

## Programmable Voltage Reference

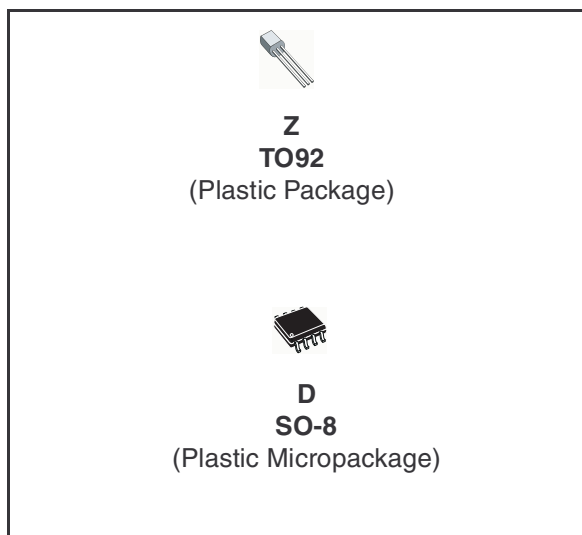
- Adjustable output voltage: 2.5 to 36V
- Sink current capability: 1 to 100mA
- Typical output impedance: 0.22Ω
- 1% and 2% voltage precision

### Description

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

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.



### Order Codes

Part Number	Temperature Range	Package	Packing	Marking
TL431CD/CDT	0, +70°C	SO-8	Tube or Tape & Reel	431C
TL431ACD/ACDT				431AC
TL431CZ/CZT/CZ-AP		TO92		TL431C
TL431ACZ/ACZT/ACZ-AP				TL431AC
TL431ID/IDT	-40, + 105°C	SO-8		431I
TL431AID/AIDT				431AI
TL431IZ/IZT/IZ-AP		TO92		TL431I
TL431AIZ/AIZT/AIZ-AP				TL431AI
TL431IYD/IYDT		SO-8 (automotive grade level)	431IY	
TL431AIYD/AIYDT			431AIY	

# 1 Pin Diagrams

Figure 1. T092 pin connections (top view)

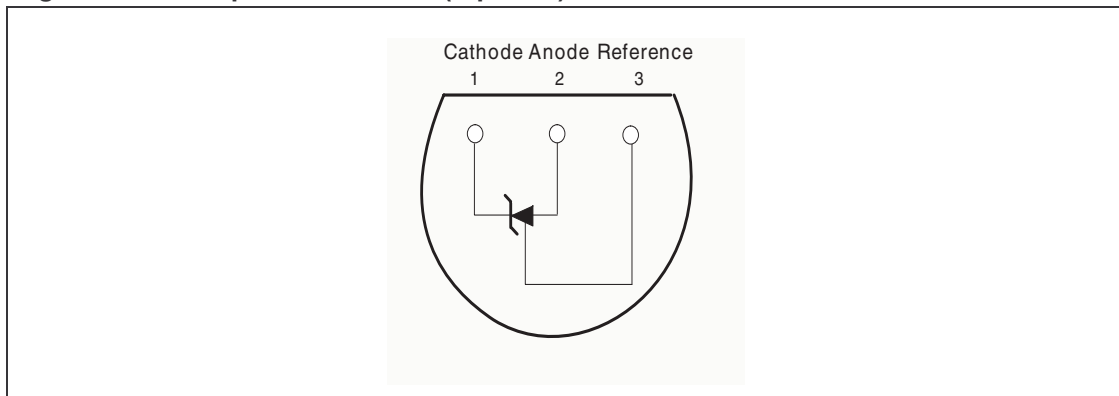
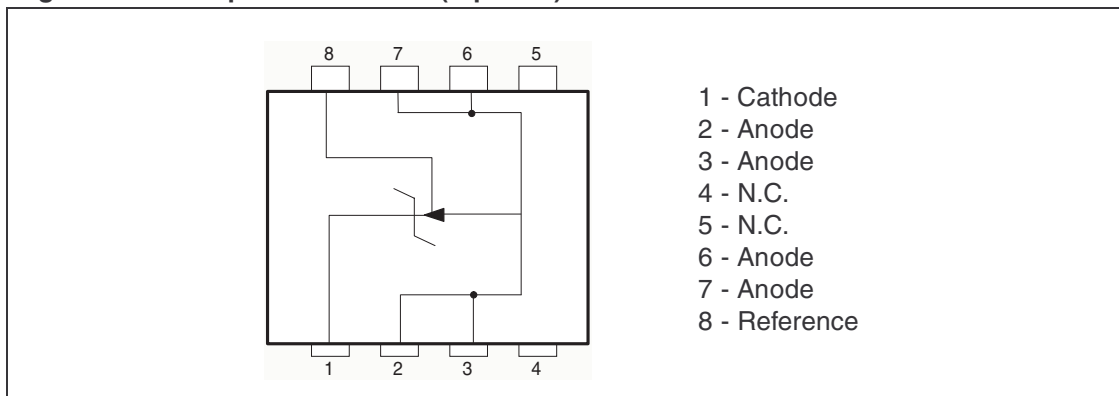


