

## PROGRAMMABLE VOLTAGE REFERENCE

- ADJUSTABLE OUTPUT VOLTAGE :  
2.5 to 36V
- SINK CURRENT CAPABILITY : 1 to 100mA
- TYPICAL OUTPUT IMPEDANCE :  $0.22\Omega$
- 1% AND 2% VOLTAGE PRECISION

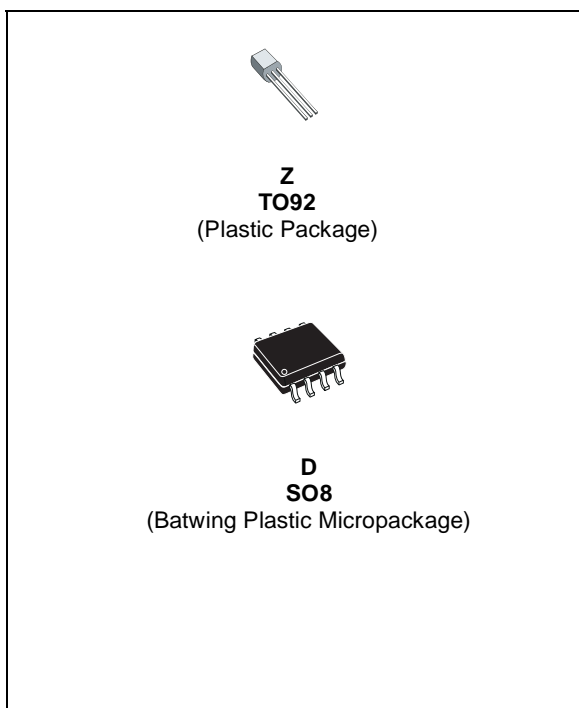
### DESCRIPTION

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  $0.22\Omega$ .

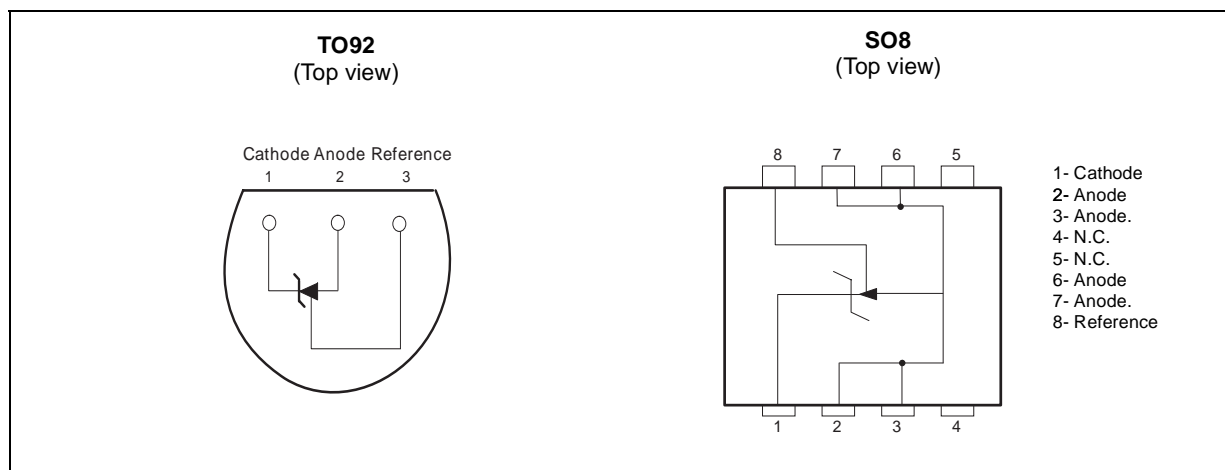
### ORDER CODE

Part Number	Temperature Range	Package	
		Z	D
TL431C/AC	0°C, +70°C	•	•
TL431I/AI	-40°C, +105°C	•	•

Z = TO92 Plastic package - also available in Bulk (Z), Tape & Reel (ZT) and Ammo Pack (AP)  
D = Small Outline Package (SO) - also available in Tape & Reel (DT)



### PIN CONNECTIONS (top view)



**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 SO8 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  
 $= 130^\circ\text{C/W}$  for SO8 batwing package

