

## Programmable Voltage Reference

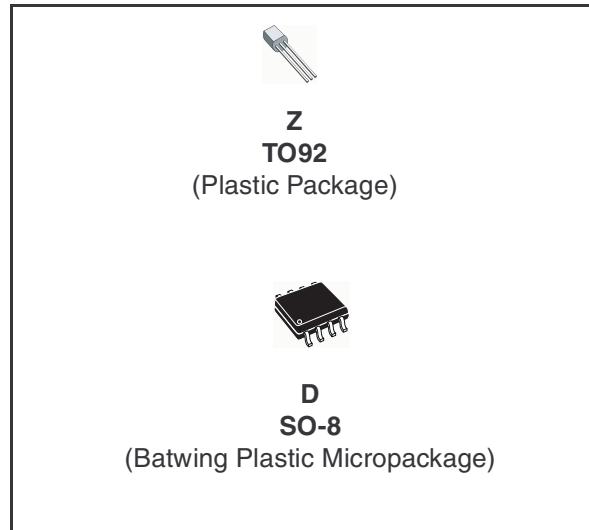
- Adjustable output voltage:  $V_{REF}$  to 36V
- Sink current capability: 1 to 100mA
- Typical output impedance:  $0.22\Omega$
- 0.4% and 0.25% voltage precision

### Description

The TL1431 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 TL1431 operates with a wide current range from 1 to 100mA with a typical dynamic impedance of  $0.2\Omega$ .



### Order Codes

Part Number	Temperature Range	Package	Packing	Marking	
TL1431CD/CDT	-20, +70°C	SO-8	Tube or Tape & Reel	1431C	
TL1431ACD/ACDT				1431AC	
TL1431CZ/CZT/CZ-AP		TO92		TL1431C	
TL1431ACZ/ACZT/ACZ-AP				TL1431AC	
TL1431ID/IDT		SO-8		1431I	
TL1431AID/AIDT				1431AI	
TL1431IZ/IZT/IZ-AP		TO92		TL1431I	
TL1431AIZ/AIZT/AIZ-AP				TL1431AI	
TL1431IYD/IYDT		SO-8 (automotive grade level)		1431IY	

# 1 Pin Diagrams

Figure 1. TO92 pin connections (top view)

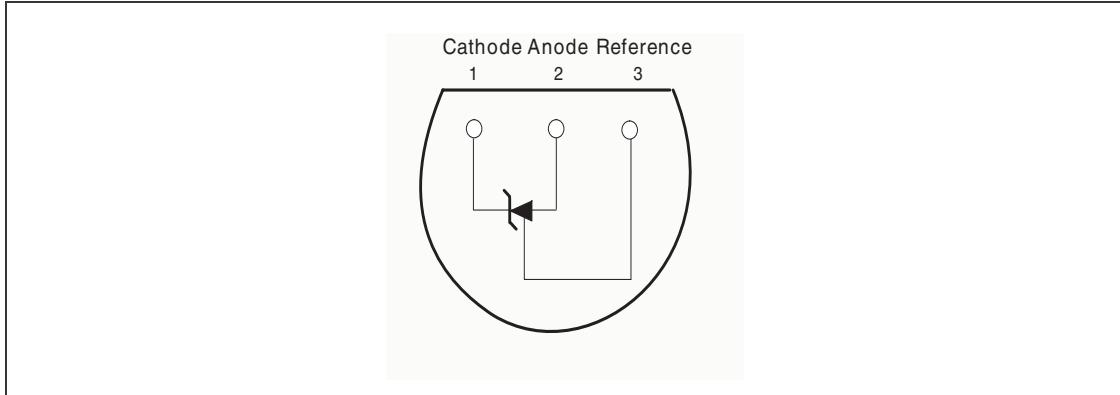
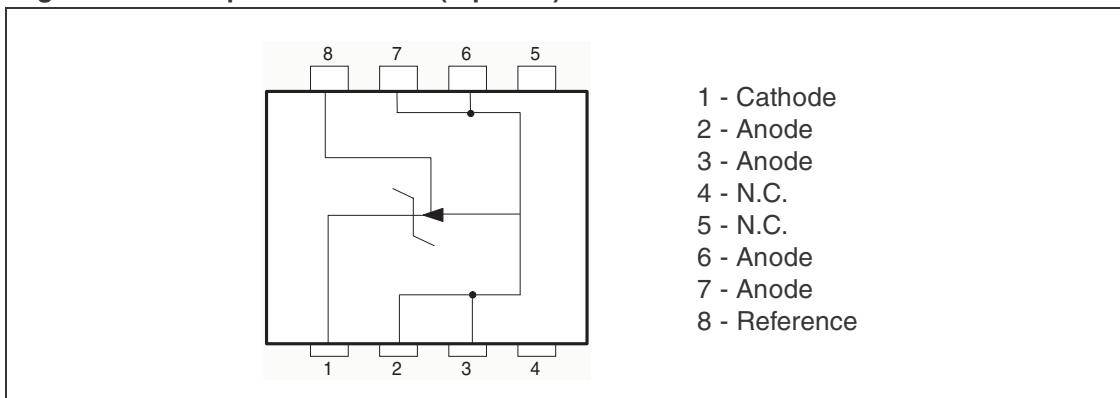


