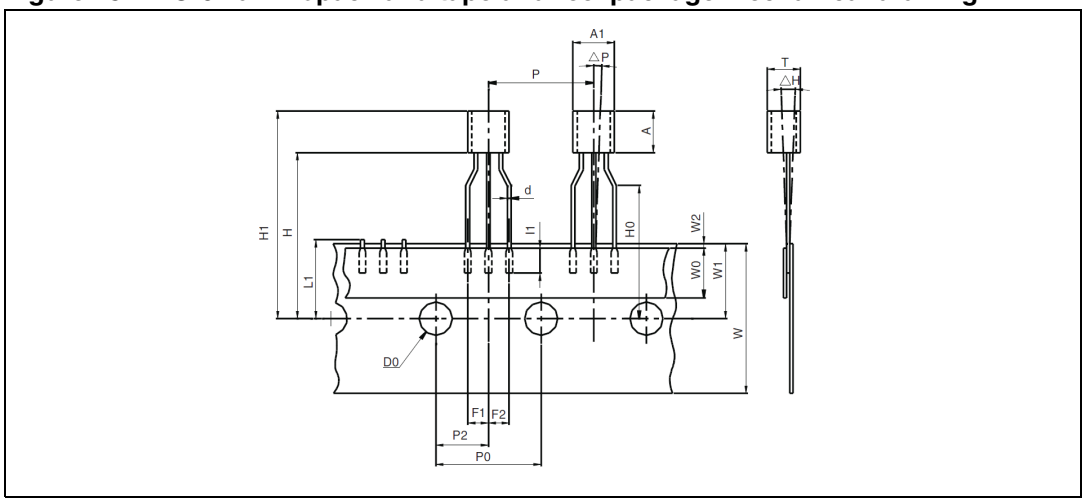


Table 7. TO-92 ammopack and tape and reel package mechanical data

Dim.	Millimeters			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 mechanical drawing

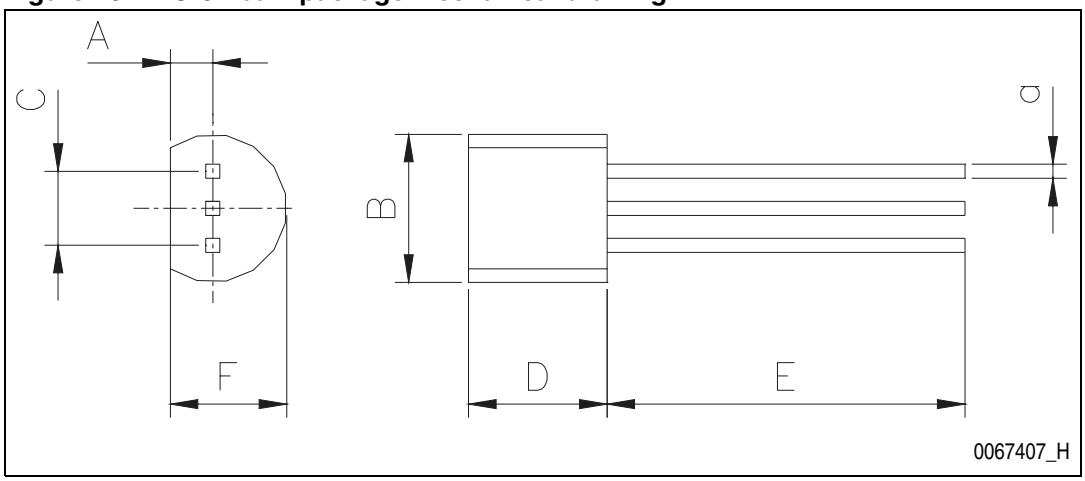


Table 8. TO-92 bulk package mechanical data

Dim.	Millimeters			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 mechanical drawing

