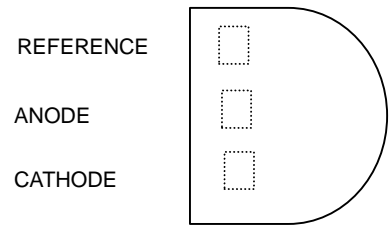




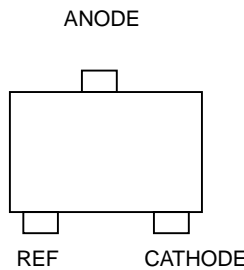
The TL431 integrated circuits are three-terminal programmable shunt regulator diodes. These monolithic IC voltage references operate as a low temperature coefficient zener which is programmable from Vref to 36 volts with two external resistors. This device exhibits a wide operating current range of 1.0 to 100 mA with a typical dynamic impedance of 0.22Ω. The characteristics of these references make them excellent replacements for zener diodes in many applications such as digital voltmeters, power supplies, and op amp circuitry. The 2.5 volt reference makes it convenient to obtain a stable reference from 5.0 volt logic supplies, and since the TL431 operates as a shunt regulator, it can be used as either a positive or negative voltage reference

## FEATURE

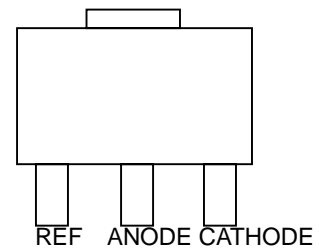
1. Programmable Output Voltage to 36 Volts
2. Low Dynamic Output Impedance, 0.22Ω Typical
3. Sink Current Capability of 1.0 to 100mA
4. Equivalent Full-Range Temperature Coefficient of 50ppm/°C Typical
5. Temperature Compensated for Operation over Full Rated Operating Temperature Range
6. Low Output Noise Voltage



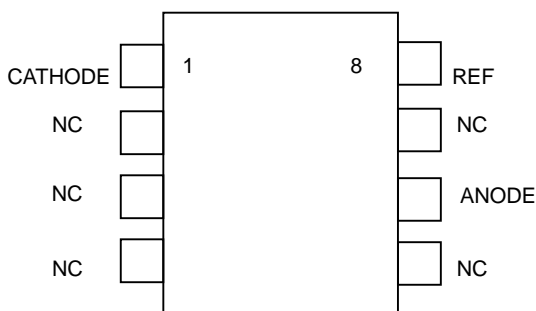
**TO-92 TOP VIEW**



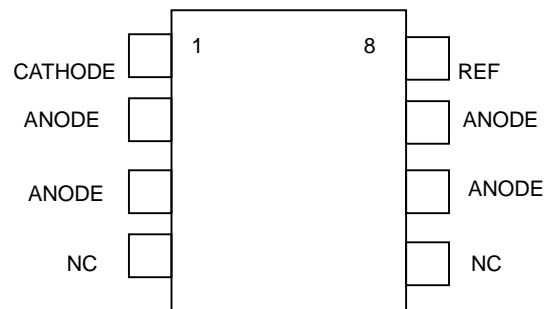
**SOT-23 TOP VIEW**



**SOT-89 TOP VIEW**



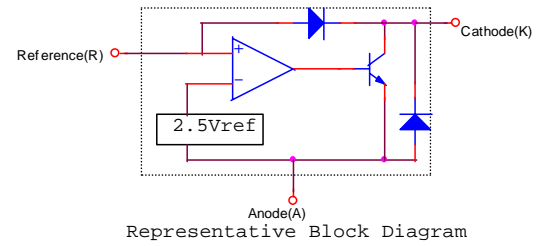
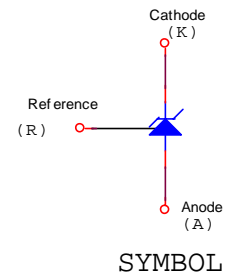
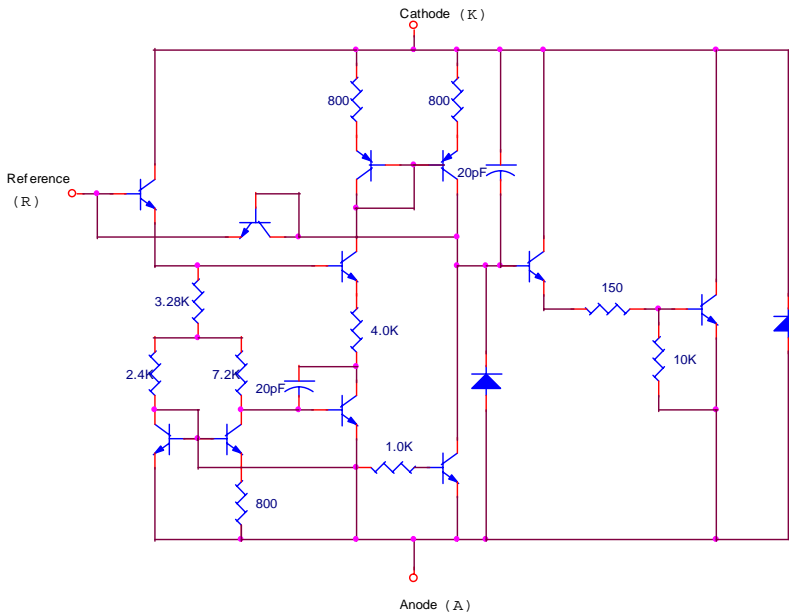
**DIP-8 TOP VIEW**