**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

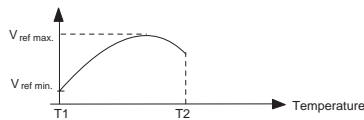
**ELECTRICAL CHARACTERISTICS**

$T_{amb} = 25^\circ\text{C}$  (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 - note 1 $V_{KA} = V_{ref}$ , $I_k = 10\text{ mA}$ , $T_{min} \leq T_{amb} \leq T_{max}$		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 - (figure 2) $I_k = 10\text{ mA}$ $\Delta V_{KA} = 10\text{V to } V_{ref}$ $\Delta V_{KA} = 36\text{V to } 10\text{V}$		-1.4 -1	-2.7 -2		-1.4 -1	-2.7 -2	mV/V
$I_{ref}$	Reference Input Current $I_k = 10\text{ mA}$ , $R_1 = 10\text{ k}\Omega$ , $R_2 = \infty$ $T_{amb} = 25^\circ\text{C}$ $T_{min} \leq T_{amb} \leq T_{max}$		1.8	4 5.2		1.8	4 5.2	$\mu\text{A}$
$\Delta I_{ref}$	Reference Input Current Deviation Over Temperature Range $I_k = 10\text{ mA}$ , $R_1 = 10\text{ k}\Omega$ , $R_2 = \infty$ $T_{min} \leq T_{amb} \leq T_{max}$		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 - note 2 $V_{KA} = V_{ref}$ , $\Delta I_k = 1\text{ to }100\text{ mA}$ , $f \leq 1\text{ kHz}$		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  $|Z_{KA}| = \frac{\Delta V_{KA}}{\Delta I_k}$

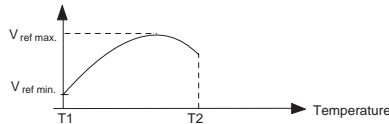


**ELECTRICAL CHARACTERISTICS**

T<sub>amb</sub> = 25°C (unless otherwise specified)

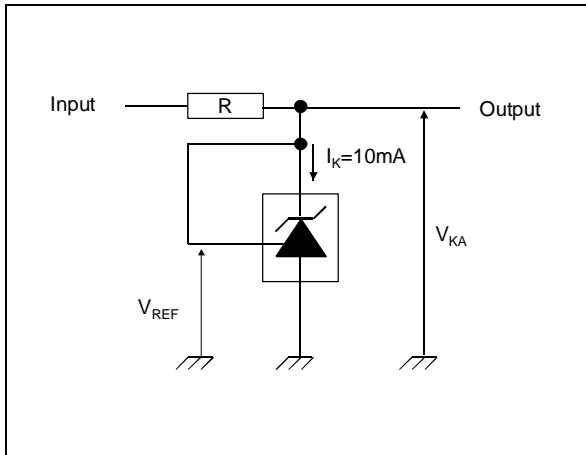
Symbol	Parameter	TL431I			TL431AI			Unit
		Min.	Typ.	Max.	Min.	Typ.	Max.	
V <sub>ref</sub>	Reference Input Voltage V <sub>KA</sub> = V <sub>ref</sub> , I <sub>k</sub> = 10 mA, T <sub>amb</sub> = 25°C T <sub>min</sub> ≤ T <sub>amb</sub> ≤ T <sub>max</sub>	2.44 2.41	2.495	2.55 2.58	2.47 2.44	2.495	2.52 2.55	V
ΔV <sub>ref</sub>	Reference Input Voltage Deviation Over-Temperature Range - note 1 V <sub>KA</sub> = V <sub>ref</sub> , I <sub>k</sub> = 10 mA, T <sub>min</sub> ≤ T <sub>amb</sub> ≤ T <sub>max</sub>		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 <sub>k</sub> = 10mA, ΔV <sub>KA</sub> = 10V to V <sub>ref</sub> ΔV <sub>KA</sub> = 36V to 10V		-1.4 -1	-2.7 -2		-1.4 -1	-2.7 -2	mV/V
I <sub>ref</sub>	Reference Input Current I <sub>k</sub> = 10mA, R1 = 10kΩ, R2 = ∞ T <sub>amb</sub> = 25°C T <sub>min</sub> ≤ T <sub>amb</sub> ≤ T <sub>max</sub>		1.8	4 6.5		1.8	4 6.5	μA
ΔI <sub>ref</sub>	Reference Input Current Deviation Over Temperature Range I <sub>k</sub> = 10mA, R1 = 10kΩ, R2 = ∞ T <sub>min</sub> ≤ T <sub>amb</sub> ≤ T <sub>max</sub>		0.8	2.5		0.8	1.2	μA
I <sub>min</sub>	Minimum Cathode Current for Regulation V <sub>KA</sub> = V <sub>ref</sub>		0.5	1		0.5	0.7	mA
I <sub>off</sub>	Off-State Cathode Current		2.6	1000		2.6	1000	nA
Z <sub>KA</sub>	Dynamic Impedance note 2 V <sub>KA</sub> = V <sub>ref</sub> , ΔI <sub>k</sub> = 1 to 100mA, f ≤ 1kHz		0.22	0.5		0.22	0.5	Ω

1) ΔV<sub>ref</sub> is defined as the difference between the maximum and minimum values obtained over the full temperature range.  
ΔV<sub>ref</sub> = V<sub>ref max.</sub> - V<sub>ref min.</sub>

