

## Programmable voltage reference

### Features

- Adjustable output voltage: 2.5 to 36V
- Sink current capability: 1 to 100mA
- Typical output impedance: 0.22Ω
- 1% and 2% voltage precision

### Description

The TL431 is a programmable shunt voltage reference with guaranteed temperature stability over the entire operating temperature range.

The output voltage may be set to any value between 2.5V and 36V with two external resistors.

The TL431 operates with a wide current range from 1 to 100mA with a typical dynamic impedance of 0.22Ω



**Z**  
**TO-92**  
(Plastic package)



**D**  
**SO-8**  
(Batwing plastic micropackage)

# 1 Schematic diagrams

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

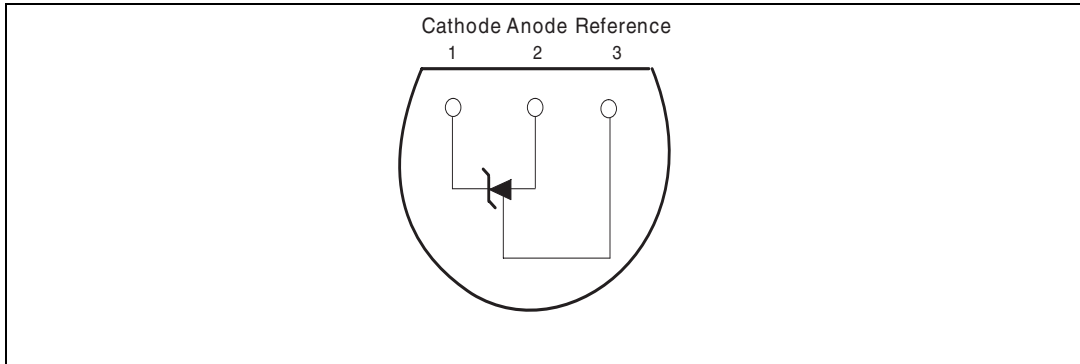


Figure 2. SO-8 batwing pin connections (top view)

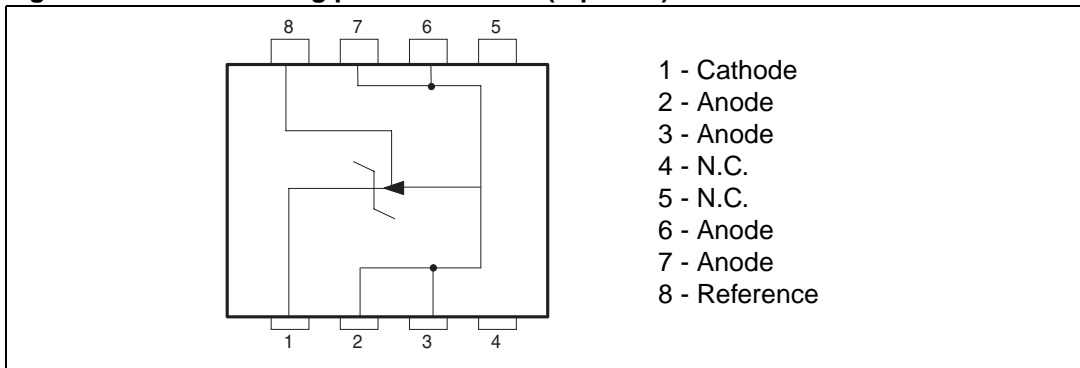
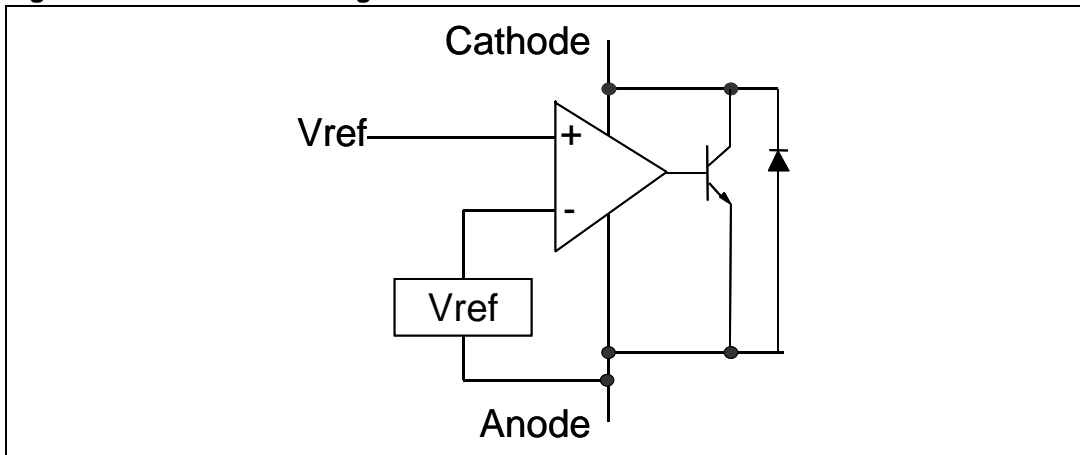