Figure 2. SO-8 pin connections (top view)



## 2 Absolute Maximum Ratings

**Table 1. Key parameters and their 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
$P_d$	Power Dissipation <sup>(1)</sup> TO92 SO-8 batwing	625 960	mW
$T_{stg}$	Storage Temperature Range	-65 to +150	°C

1.  $P_d$  is calculated with  $T_{amb} = +25^{\circ}\text{C}$ ,  $T_j = +150^{\circ}\text{C}$  and  
 $R_{thja} = 200^{\circ}\text{C/W}$  for TO92 package  
 $R_{thja} = 130^{\circ}\text{C/W}$  for SO-8 batwing package

**Table 2. Operating conditions**

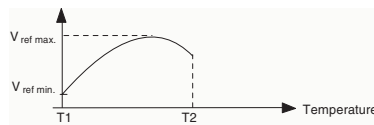
Symbol	Parameter	Value	Unit
$V_{KA}$	Cathode to Anode Voltage	$V_{ref}$ to 36	V
$I_k$	Cathode Current	1 to 100	mA
$T_{oper}$	Operating Free-air Temperature Range TL431C/AC TL431I/AI	0 to +70 -40 to +105	°C

### 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 $10\text{V}$		-1.4 -1	-2.7 -2		-1.4 -1	-2.7 -2	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> $V_{KA} = V_{ref}$ , $\Delta I_k = 1$ to $100\text{ mA}$ , $f \leq 1\text{ kHz}$		0.22	0.5		0.22	0.5	$\Omega$

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

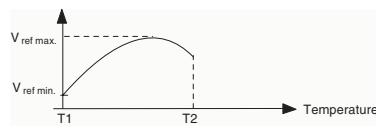


2. The dynamic Impedance is defined as  $|Z_{KA}| = \frac{\Delta V_{KA}}{\Delta I_k}$

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	2.49 5	2.55 2.58	2.47 2.44	2.49 5	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 $I_k = 10\text{ mA}$ , $\Delta V_{KA} = 10\text{ V to } V_{ref}$ $\Delta V_{KA} = 36\text{ V to } 10\text{ V}$		-1.4 -1	-2.7 -2		-1.4 -1	-2.7 -2	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.  $\Delta V_{ref}$  is defined as the difference between the maximum and minimum values obtained over the full temperature range.  
 $\Delta V_{ref} = V_{ref\ max.} - V_{ref\ min.}$