Figure 2. SO-8 pin connections (top view)



## 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
$T_J$	Junction temperature	+150	°C
$P_d$	Power Dissipation <sup>(1)</sup> TO92 SO-8 batwing	625 960	mW
$T_{stg}$	Storage Temperature Range	-65 to +150	°C

1. Calculated with  $T_J=+150^\circ\text{C}$  and  $T_{AMB}=+25^\circ\text{C}$  with relative  $R_{THJ-A}$  depending on the package

**Table 2. Operating conditions**

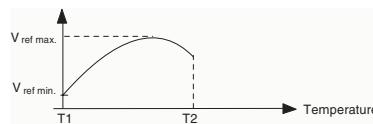
Symbol	Parameter	Value	Unit
$V_{KA}$	Cathode to Anode Voltage	$V_{ref}$ to 36	V
$I_k$	Cathode Current	1 to 100	mA
$T_{oper}$	Operating Free-air Temperature Range TL1431C/AC TL1431I/AI	-200 to +70 -40 to +105	°C
$R_{THJ-A}$	Thermal resistance Junction to Ambient SO 8 Batwing TO92	130 200	°C/W

### 3 Electrical Characteristics

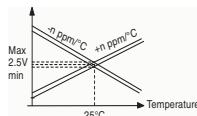
**Table 3.**  $T_{amb} = 25^{\circ}\text{C}$  (unless otherwise specified)

Symbol	Parameter	TL1431C			TL1431AC			Unit
		Min.	Typ.	Max.	Min.	Typ.	Max.	
$V_{ref}$	Reference Input Voltage - figure 1 $V_{KA} = V_{ref}$ , $I_k = 10 \text{ mA}$	2.490	2.500	2.510	2.493	2.500	2.507	V
$\Delta V_{ref}$	Reference Input Voltage Deviation Over Temperature Range <sup>(1)</sup> - figure 1 $V_{KA} = V_{ref}$ , $I_k = 10 \text{ mA}$ , $T_{min} \leq T_{amb} \leq T_{max}$		3	20		3	20	mV
$\frac{\Delta V_{ref}}{\Delta T}$	Temperature Coefficient of Reference Input Voltage <sup>(2)</sup> $V_{KA} = V_{ref}$ , $I_k = 10 \text{ mA}$ , $T_{min} \leq T_{amb} \leq T_{max}$		$\pm 13$	$\pm 90$		$\pm 13$	$\pm 90$	ppm/ $^{\circ}\text{C}$
$\frac{\Delta V_{ref}}{\Delta V_{ka}}$	Ratio of Change in Reference Input Voltage to Change in Cathode to Anode Voltage - figure 2 $I_k = 10 \text{ mA}$ - $\Delta V_{KA} = 36 \text{ V}$ to $3 \text{ V}$	-2	-1.1		-2	-1.1		mV/V
$I_{ref}$	Reference Input Current $I_k = 10 \text{ mA}$ , $R_1 = 10 \text{ k}\Omega$ , $R_2 = \infty$ $T_{min} \leq T_{amb} \leq T_{max}$		1.5	2.5		1.5	2.5	$\mu\text{A}$
$\Delta I_{ref}$	Reference Input Current Deviation Over Temperature Range $I_k = 10 \text{ mA}$ , $R_1 = 10 \text{ k}\Omega$ , $R_2 = \infty$ $T_{min} \leq T_{amb} \leq T_{max}$		0.2	1.2		0.2	1.2	$\mu\text{A}$
$I_{min}$	Minimum Cathode Current for Regulation - figure 1 $V_{KA} = V_{ref}$		0.5	1		0.5	0.6	mA
$I_{off}$	Off-State Cathode Current - figure 3		180	500		180	500	nA
$ Z_{KA} $	Dynamic Impedance <sup>(3)</sup> $V_{KA} = V_{ref}$ , $\Delta I_k = 1$ to $100 \text{ mA}$ , $f \leq 1 \text{ kHz}$		0.2	0.5		0.2	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 temperature coefficient is defined as the slopes (positive and negative) of the voltage vs temperature limits within which the reference is guaranteed.