Figure 3. TL431 block diagram



## 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
$P_{diss}$	Power dissipation <sup>(1)</sup> TO-92 SO-8 batwing	625 960	mW
$T_{stg}$	Storage temperature range	-65 to +150	°C

1.  $P_{diss}$  is calculated with  $T_{amb} = +25^{\circ}\text{C}$ ,  $T_j = +150^{\circ}\text{C}$  and  
 $R_{thja} = 200^{\circ}\text{C/W}$  for TO-92 package  
 $R_{thja} = 130^{\circ}\text{C/W}$  for SO-8 batwing package

**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	0 to +70 -40 to +105	°C

### 3 Electrical characteristics

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

Symbol	Parameter	TL431C			TL431AC			Unit
		Min.	Typ.	Max.	Min.	Typ.	Max.	
$V_{ref}$	Reference input voltage $V_{KA} = V_{ref}$ , $I_k = 10\text{ mA}$ , $T_{amb} = 25^{\circ}\text{C}$ $T_{min} \leq T_{amb} \leq T_{max}$	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 over temperature 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 $I_k = 10\text{ mA}$ , $R1 = 10\text{ k}\Omega$ , $R2 = \infty$ $T_{amb} = 25^{\circ}\text{C}$ $T_{min} \leq T_{amb} \leq T_{max}$		1.8	4 5.2		1.8	4 5.2	$\mu\text{A}$
$\Delta I_{ref}$	Reference input current deviation over temperature 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 [Reference input voltage deviation over temperature range](#).

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

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

Symbol	Parameter	TL431I			TL431AI			Unit
		Min.	Typ.	Max.	Min.	Typ.	Max.	
$V_{ref}$	Reference input voltage $V_{KA} = V_{ref}$ , $I_k = 10\text{ mA}$ , $T_{amb} = 25^{\circ}\text{C}$ $T_{min} \leq T_{amb} \leq T_{max}$	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 over temperature 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 $I_k = 10\text{ mA}$ , $R1 = 10\text{ k}\Omega$ , $R2 = \infty$ $T_{amb} = 25^{\circ}\text{C}$ $T_{min} \leq T_{amb} \leq T_{max}$		1.8	4 6.5		1.8	4 6.5	$\mu\text{A}$
$\Delta I_{ref}$	Reference input current deviation over temperature 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 [Reference input voltage deviation over temperature range](#) below.