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

Figure 3. Test circuit for  $V_{KA} = V_{REF}$

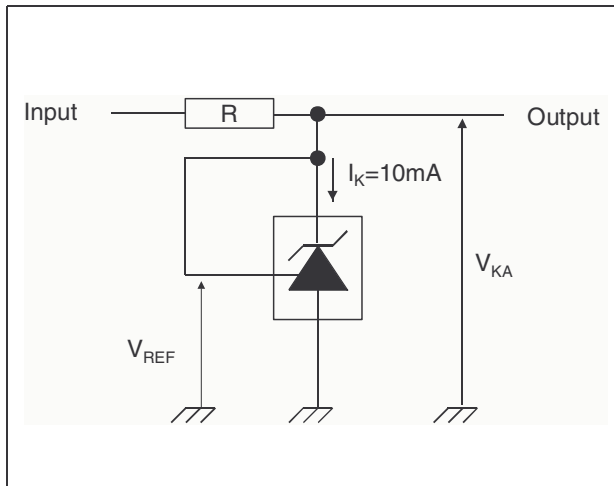


Figure 4. Test circuit for  $V_{KA} = V_{REF}$

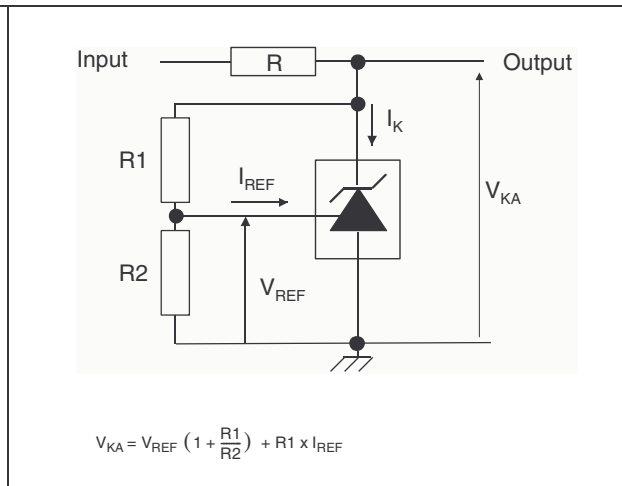


Figure 5. Test circuit for  $I_{OFF}$

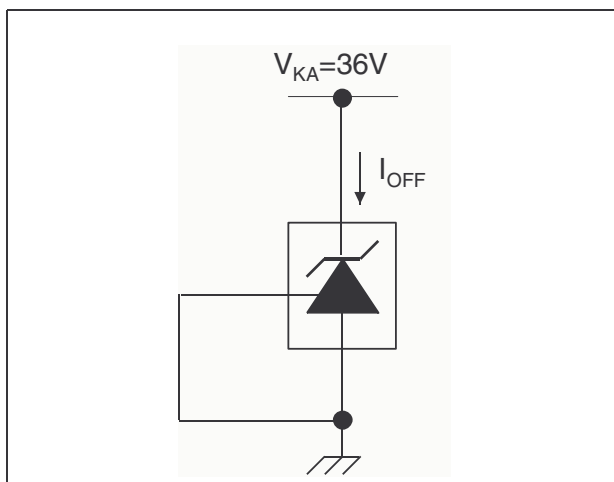


Figure 6. Test circuit for phase margin and voltage gain

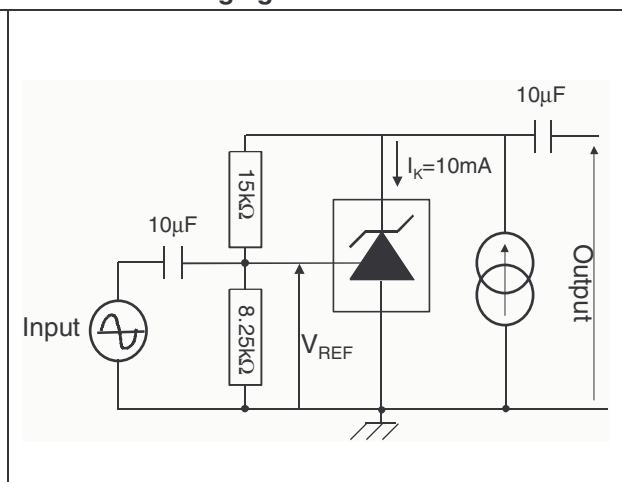


Figure 7. Block diagram of TL431

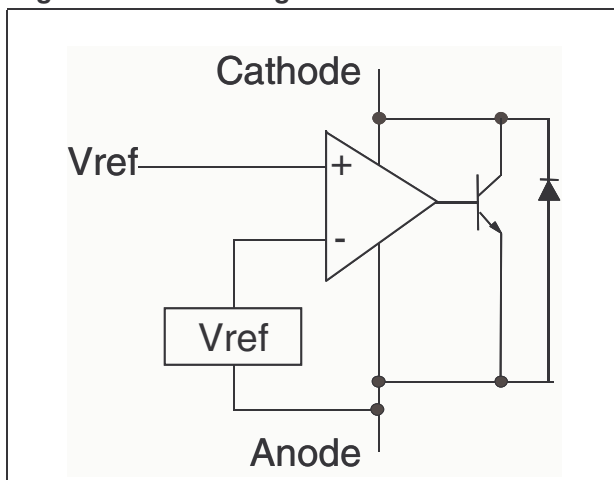


Figure 8. Test circuit for response time

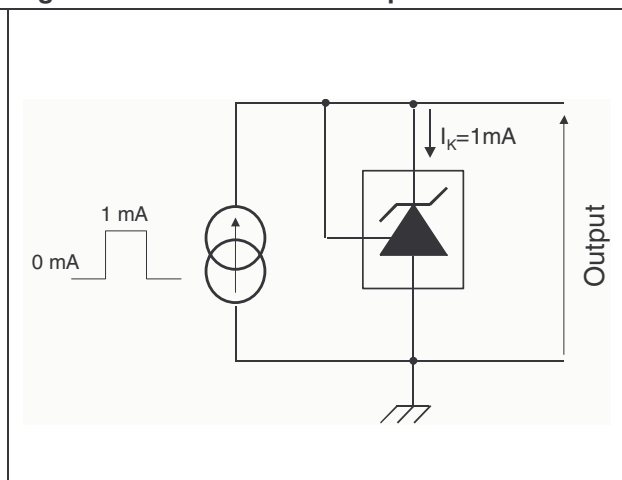


Figure 9. Reference voltage vs. temp.