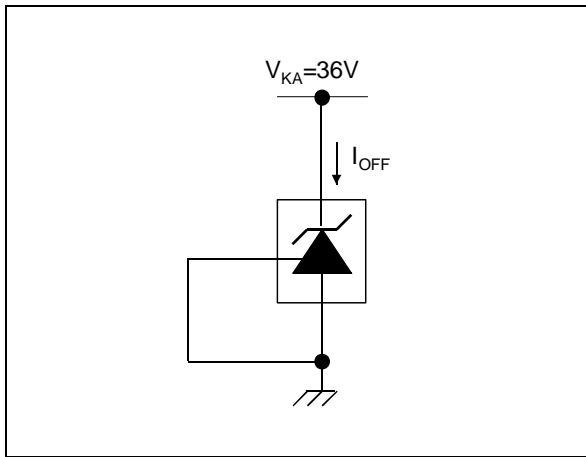


2) The dynamic Impedance is defined as  $|Z_{KA}| = \frac{\Delta V_{KA}}{\Delta I_K}$

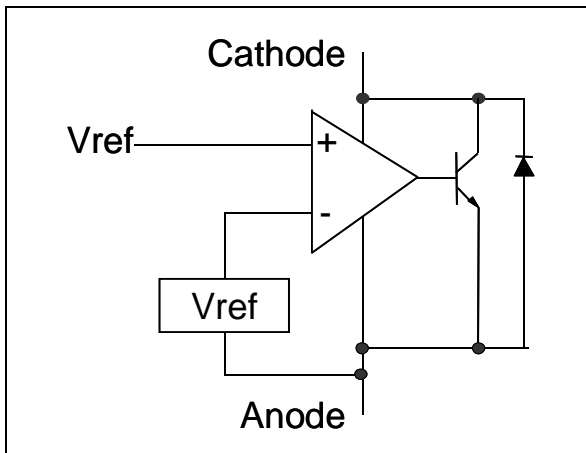
**Figure 1 :** Test Circuit for  $V_{KA} = V_{REF}$



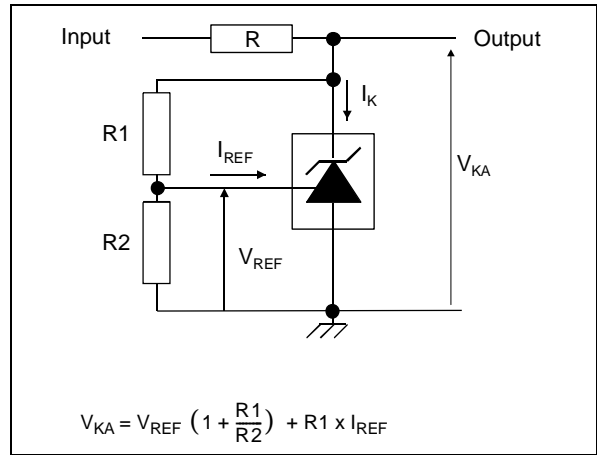
**Figure 3 :** Test Circuit for  $I_{OFF}$



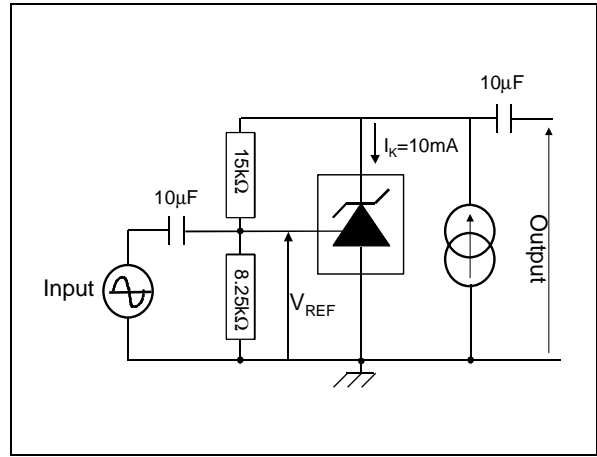
**Figure 5 :** Block diagram of TL431



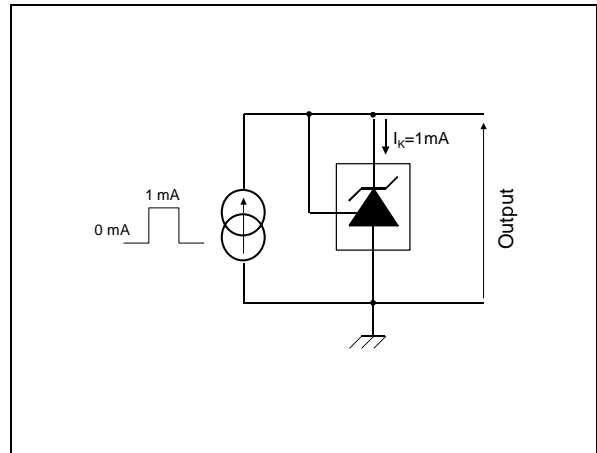
**Figure 2 :** Test Circuit for  $V_{KA} > V_{REF}$