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

### Reference input voltage deviation over temperature range

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

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

**Figure 4.** Reference input voltage deviation over temperature range

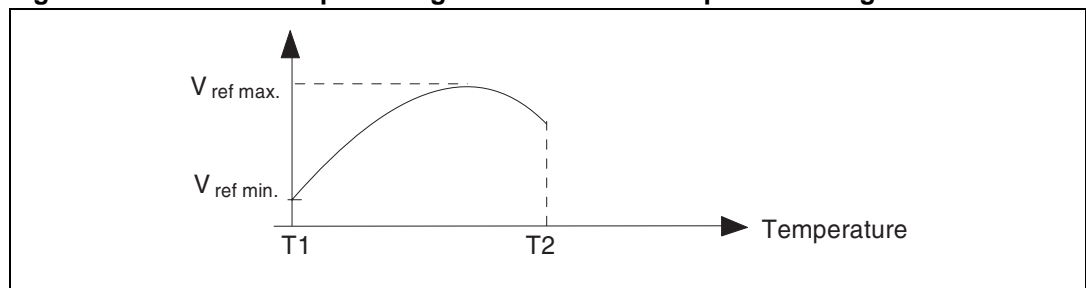


Figure 5. Test circuit for  $V_{KA} = V_{ref}$

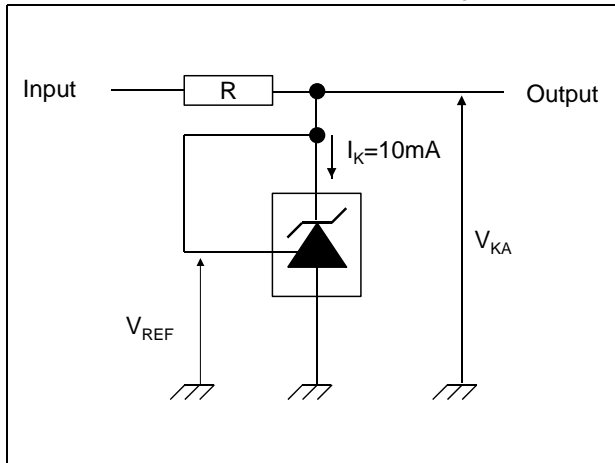


Figure 6. Test circuit for programming mode

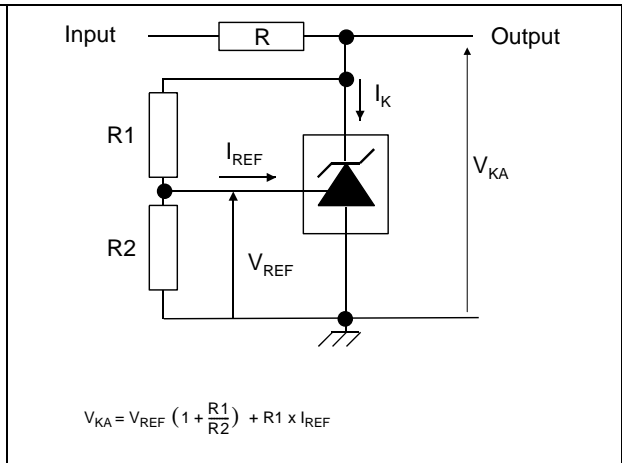


Figure 7. Test circuit for  $I_{off}$

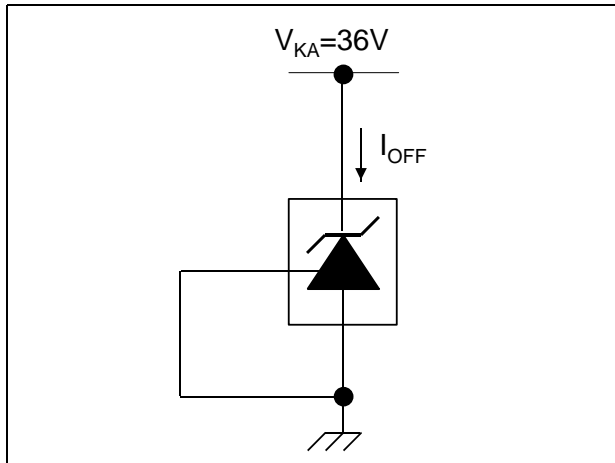


Figure 8. Test circuit for phase margin and voltage gain