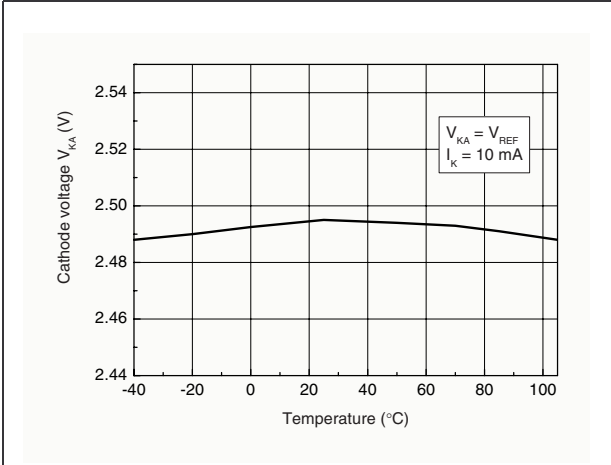


Figure 10. Reference voltage vs. cathode current

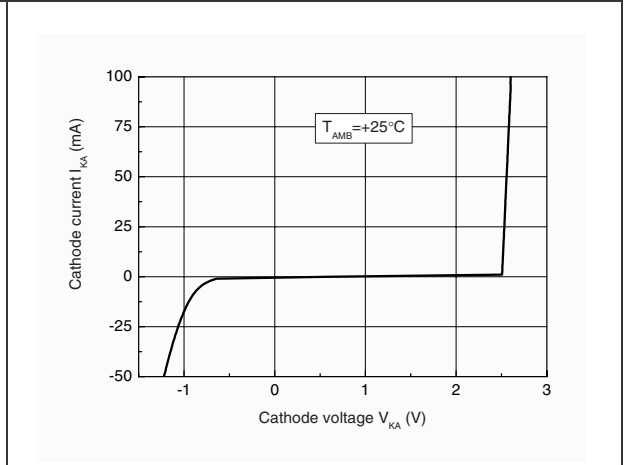


Figure 11. Reference voltage vs. cathode current Figure 12. Reference current vs. temp.

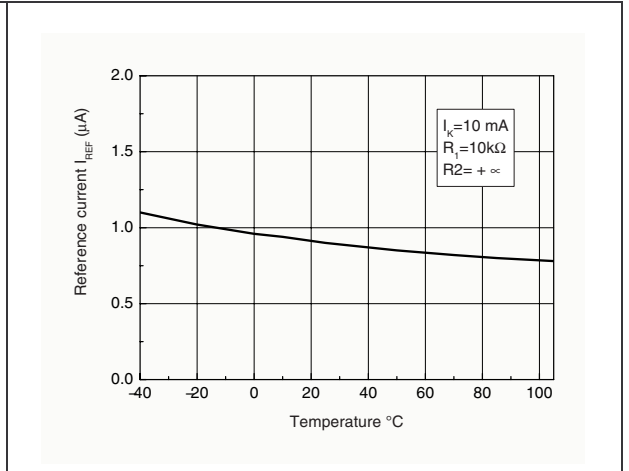
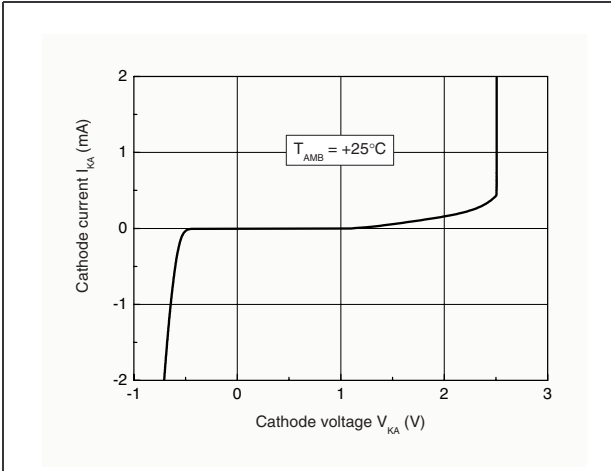


Figure 13. Off-state cathode current vs. temp. Figure 14. Ratio of change in  $V_{REF}$  to change in  $V_{KA}$  vs. temp.