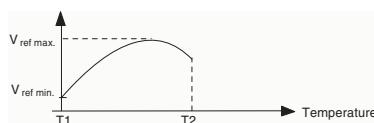


3. The dynamic Impedance is defined as  $|Z_{KA}| = \frac{\Delta V_{KA}}{\Delta I_K}$

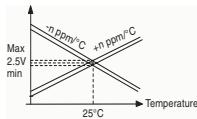
**Table 4.**  $T_{amb} = 25^\circ\text{C}$  (unless otherwise specified)

Symbol	Parameter	TL1431I			TL1431AI			Unit
		Min.	Typ.	Max.	Min.	Typ.	Max.	
$V_{ref}$	Reference Input Voltage - figure 1 $V_{KA} = V_{ref}$ , $I_k = 10 \text{ mA}$	2.490	2.500	2.510	2.493	2.500	2.507	V
$\Delta V_{ref}$	Reference Input Voltage Deviation Over Temperature Range <sup>(1)</sup> - figure 1 $V_{KA} = V_{ref}$ , $I_k = 10 \text{ mA}$ , $T_{min} \leq T_{amb} \leq T_{max}$		7	30		7	30	mV
$\frac{\Delta V_{ref}}{\Delta T}$	Temperature Coefficient of Reference Input Voltage <sup>(2)</sup> $V_{KA} = V_{ref}$ , $I_k = 10 \text{ mA}$ , $T_{min} \leq T_{amb} \leq T_{max}$		$\pm 22$	$\pm 100$		$\pm 22$	$\pm 100$	ppm/ $^\circ\text{C}$
$\frac{\Delta V_{ref}}{\Delta V_{ka}}$	Ratio of Change in Reference Input Voltage to Change in Cathode to Anode Voltage - figure 2 $I_k = 10 \text{ mA}$ - $\Delta V_{KA} = 36 \text{ V}$ to $3 \text{ V}$		-1.1	2		-1.1	2	mV/V
$I_{ref}$	Reference Input Current $I_k = 10 \text{ mA}$ , $R_1 = 10 \text{ k}\Omega$ , $R_2 = \infty$ $T_{min} \leq T_{amb} \leq T_{max}$		1.5	2.5		1.5	2.5	$\mu\text{A}$
$\Delta I_{ref}$	Reference Input Current Deviation Over Temperature Range $I_k = 10 \text{ mA}$ , $R_1 = 10 \text{ k}\Omega$ , $R_2 = \infty$ $T_{min} \leq T_{amb} \leq T_{max}$		0.5	1		0.8	1.2	$\mu\text{A}$
$I_{min}$	Minimum Cathode Current for Regulation - figure 1 $V_{KA} = V_{ref}$		0.5	1		0.5	0.7	mA
$I_{off}$	Off-State Cathode Current - figure 3		180	500		180	500	nA
$ Z_{KA} $	Dynamic Impedance <sup>(3)</sup> $V_{KA} = V_{ref}$ , $\Delta I_k = 1$ to $100 \text{ mA}$ , $f \leq 1 \text{ kHz}$		0.2	0.5		0.2	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 temperature coefficient is defined as the slopes (positive and negative) of the voltage vs temperature limits within which the reference is guaranteed.