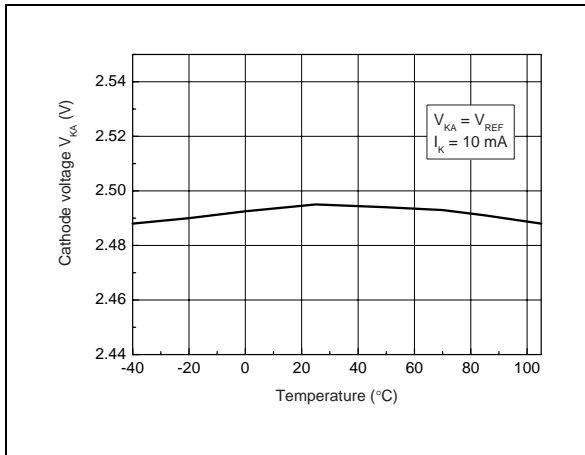
**Figure 4 :** Test Circuit for Phase Margin and Voltage Gain



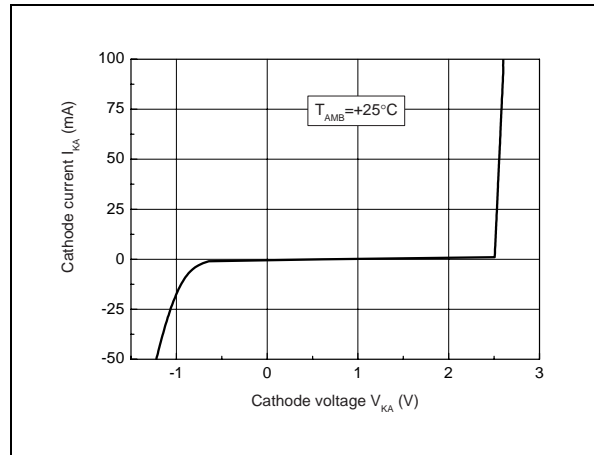
**Figure 6 :** Test Circuit for Response time