**SOP-8 TOP VIEW**



## ● BLOCK DIAGRAM



## ● ABSOLUTE MAXIMUM RATINGS

(Full operating ambient temperature range applies, unless otherwise noted)

Rating	Symbol	Value	Unit
Cathode To Anode Voltage	$V_{KA}$	37	V
Cathode Current Range, Continuous	$I_K$	-100 to +150	mA
Reference Input Current Range, Continuous	$I_{ref}$	-0.05 to +10	mA
Operating Junction Temperature	$T_J$	150	°C
Operating Ambient Temperature Range TL431CT/CP/CD/CH/CLT1	$T_A$	-20 ~ +85	°C
Storage temperature Range	$T_{stg}$	-65 to +150	°C
Total Power Dissipation @ $T_A=25^\circ\text{C}$ Derate above 25°C Ambient Temperature	$P_D$	0.70	W
T,D Suffix Package			
P Suffix Package			
H Suffix Package			
LT1 Suffix Package		0.28	



Total Power Dissipation @T <sub>C</sub> =25°C Derate above 25°C Case Temperature T,D Suffix Package P Suffix Package H Suffix Package LT1 Suffix Package	P <sub>D</sub>	1.5 3.0	W
---	----------------	------------	---

● THERMAL CHARACTERISTICS

Characteristics	Symbol	T,D Suffix	P Suffix	H Suffix	LT1 Suffix	Unit
Thermal Resistance, Junction to Ambient	R <sub>θJA</sub>	178	114	110	575	°C/W
Thermal Resistance, Junction to Case	R <sub>θJC</sub>	83	41	8	150	°C/W

● RECOMMENDED OPERATING CONDITIONS

Condition/Value	Symbol	Min	Max	Unit
Cathode to Anode Voltage	V <sub>KA</sub>	V <sub>ref</sub>	36	V
Cathode Current	I <sub>K</sub>	1.0	100	mA

● ELECTRICAL CHARACTERISTICS(Ambient temperature at 25°C unless otherwise noted)

Characteristic	Symbol	TL431			Unit
		Min	Typ	Max	
Reference Input Voltage (Fig 1) V <sub>KA</sub> =V <sub>ref</sub> , I <sub>K</sub> =10mA T <sub>A</sub> =+25°C Tolerance 0.5% 1% 2% T <sub>A</sub> =T <sub>low</sub> to T <sub>high</sub> (Note 1)	V <sub>ref</sub>	2.483 2.470 2.445 2.453	2.495	2.507 2.520 2.55 2.537	V
Reference Input Voltage Deviation Over Temperature Range (Fig 1, Note 1,2) V <sub>KA</sub> =V <sub>ref</sub> . I <sub>K</sub> =10mA	ΔV <sub>ref</sub>	--	3.0	17	mV
Ratio of Change in Reference Input Voltage To Change in Cathode to Anode Voltage I <sub>K</sub> =10mA (Figure 2), ΔV <sub>KA</sub> =10V to V <sub>ref</sub> ΔV <sub>KA</sub> =36V to 10V	$\frac{\Delta V_{ref}}{\Delta V_{KA}}$	-- --	-1.4 -1.0	-2.7 -2.0	mV/V