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

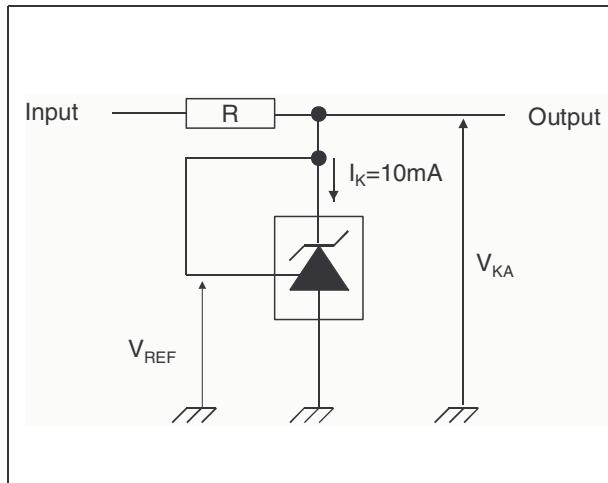
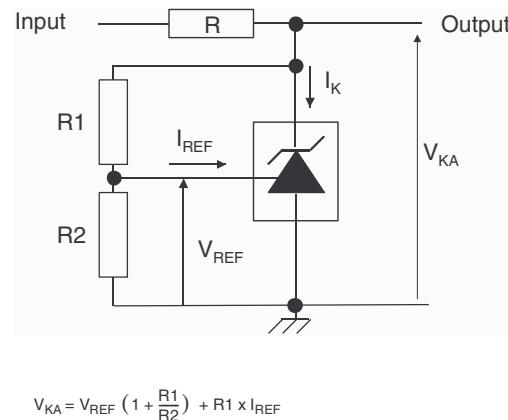
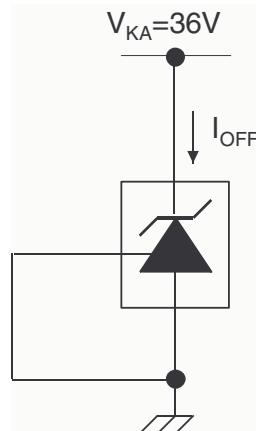
Figure 3. Test circuit for  $V_{KA} = V_{REF}$ Figure 4. Test circuit for  $V_{KA} = V_{REF}$ Figure 5. Test circuit for  $I_{OFF}$ 

Figure 6. Test circuit for phase margin and voltage gain

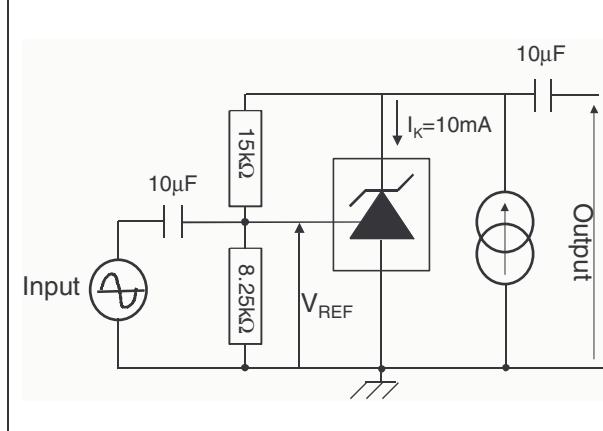


Figure 7. Block diagram of TL1431

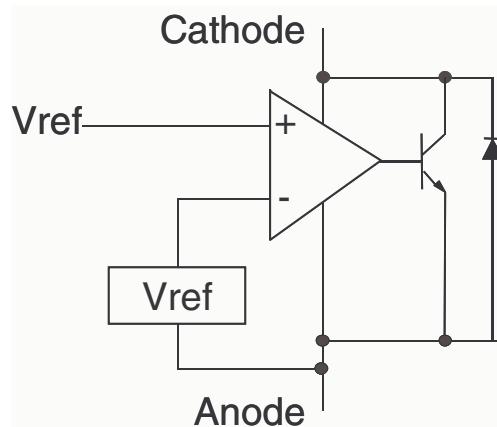
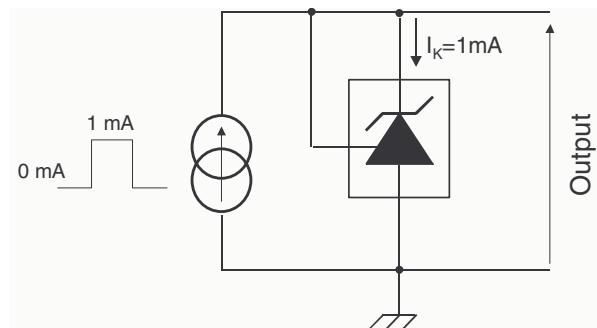