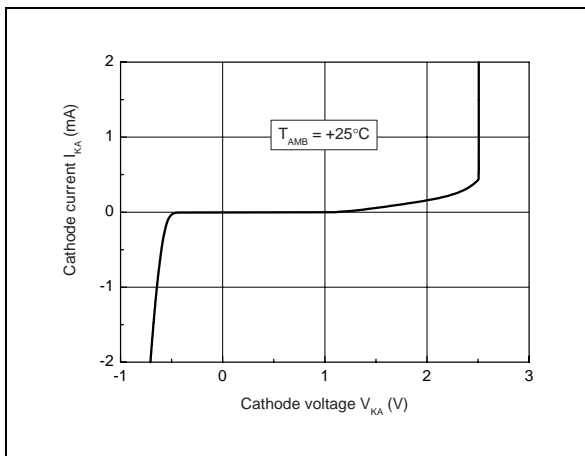
Reference voltage vs Temperature



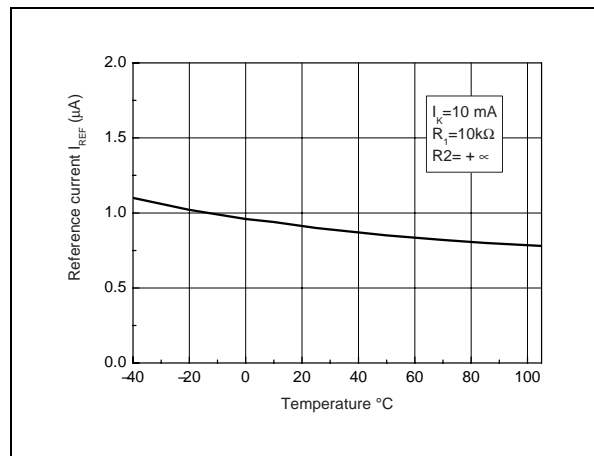
Reference voltage vs cathode current



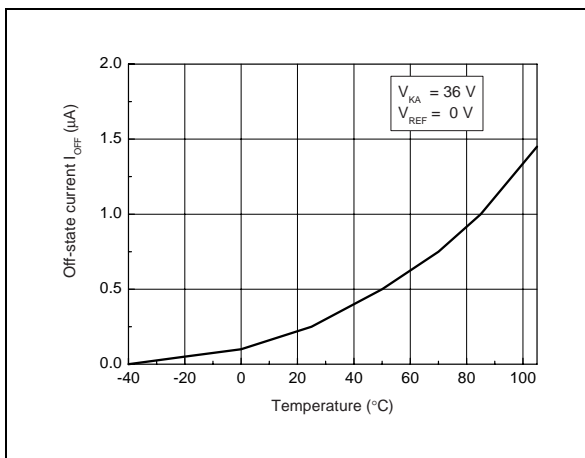
Reference voltage vs cathode current



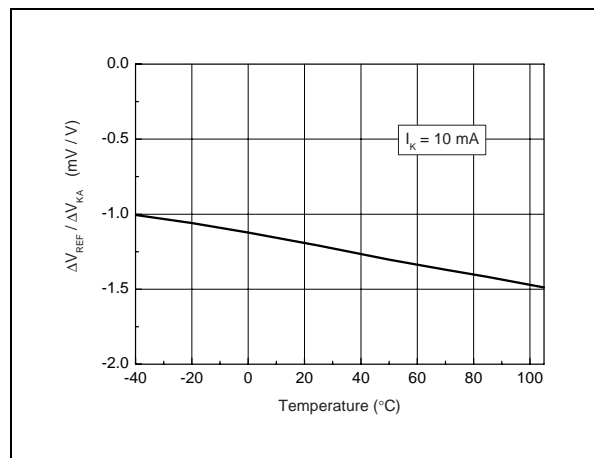
Reference current vs temperature



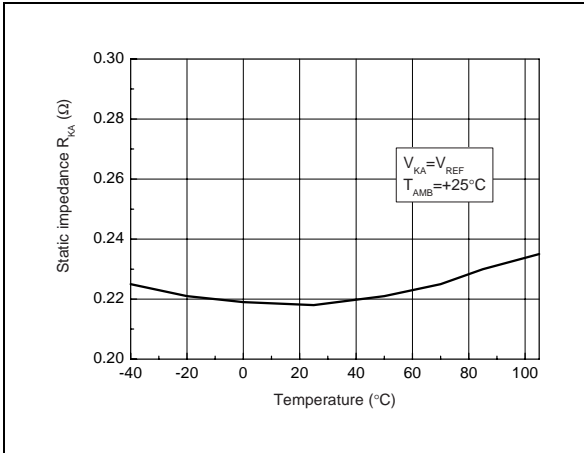
Off-state cathode current vs temperature



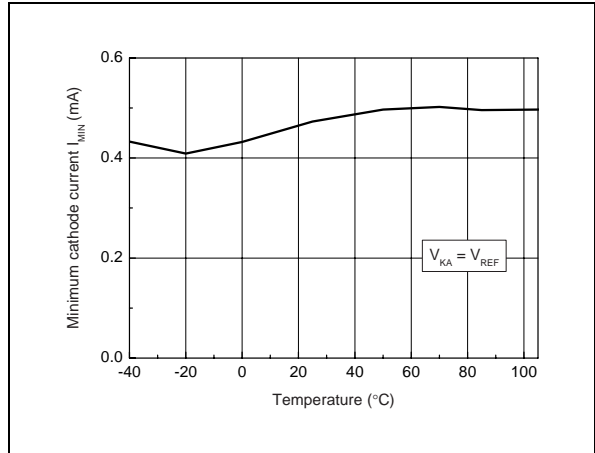
Ratio of change in  $V_{REF}$  to change in  $V_{KA}$  vs Temperature



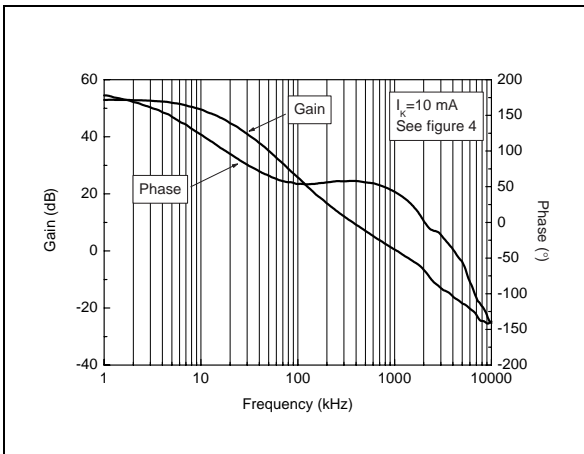
Static impedance  $R_{KA}$  vs Temperature