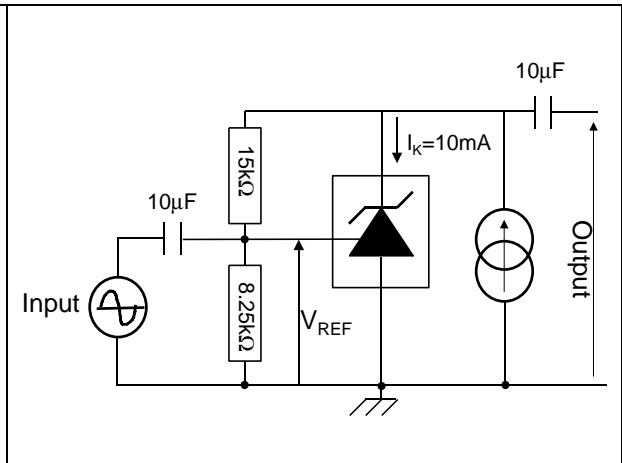


Figure 9. Test circuit for response time

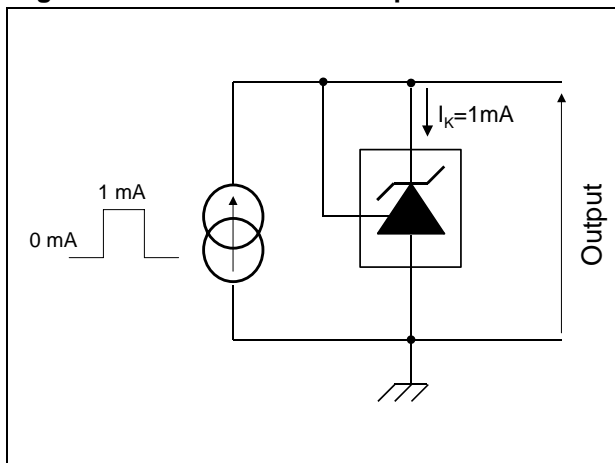


Figure 10. Reference voltage vs. temperature

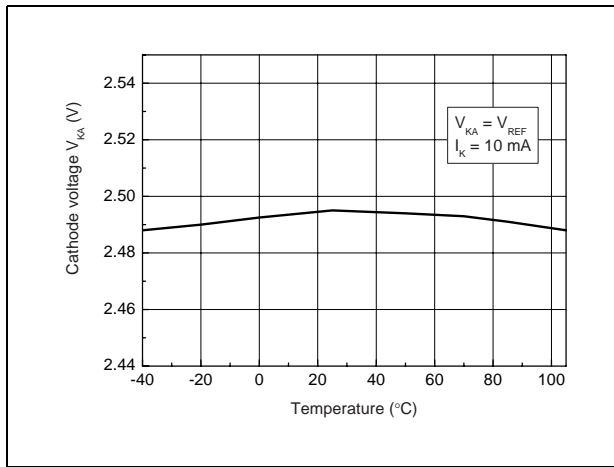


Figure 11. Reference voltage vs. cathode current

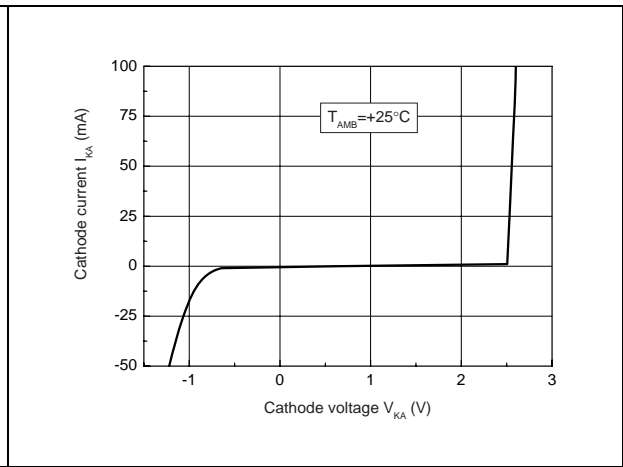


Figure 12. Reference voltage vs. cathode current

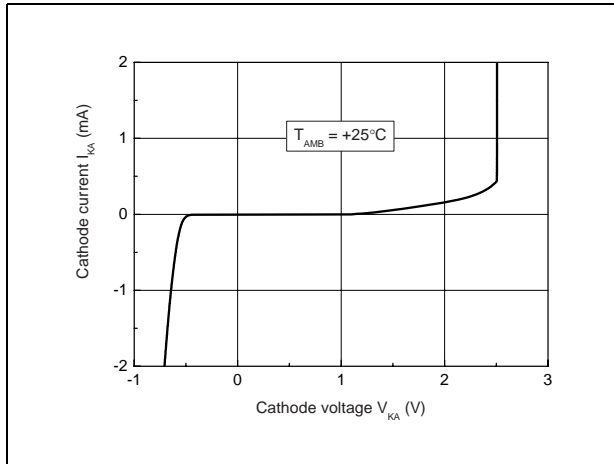


Figure 13. Reference current vs. temperature

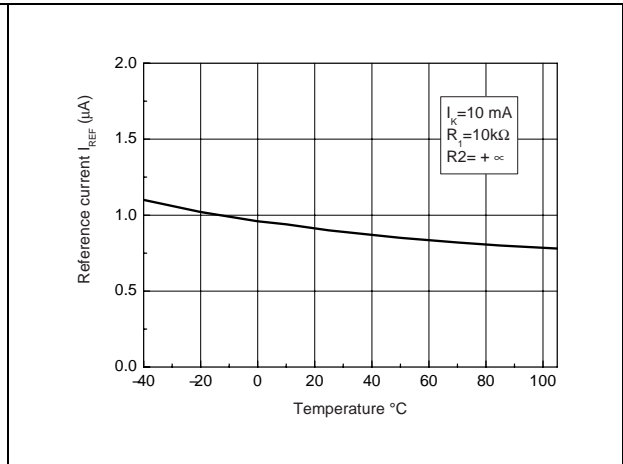


Figure 14. Off-state cathode current vs. temperature

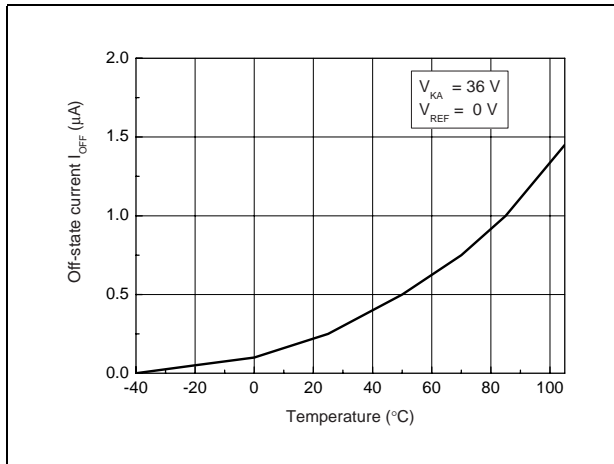


Figure 15. Ratio of change in  $V_{REF}$  to change in  $V_{KA}$  vs. temperature