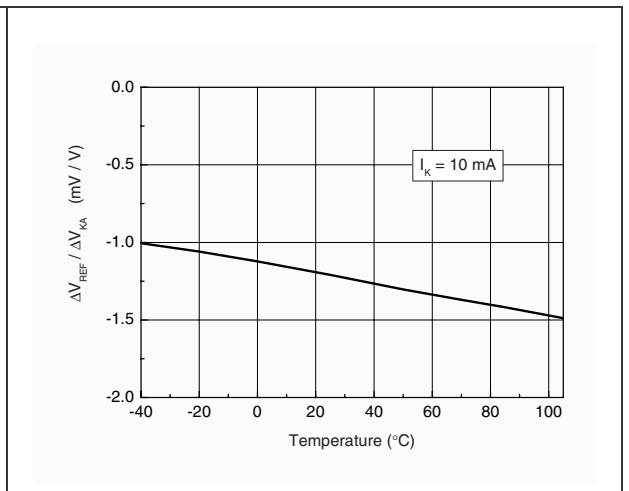
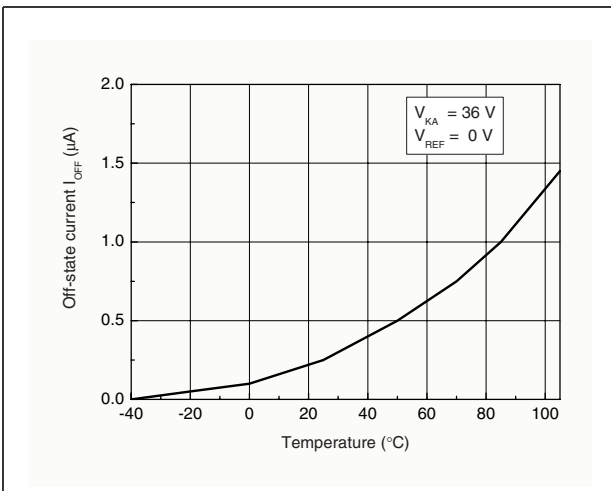


Figure 15. Static impedance  $R_{KA}$  vs. temp.

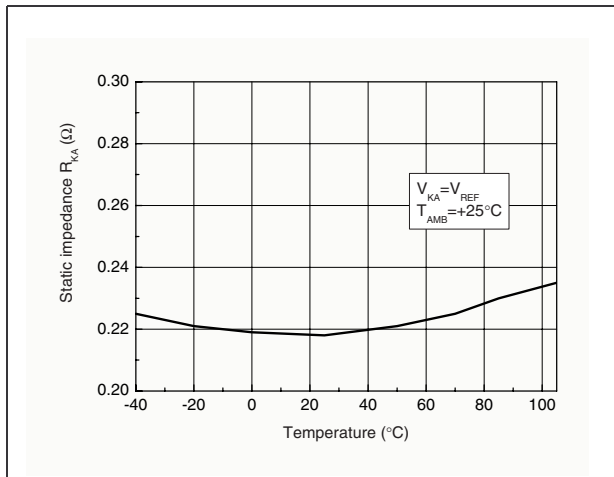


Figure 16. Maximum operating current vs. temp.