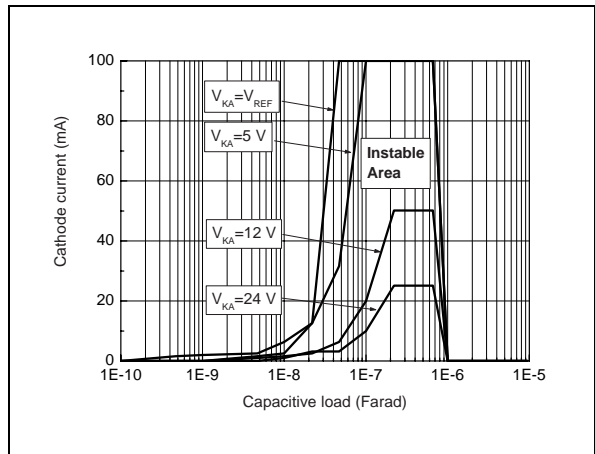
Minimum operating current vs temperature



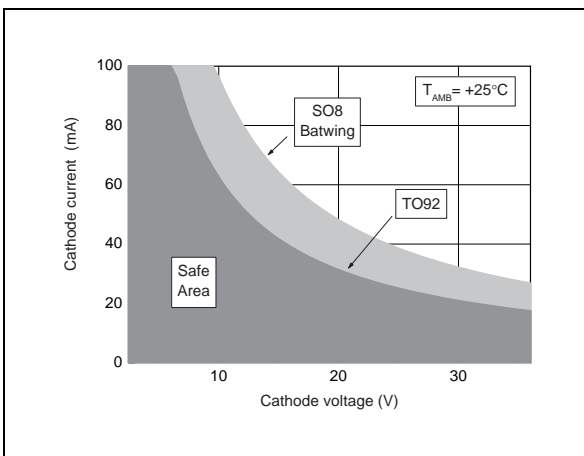
Gain & Phase vs Frequency



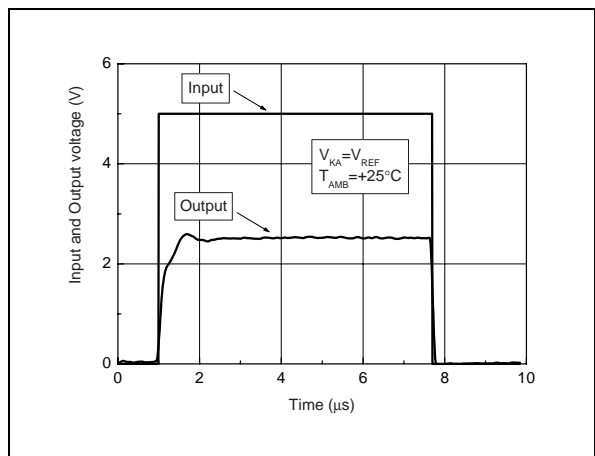
Stability behaviour with capacitive loads