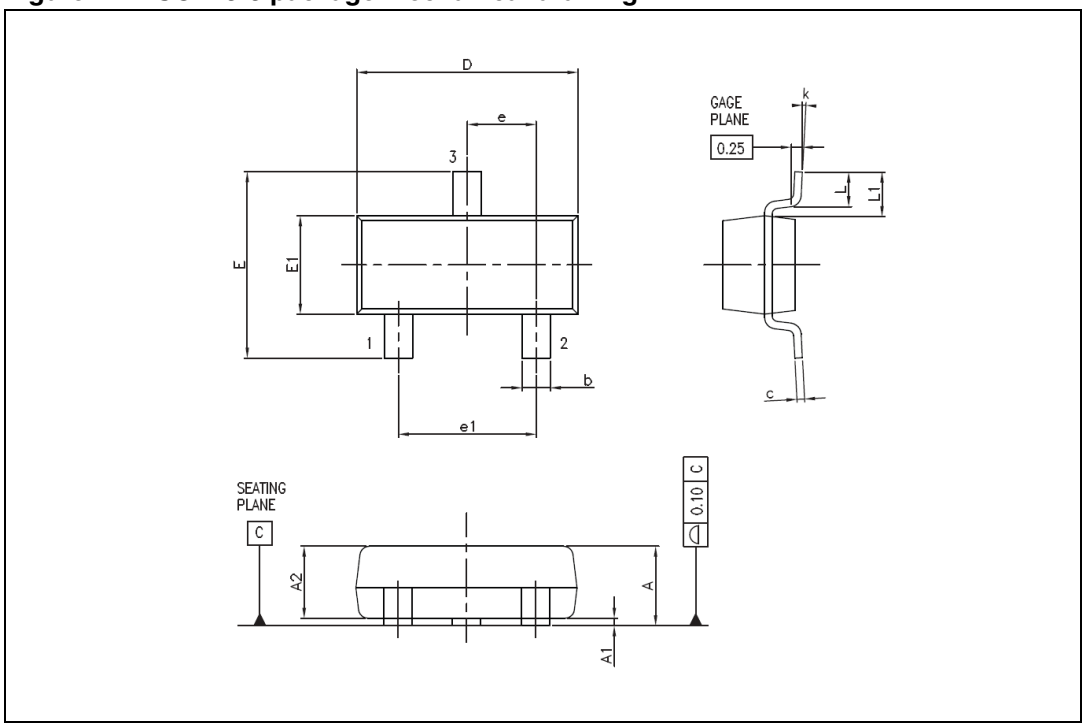


Table 9. SOT23-3 package mechanical data

Dimensions						
Ref.	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 mechanical drawing