Figure 8. Test circuit for response time



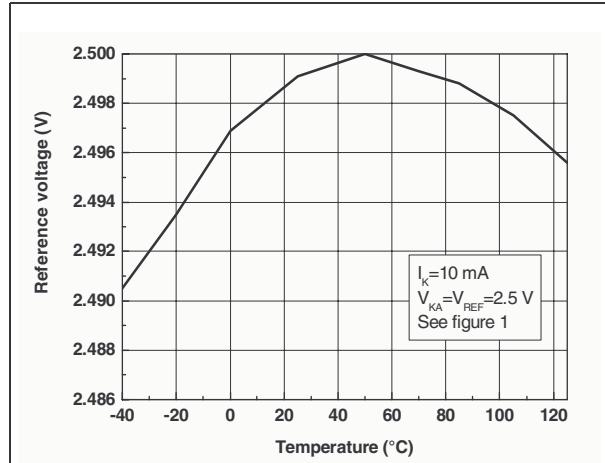
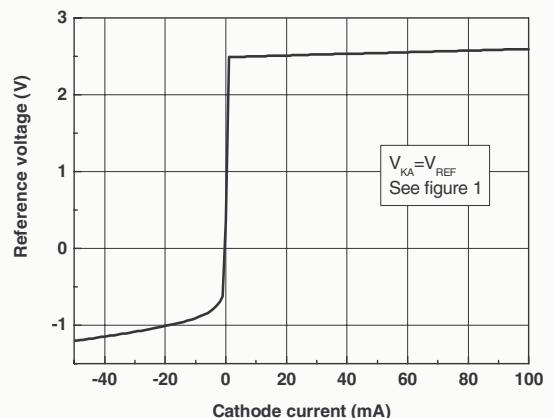
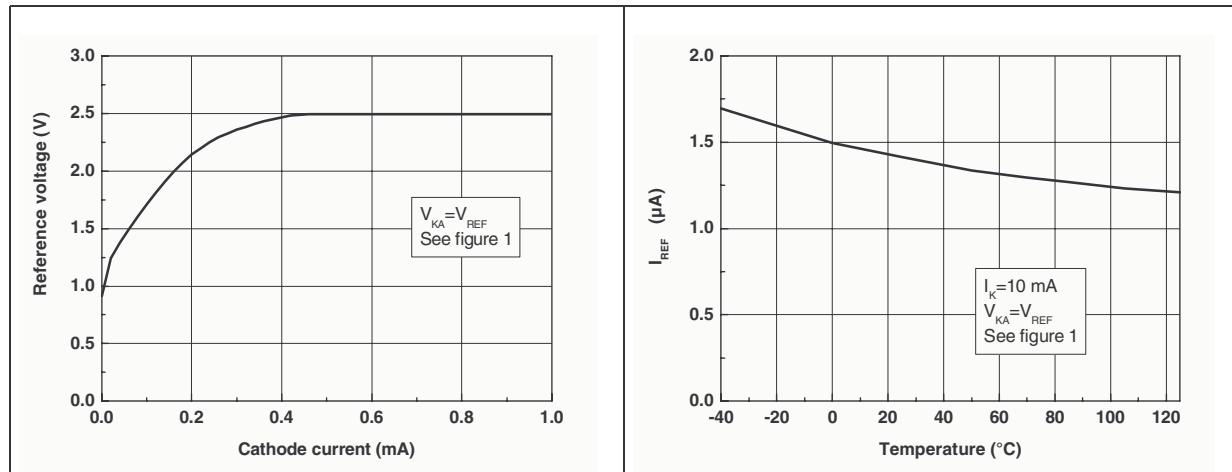
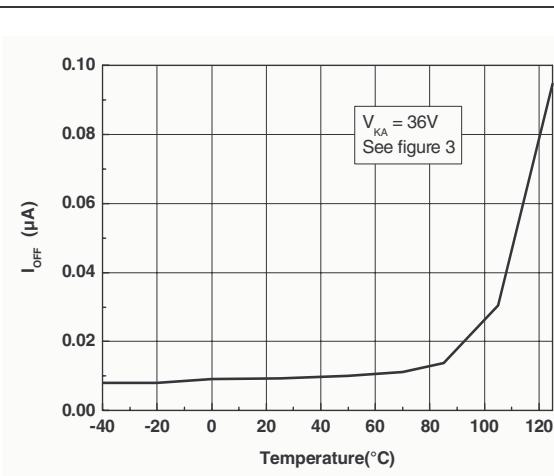
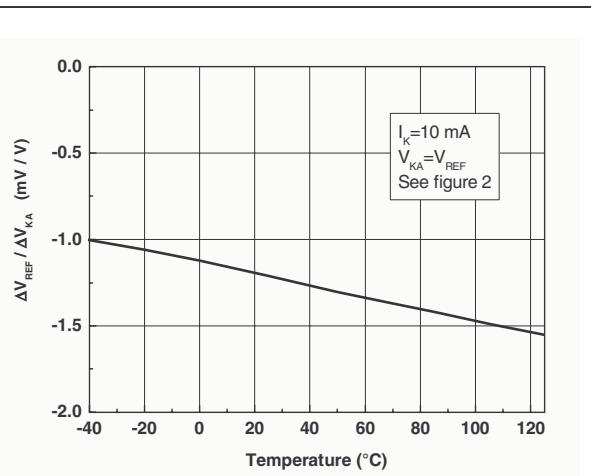
**Figure 9. Reference voltage vs. temp.****Figure 10. Reference voltage vs. cathode current****Figure 11. Reference voltage vs. cathode current**    **Figure 12. Reference current vs. temp.****Figure 13. Off-state cathode current vs. temp.****Figure 14. Ratio of change in  $V_{REF}$  to change in  $V_{KA}$  vs. temp.**