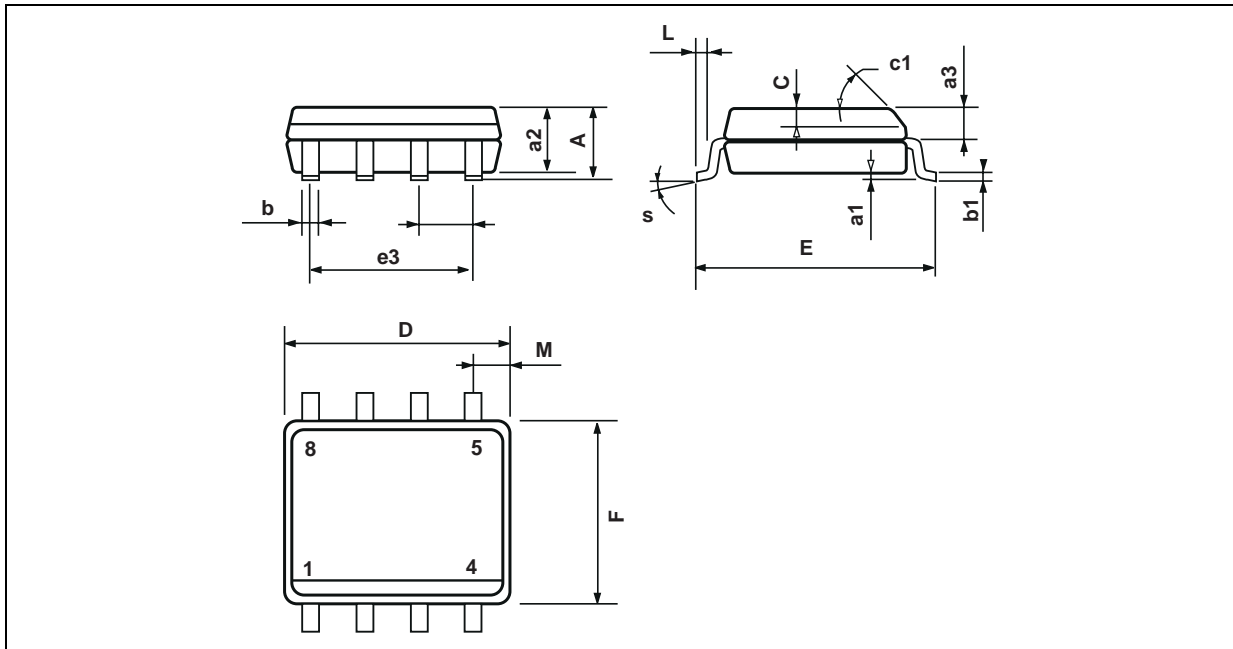
Maximum Power dissipation



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

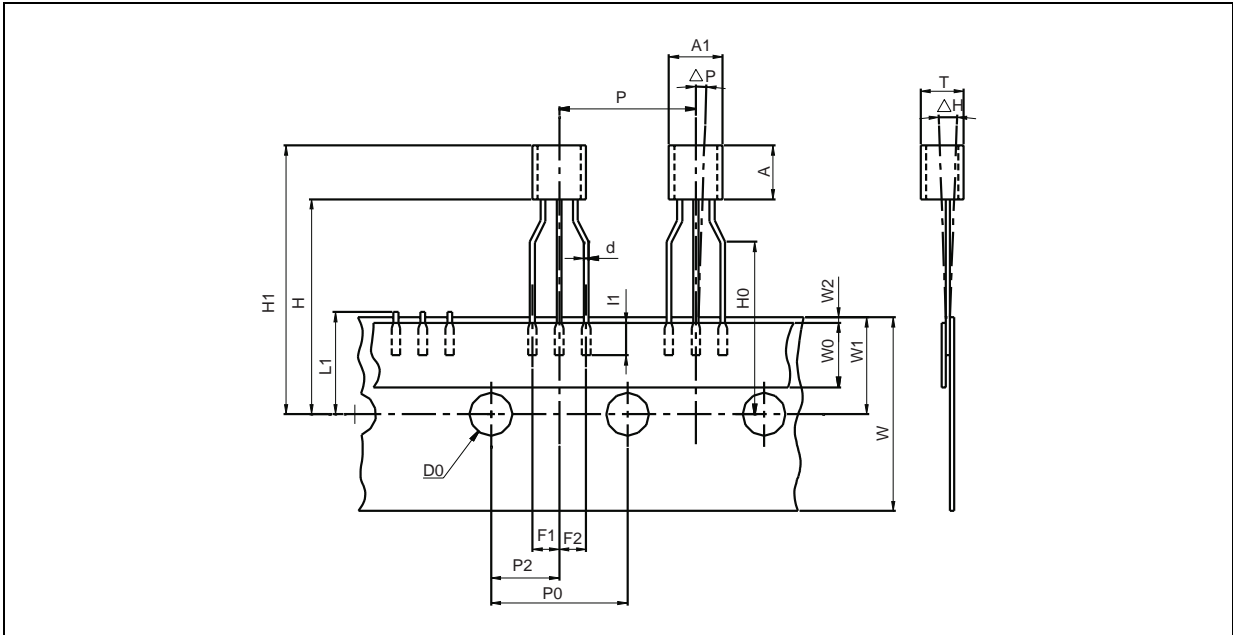


**PACKAGE MECHANICAL DATA**  
**8 PINS - BATWING PLASTIC MICROPACKAGE (SO)**



Dim.	Millimeters			Inches		
	Min.	Typ.	Max.	Min.	Typ.	Max.
A			1.75			0.069
a1	0.1		0.25	0.004		0.010
a2			1.65			0.065
a3	0.65		0.85	0.026		0.033
b	0.35		0.48	0.014		0.019
b1	0.19		0.25	0.007		0.010
C	0.25		0.5	0.010		0.020
c1	45° (typ.)					
D	4.8		5.0	0.189		0.197
E	5.8		6.2	0.228		0.244
e		1.27			0.050	
e3		3.81			0.150	
F	3.8		4.0	0.150		0.157
L	0.4		1.27	0.016		0.050
M			0.6			0.024
S	8° (max.)					