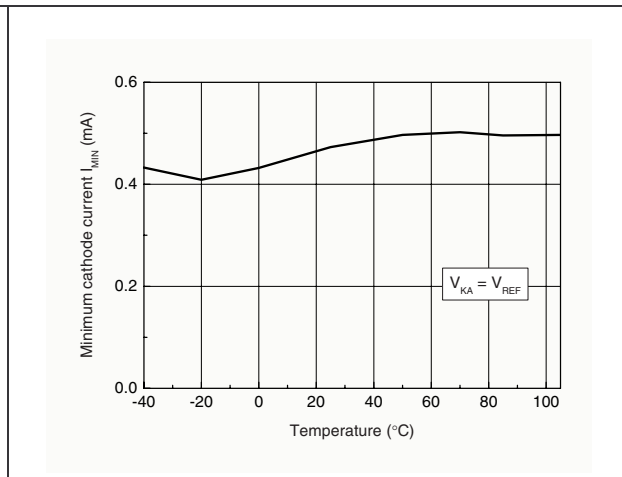


Figure 17. Gain & phase vs. frequency

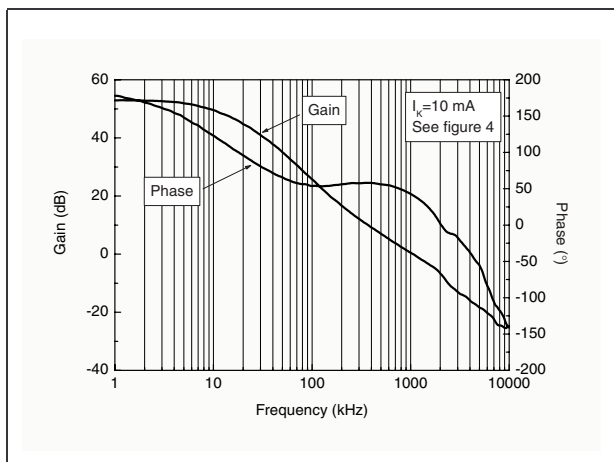


Figure 18. Stability behaviour with capacitive loads

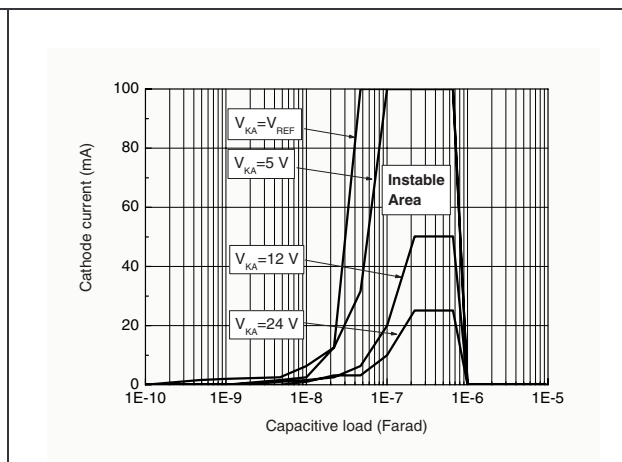


Figure 19. Maximum power dissipation

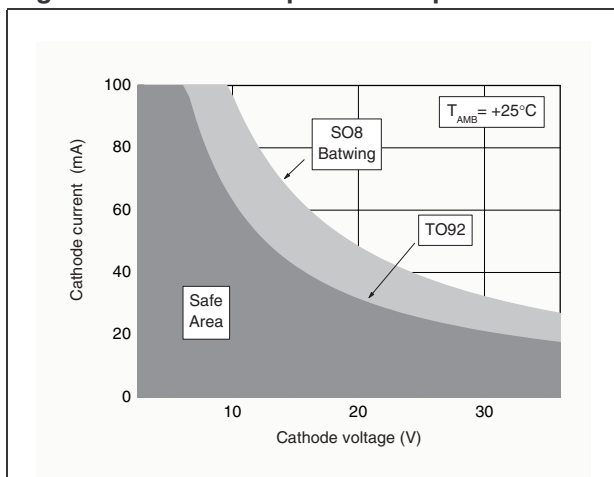
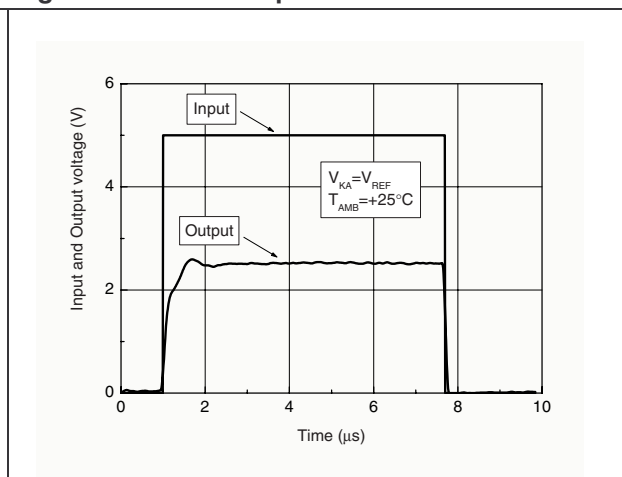