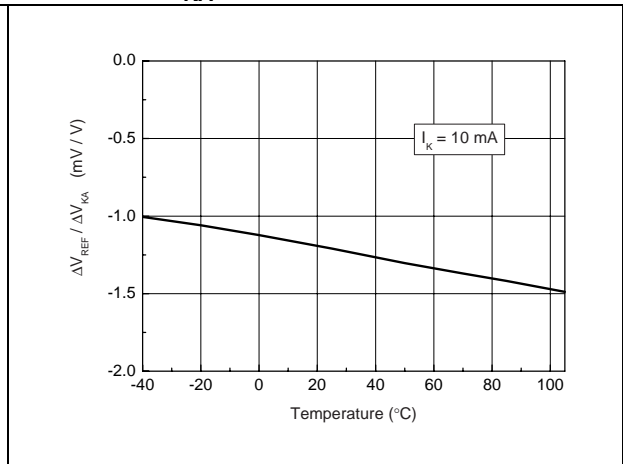


Figure 16. Static impedance  $R_{KA}$  vs. temperature

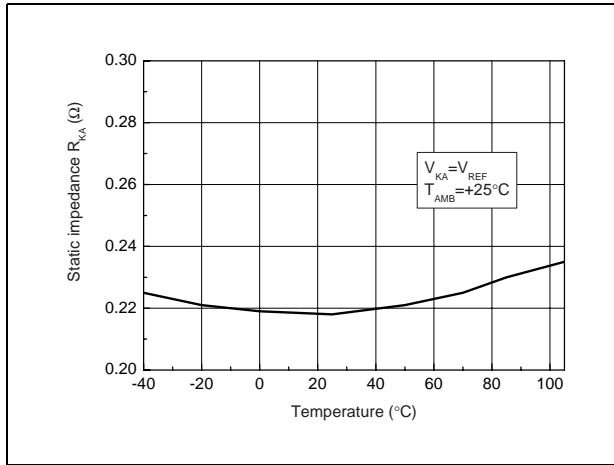


Figure 17. Minimum operating current vs. temperature

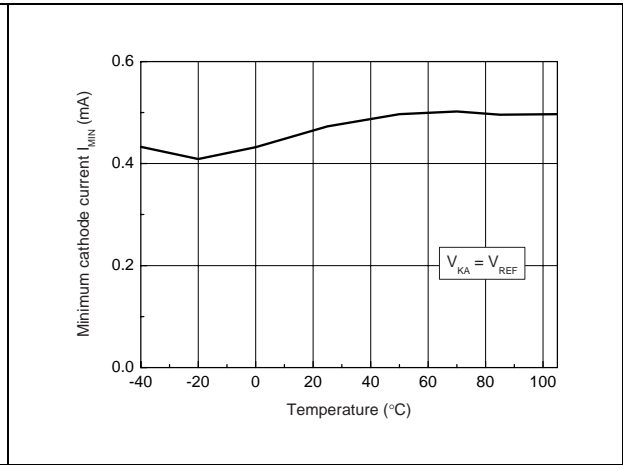


Figure 18. Gain & phase vs. frequency