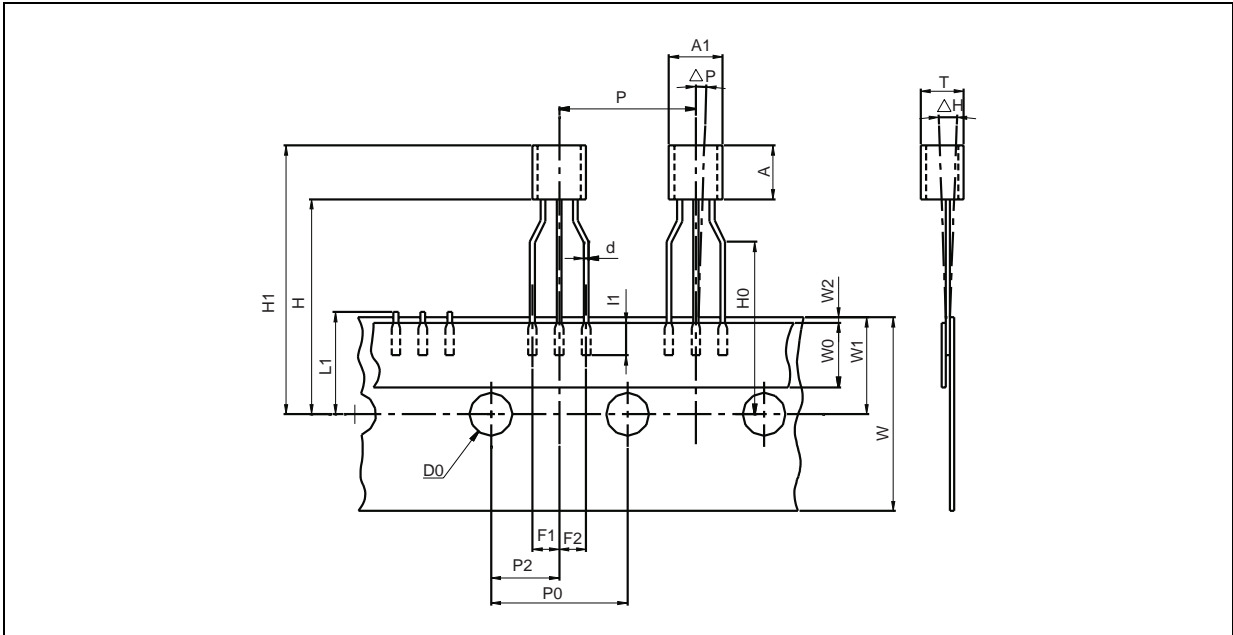
**PACKAGE MECHANICAL DATA**  
**3 PINS - PLASTIC PACKAGE TO92 (TAPE & REEL)**



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	
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
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

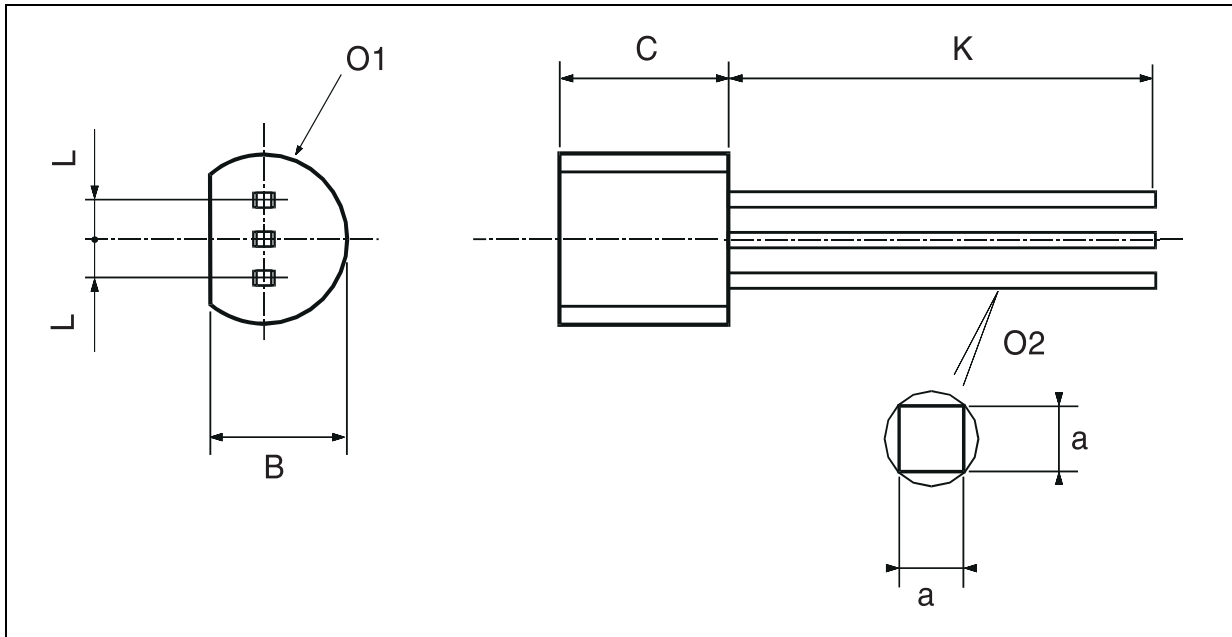


**PACKAGE MECHANICAL DATA**  
**3 PINS - PLASTIC PACKAGE TO92 (TAPE AMMO PACK)**



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	
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
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

**PACKAGE MECHANICAL DATA**  
**3 PINS - PLASTIC PACKAGE TO92 (BULK)**



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		

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