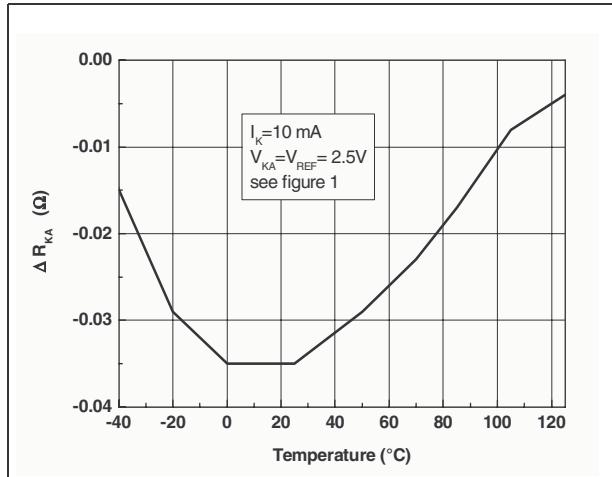
Figure 15. Drift of  $R_{KA}$  vs. temp.

Figure 16. Maximum operating current vs. temp.

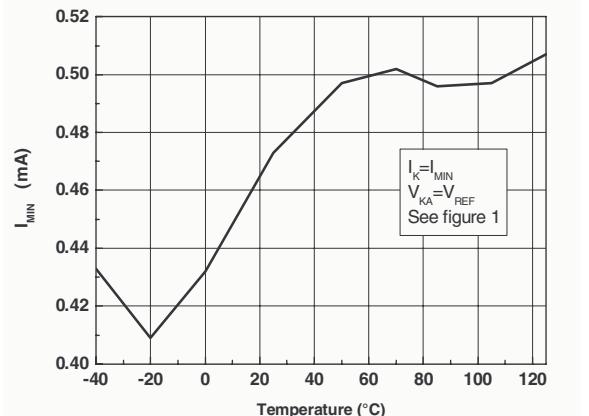


Figure 17. Gain &amp; phase vs. frequency

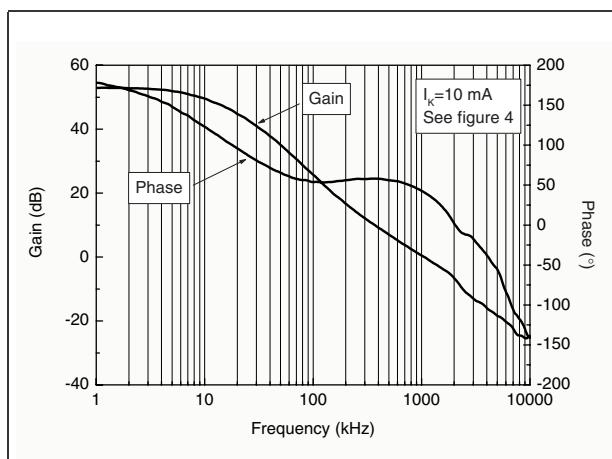


Figure 18. Stability behaviour with capacitive loads

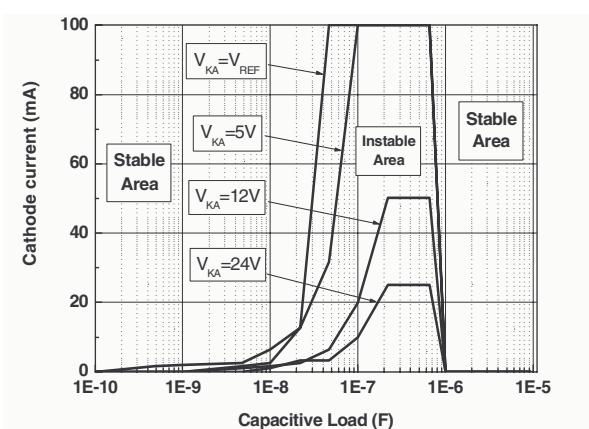
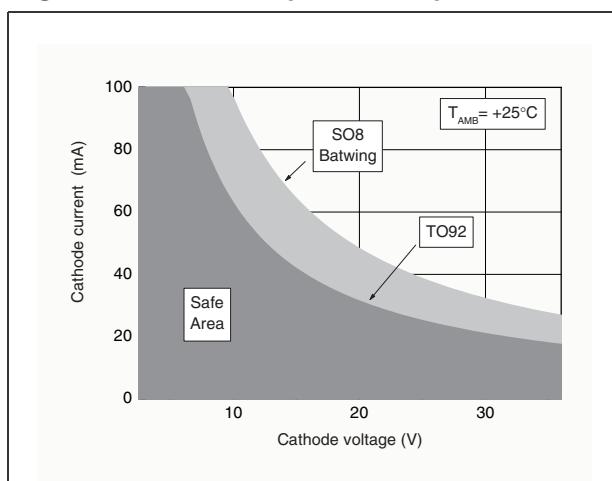