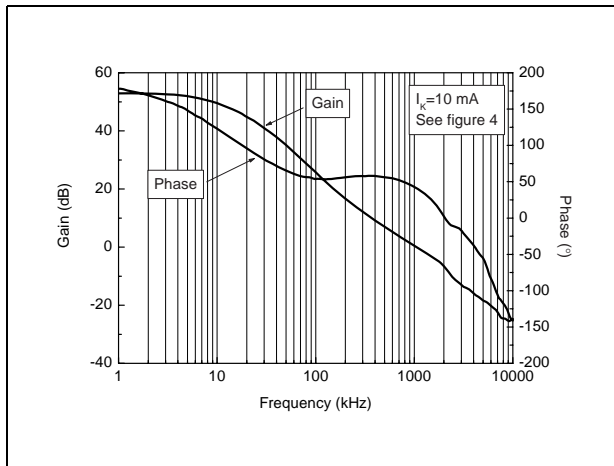


Figure 19. Stability behavior with capacitive loads

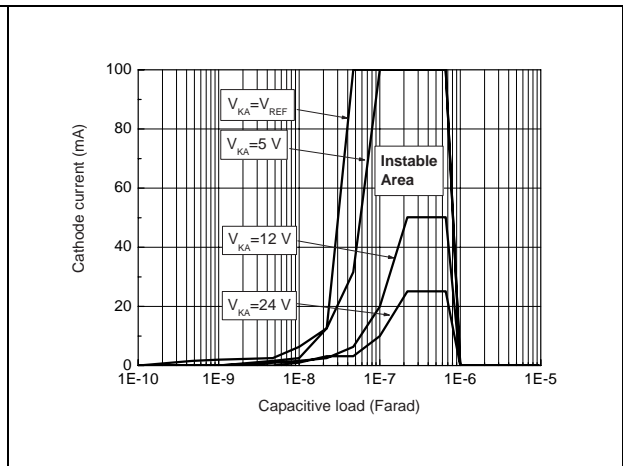


Figure 20. Maximum power dissipation

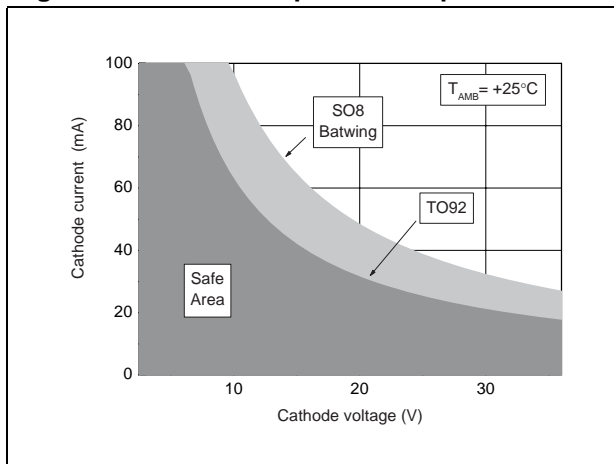
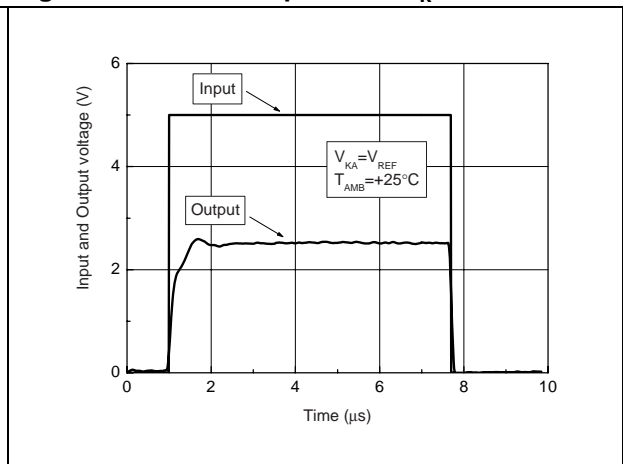