Figure 20. Pulse response for  $I_K = 1\text{mA}$





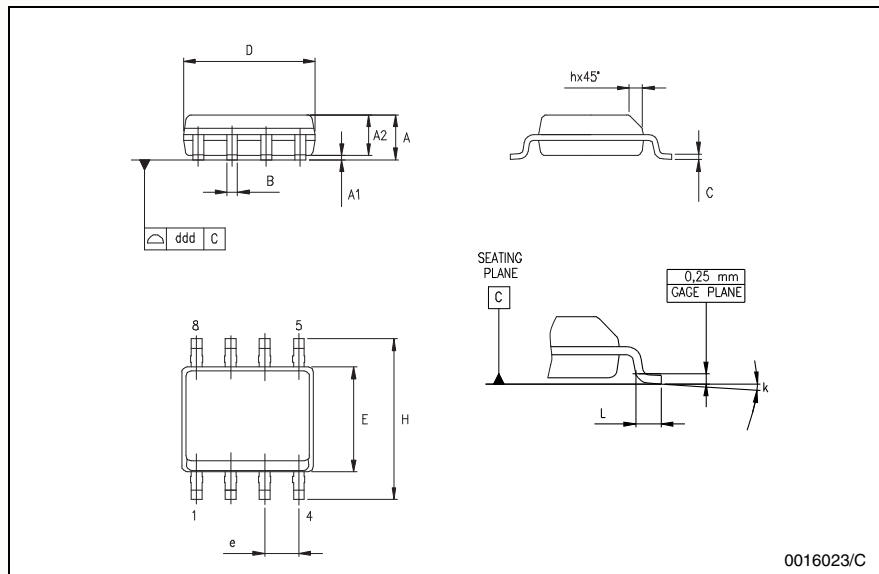
## 4 Package Mechanical Data

In order to meet environmental requirements, ST 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 ST trademark. ECOPACK specifications are available at: [www.st.com](http://www.st.com).

### 4.1 SO-8 Package

**SO-8 MECHANICAL DATA**

DIM.	mm.			inch		
	MIN.	TYP.	MAX.	MIN.	TYP.	MAX.
A	1.35		1.75	0.053		0.069
A1	0.10		0.25	0.04		0.010
A2	1.10		1.65	0.043		0.065
B	0.33		0.51	0.013		0.020
C	0.19		0.25	0.007		0.010
D	4.80		5.00	0.189		0.197
E	3.80		4.00	0.150		0.157
e		1.27			0.050	
H	5.80		6.20	0.228		0.244
h	0.25		0.50	0.010		0.020
L	0.40		1.27	0.016		0.050
k	$\delta^{\circ}$ (max.)					
ddd			0.1			0.04