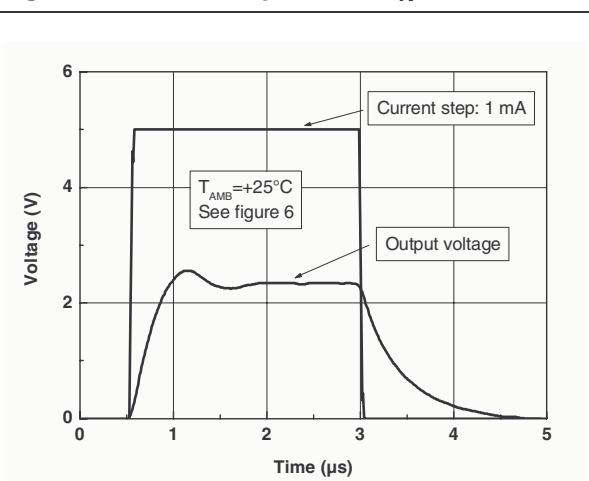


Figure 19. Maximum power dissipation

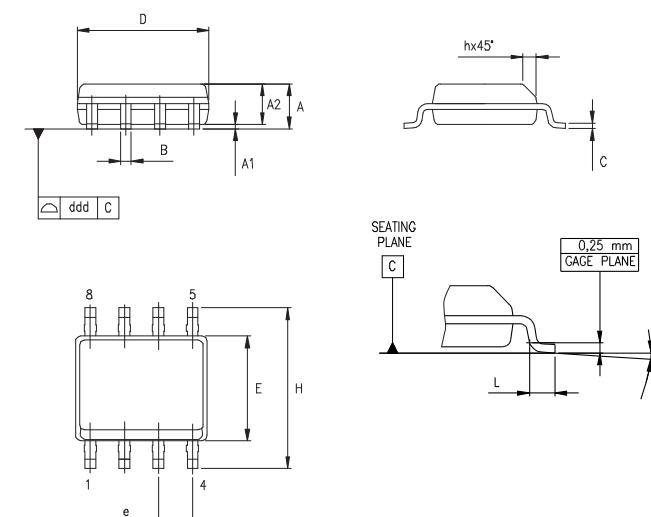
Figure 20. Pulse response for  $I_K = 1 \text{ mA}$ 

## 4 Package Mechanical Data

In order to meet environmental requirements, ST offers these devices in ECOPACK® 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 Batwing 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	8° (max.)					
ddd			0.1			0.04