Figure 21. Pulse response for  $I_K = 1\text{ mA}$

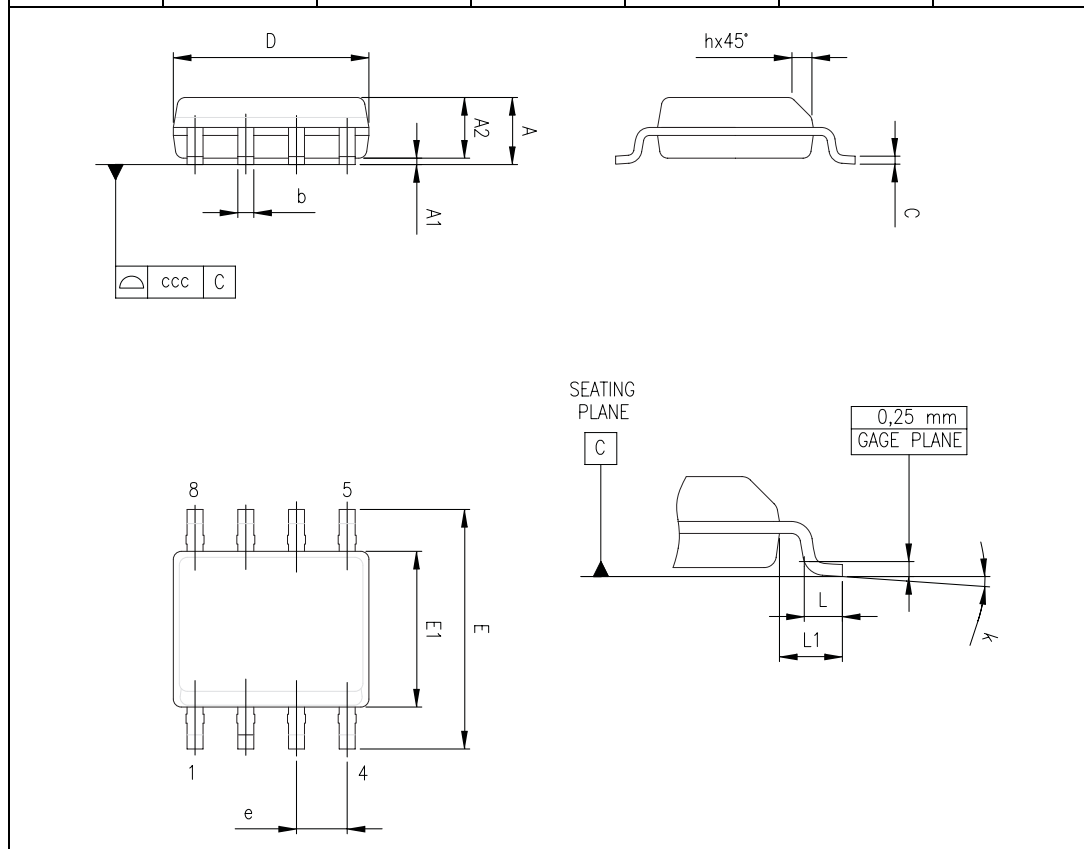


## 4 Package information

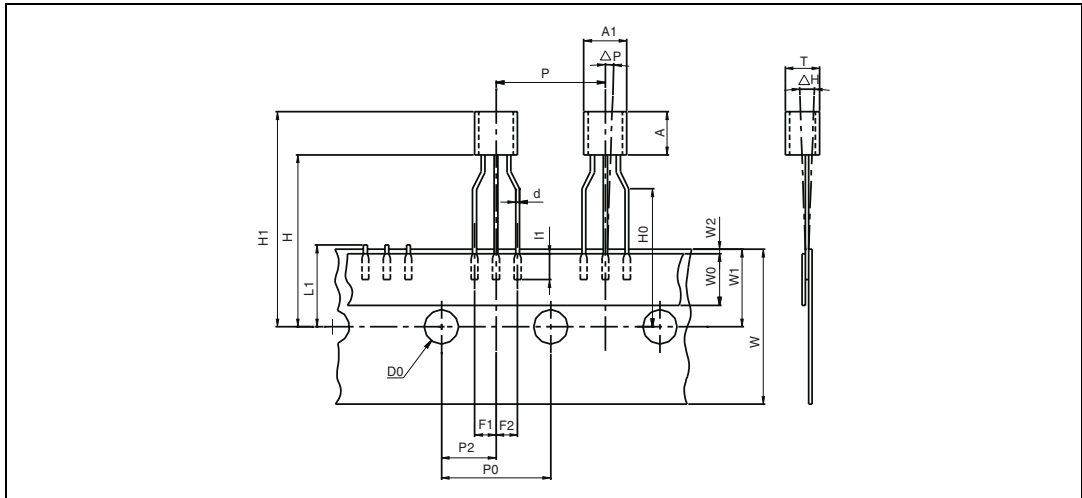
In order to meet environmental requirements, STMicroelectronics offers these devices in ECOPACK<sup>®</sup> packages. These packages have a lead-free second level interconnect. The category of second level interconnect is marked on the package and on the inner box label, in compliance with JEDEC Standard JESD97. The maximum ratings related to soldering conditions are also marked on the inner box label. ECOPACK is an STMicroelectronics trademark. ECOPACK specifications are available at: [www.st.com](http://www.st.com).