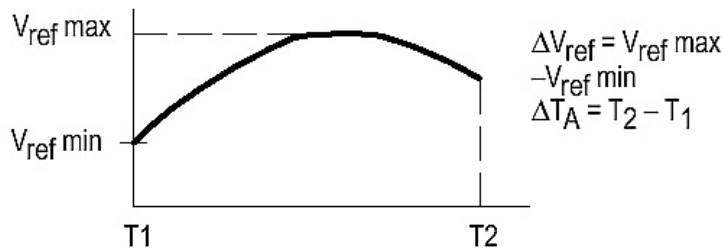
Reference Input Current (Figure 2) $I_K=10\text{mA}$ , $R_1=10\text{k}$ , $R_2=\infty$ $T_A=+25^\circ\text{C}$ $T_A=T_{\text{low}}$ to $T_{\text{high}}$ (Note 1)	$I_{\text{ref}}$	--	1.8	4.0	$\mu\text{A}$
Reference Input Current Deviation Over Temperature Range (Figure 2, Note 1) $I_K=10\text{mA}$ , $R_1=10\text{k}$ , $R_2=\infty$	$\Delta I_{\text{ref}}$	--	0.4	1.2	$\mu\text{A}$
Minimum Cathode Current for Regulation $V_{KA}=V_{\text{ref}}$ (Figure 1)	$I_{\text{min}}$	--	0.5	1.0	$\text{mA}$
Off-State Cathode Current (Figure 3) $V_{KA}=36\text{V}$ , $V_{\text{ref}}=0\text{V}$	$I_{\text{off}}$	--	260	1000	$\text{nA}$
Dynamic Impedance (Figure 1, Note 3) $V_{KA}=V_{\text{ref}}$ , $\Delta I_K=1.0\text{mA}$ to $100\text{mA}$ , $f_{\leq} 1.0\text{kHz}$	$ Z_{KA} $	--	0.22	0.5	$\Omega$

**1**

$T_{\text{low}}=0^\circ\text{C}$ ,  $T_{\text{high}}=+70^\circ\text{C}$

**2**

The deviation parameter  $\Delta V_{\text{ref}}$  is defined as the differences between the maximum and minimum values obtained over the full operating ambient temperature range the applies.



The average temperature coefficient of the reference input voltage,  $\alpha V_{\text{ref}}$ , is defined as:

$$\alpha V_{\text{ref}} \frac{\text{ppm}}{^\circ\text{C}} = \frac{\frac{\Delta V_{\text{ref}}}{V_{\text{ref}} @ 25^\circ\text{C}} \times 10^6}{\Delta T_A} = \frac{\Delta V_{\text{ref}} \times 10^6}{\Delta T_A (V_{\text{ref}} @ 25^\circ\text{C})}$$

$\alpha V_{\text{ref}}$  can be positive or negative depending on whether  $V_{\text{ref}}$  Min or  $V_{\text{ref}}$  Max occurs at the lower ambient temperature. (Refer to Figure 6)

Example:  $\Delta V_{\text{ref}}=8.0\text{mV}$  and slope is positive,  $V_{\text{ref}} @ 25^\circ\text{C}=2.495\text{V}$ ,  $\Delta T_A=70^\circ\text{C}$

$$\alpha V_{\text{ref}} = \frac{0.008 \times 10^6}{70(2.495)} = 45.8 \text{ ppm}/^\circ\text{C}$$



### 3

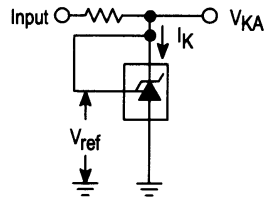
The dynamic impedance  $Z_{KA}$  is defined as:

$$|Z_{KA}| = \frac{\Delta V_{KA}}{\Delta I_K}$$

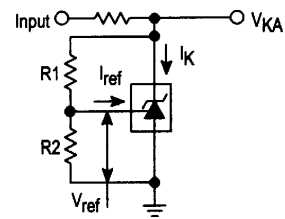
When the device is programmed with two external resistors,  $R1$  and  $r2$ , (refer to Figure 2) the total dynamic impedance of the circuit is defined as:

$$|Z_{KA}'| \approx |Z_{KA}| \left(1 + \frac{R1}{R2}\right)$$

## ● TEST CIRCUITS

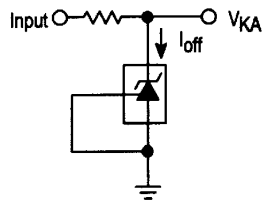


**Fig 1. Test Circuit for V<sub>KA</sub>=V<sub>ref</sub>**



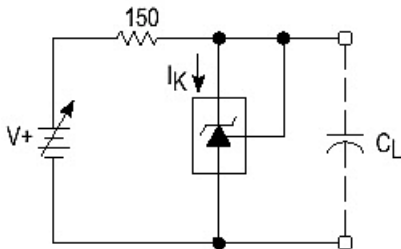
$$V_{KA} = V_{ref} \left(1 + \frac{R1}{R2}\right) + I_{ref} \cdot R1$$