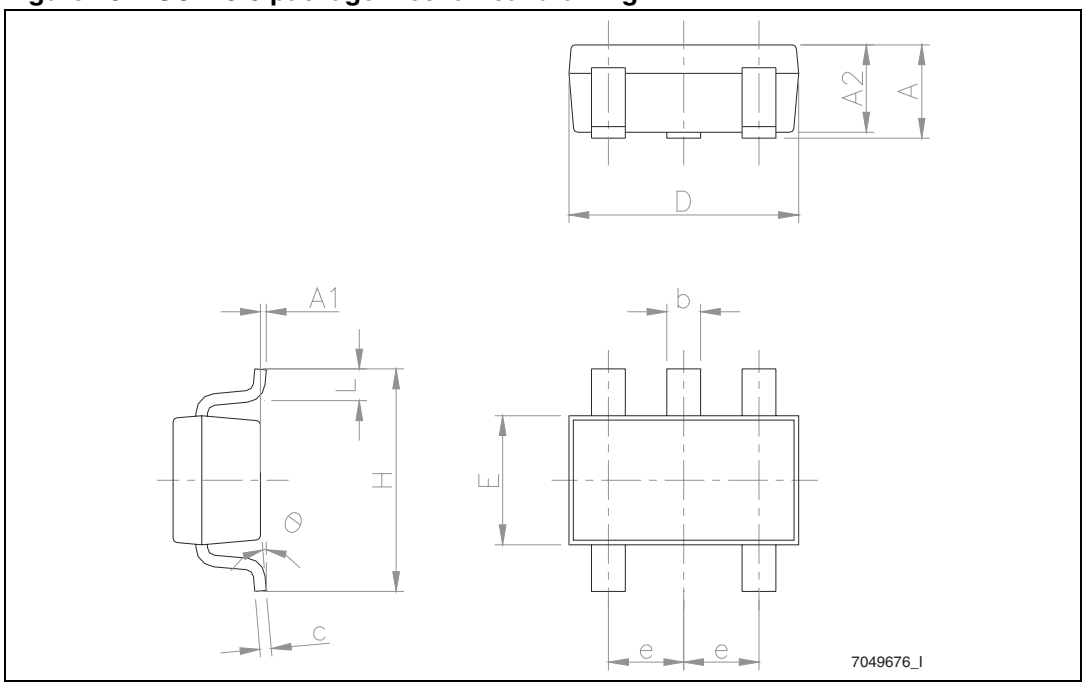


Table 10. SOT23-5 package mechanical data

Ref.	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 mechanical drawing

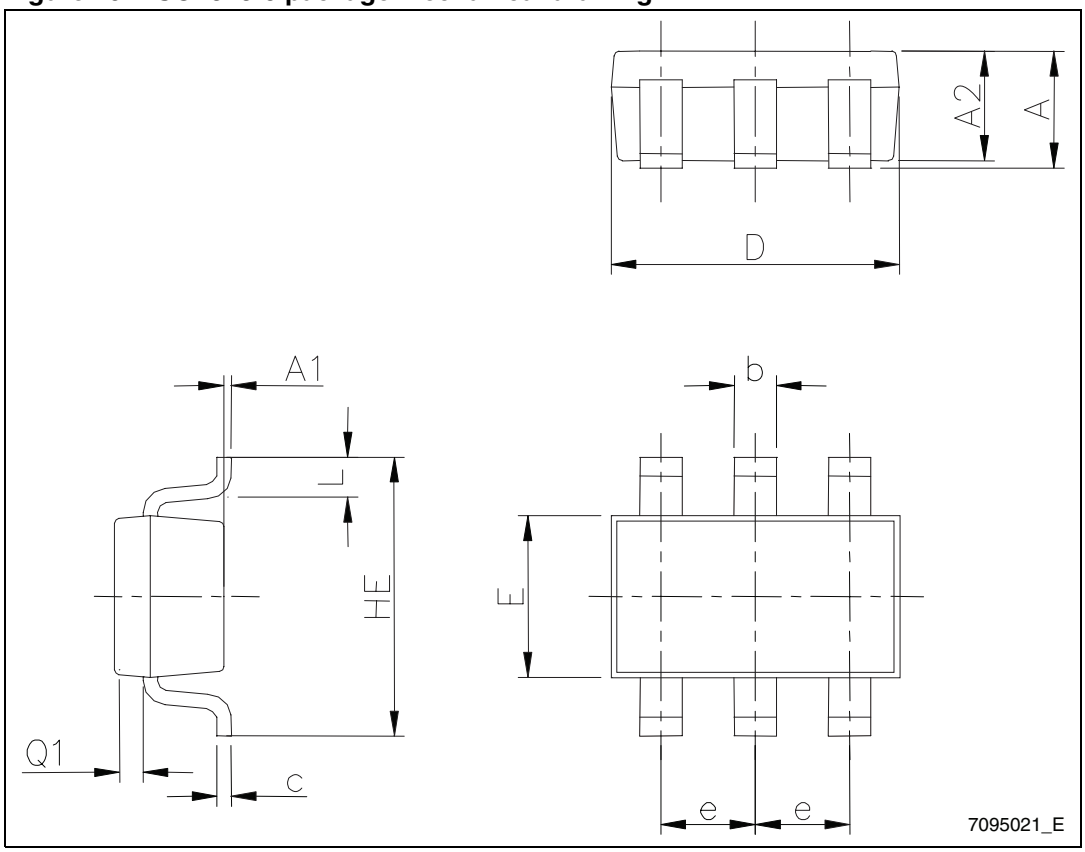


Table 11. SOT323-6 package mechanical data

Ref.	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
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 (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 & 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 *Figure 7* and of *Figure 18*. Added footnote to *Table 8: TO-92 bulk package mechanical data*.
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 *Table 3* and *Table 4*. Increased temperature range to 125°C in temperature curves. Added *Table 5*, dedicated to automotive version. Increased high temperature for automotive range up to +125°C in *Table 5* and in *Table 12: Order codes*. Inserted accuracy column in *Table 12*.
09-Jun-2009	7	Corrected minor error in package column in *Table 12*.
14-Mar-2011	8	Added *Figure 3 on page 3*, *Section 4.4 on page 15* and *Section 4.5 on page 16*.
07-Oct-2011	9	Added new package mechanical data *Table 11 on page 17* and *Figure 29 on page 17*. Updated *Table 12 on page 18*.

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