### 4.1 SO-8 package

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
H	5.80	6.00	6.20	0.228	0.236	0.244
E1	3.80	3.90	4.00	0.150	0.154	0.157
e		1.27			0.050	
h	0.25		0.50	0.010		0.020
L	0.40		1.27	0.016		0.050
k	1°		8°	1°		8°
ccc			0.10			0.004

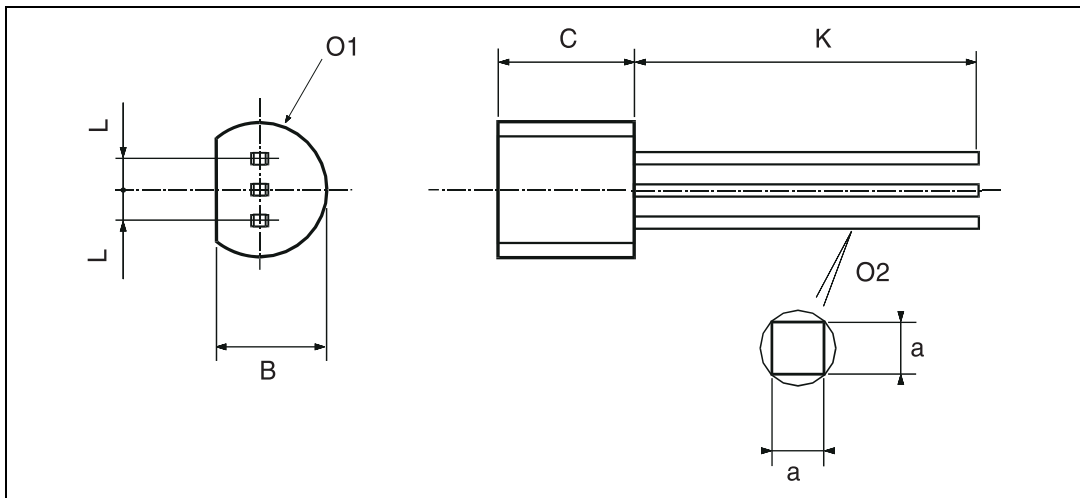


## 4.2 TO-92 ammo pack and tape & reel package



Dim.	Millimeters			Inches		
	Min	Typ.	Max.	Min.	Typ.	Max.
AL			5.0			0.197
A			5.0			0.197
T			4.0			0.157
d		0.45			0.018	
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



Dim.	Millimeters			Inches		
	Min	Typ.	Max.	Min.	Typ.	Max.
L		1.27			0.05	
B	3.2	3.7	4.2	0.126	0.1457	0.1654
O1	4.45	5.00	5.2	0.1752	0.1969	0.2047
C	4.58	5.03	5.33	0.1803	0.198	0.2098
K	12.7			0.5		
O2	0.407	0.5	0.508	0.016	0.0197	0.02
a	0.35			0.0138		

## 5 Ordering information

**Table 5. Order codes**

Part number	Temperature range	Package	Packing	Marking
TL431CD/CDT	0°C to +70°C	SO-8	Tube or tape & reel	431C
TL431ACD/ACDT				431AC
TL431CZ/CZT/CZ-AP		TO-92		TL431C
TL431ACZ/ACZT/ACZ-AP				TL431AC
TL431ID/IDT	-40°C to + 105°C	SO-8		431I
TL431AID/AIDT				431AI
TL431IZ/IZT/IZ-AP		TO-92		TL431I
TL431AIZ/AIZT/AIZ-AP				TL431AI
TL431IYD/IYDT <sup>(1)</sup>	SO-8 (automotive grade level)	431IY		
TL431AIYD/AIYDT <sup>(1)</sup>		431AIY		

1. Qualified and characterized according to AEC Q100 and Q003 or equivalent, advanced screening according to AEC Q001 & Q 002 or equivalent.

## 6 Revision history

Date	Revision	Changes
1-Mar-2002	1	Initial release.
1-Nov-2005	2	PPAP references inserted in order codes table on cover page.
13-Dec-2006	3	Corrected TO-92 package information.
8-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 <a href="#">Figure 5</a> and of <a href="#">Figure 16</a> . Added footnote to <a href="#">Table 5: Order codes</a> .

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