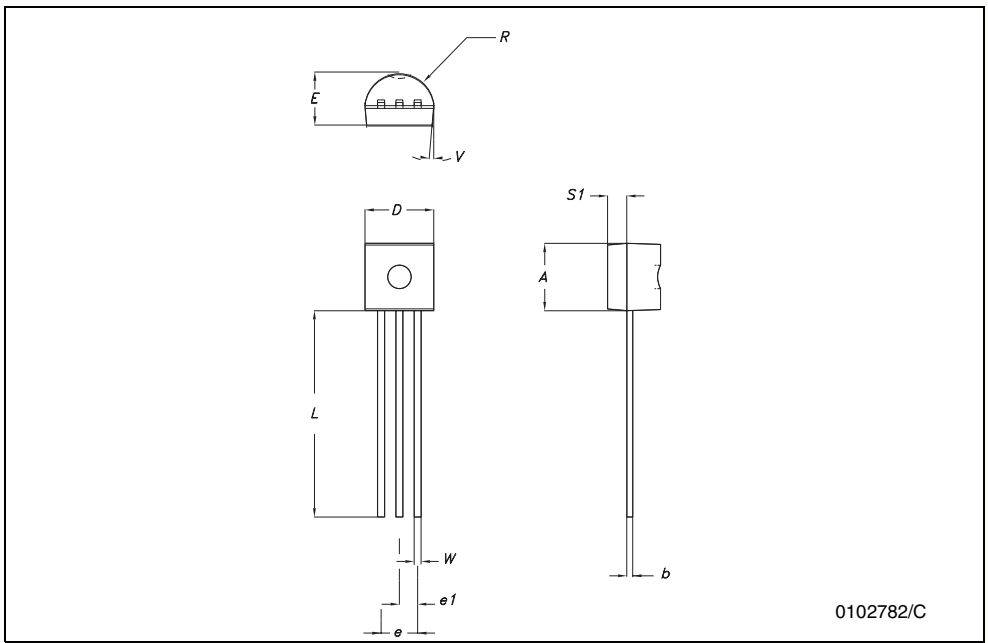


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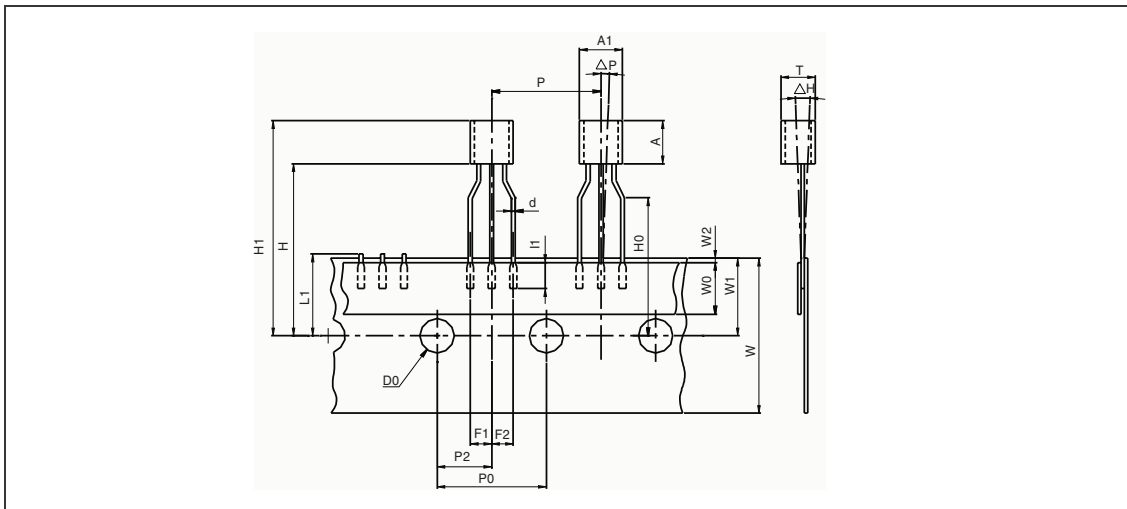
### 4.2 TO92 (Tape & Reel) Package

**TO-92 MECHANICA DATA**

DIM.	mm.			mils		
	MIN.	TYP.	MAX.	MIN.	TYP.	MAX.
A	4.32		4.95	170.1		194.9
b	0.36		0.51	14.2		20.1
D	4.45		4.95	175.2		194.9
E	3.30		3.94	129.9		155.1
e	2.41		2.67	94.9		105.1
e1	1.14		1.40	44.9		55.1
L	12.7		15.49	500.0		609.8
R	2.16		2.41	85.0		94.9
S1	0.92		1.52	36.2		59.8
W	0.41		0.56	16.1		22.0

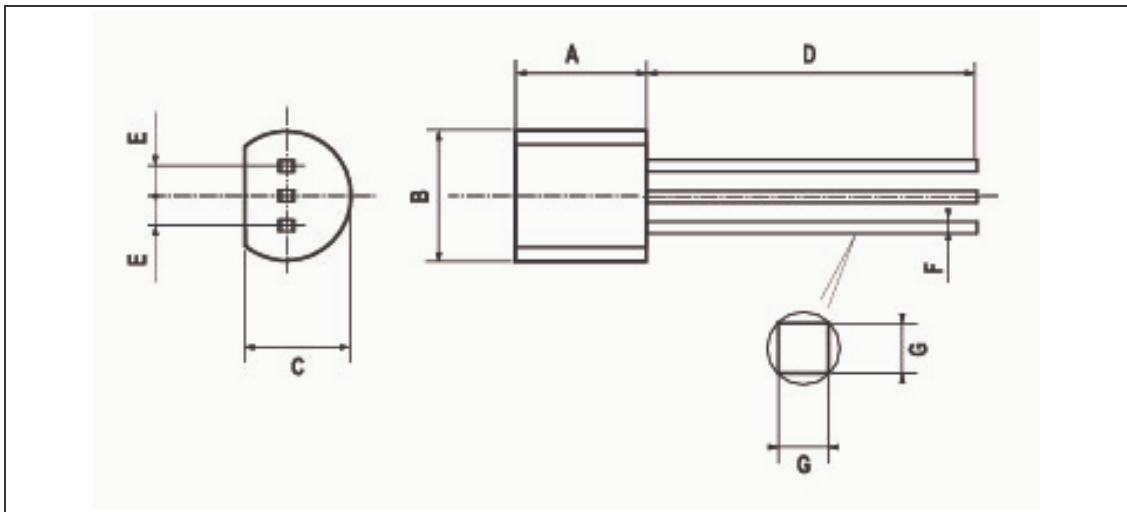


## 4.3 TO92 (Tape Ammo Pack) Package



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

### 4.4 TO92 (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 Revision History

Date	Revision	Changes
March 2002	1	Initial release.
Nov. 2005	2	PPAP references inserted in the datasheet see <i>Table : Order Codes on page 1</i> .

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