**Fig 2. Test Circuit for V<sub>KA</sub>>V<sub>ref</sub>**

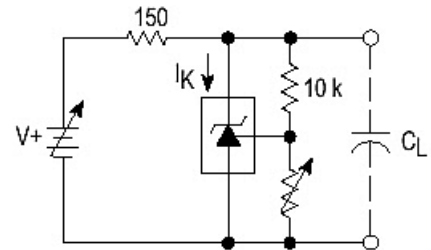


**Fig 3. Test Circuit for I<sub>off</sub>**

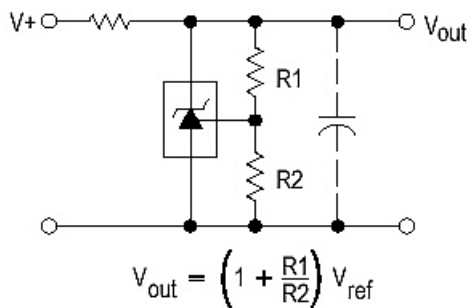
## ● APPLICATION EXAMPLE



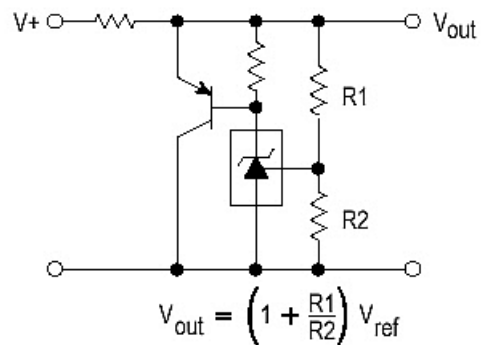
**Fig 4. Test circuit for curves A of stability boundary conditions**



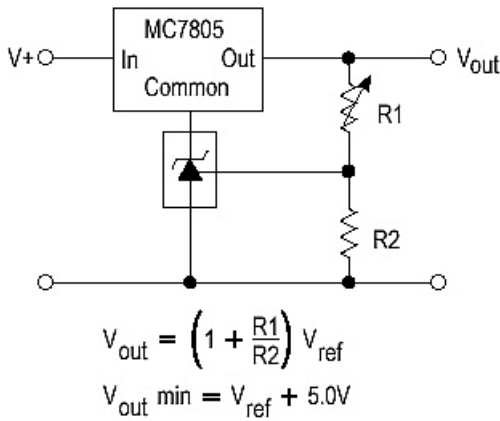
**Fig 5. Test circuit for curves B.C and D of stability boundary conditions**



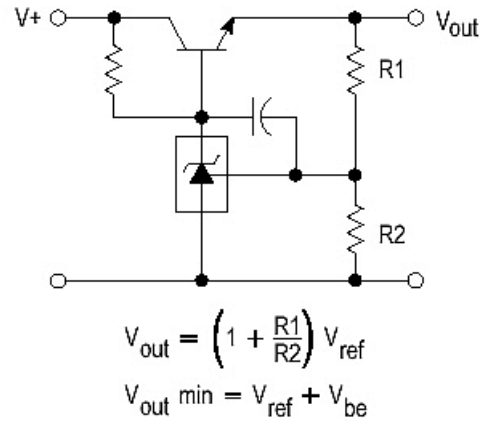
**Fig 6. Shunt regulator**



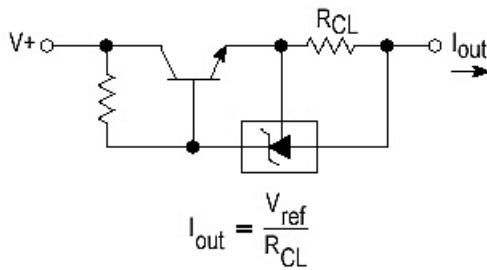
**Fig 7. High current shunt regulator**



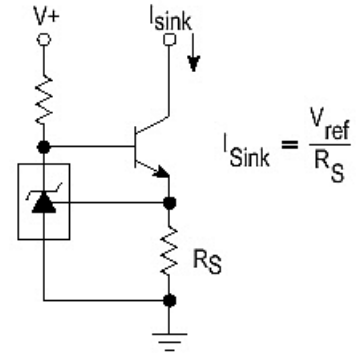
**Fig 8. Output control of a three-Terminal fixed regulator**