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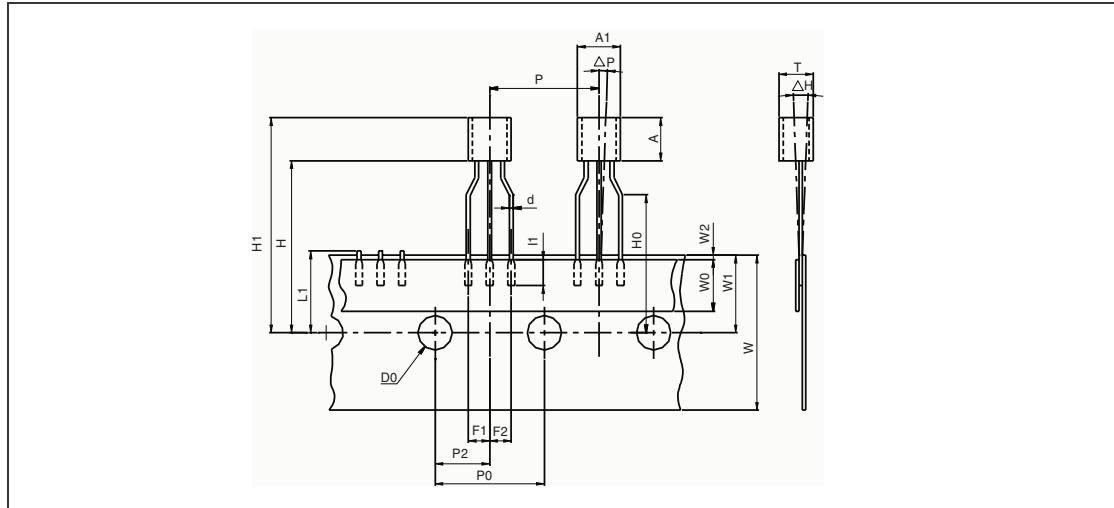
## 4.2 TO92 (Tape & Reel) Package

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

The diagram illustrates the physical dimensions of a TO-92 package. It shows a top view of the lead frame with leads labeled L, a side view of the chip carrier with height D, and a cross-sectional view of the lead frame with width W and lead thickness e1. The lead pitch is labeled b. Other dimensions shown include the total width R, the lead height V, the chip height E, the lead spacing S1, and the chip width A.

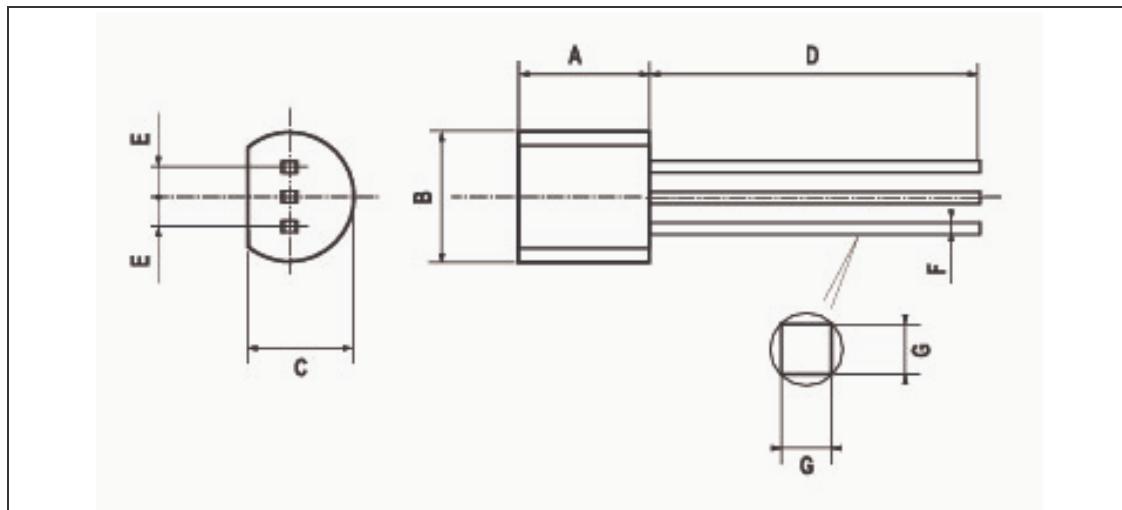
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### 4.3 TO92 (Tape Ammo Pack) Package



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
P0	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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