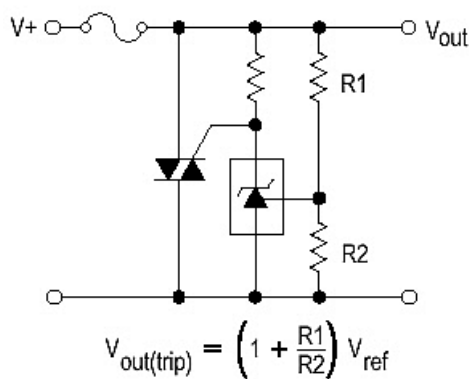
**Fig 9. Series pass regulator**



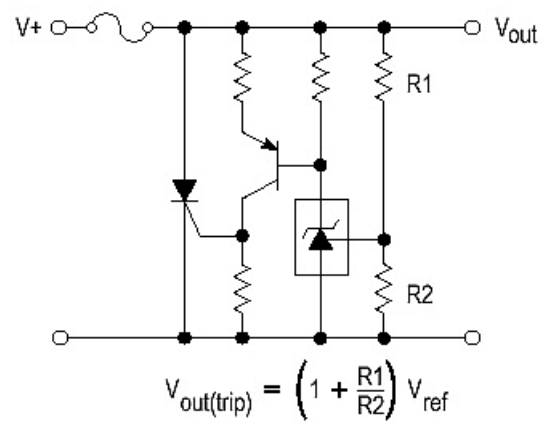
**Fig 10 .Constant current source**



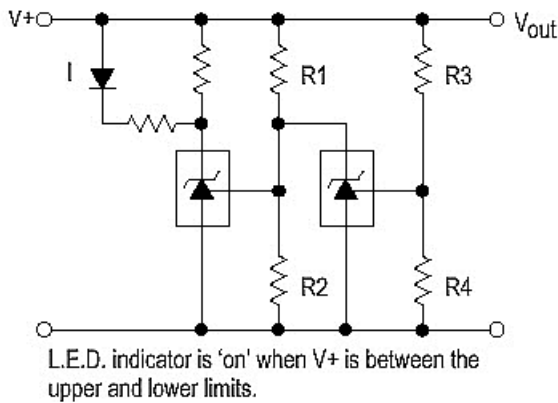
**Fig 11 .Constant current sink**



**Fig 12 .Triac crowbar**

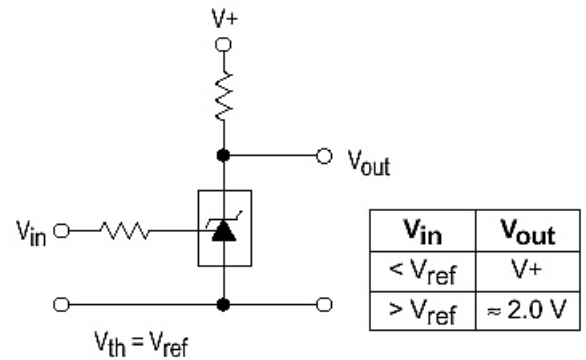


**Fig 13.SCR crowbar**

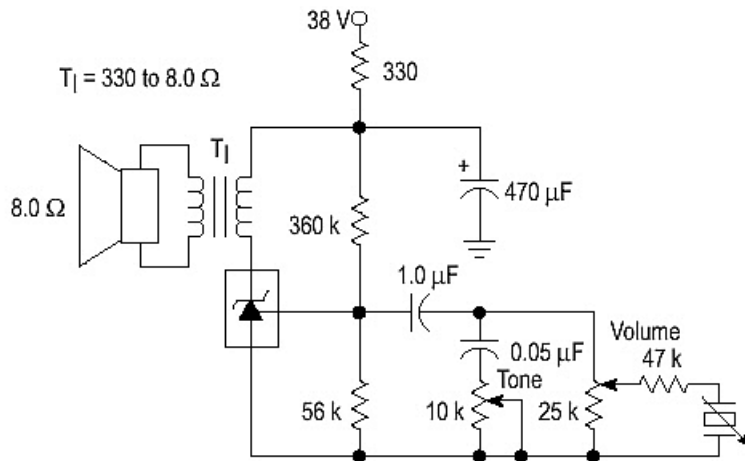


$$\text{Upper Limit} = \left(1 + \frac{R3}{R4}\right) V_{ref} \quad \text{Lower Limit} = \left(1 + \frac{R1}{R2}\right) V_{ref}$$

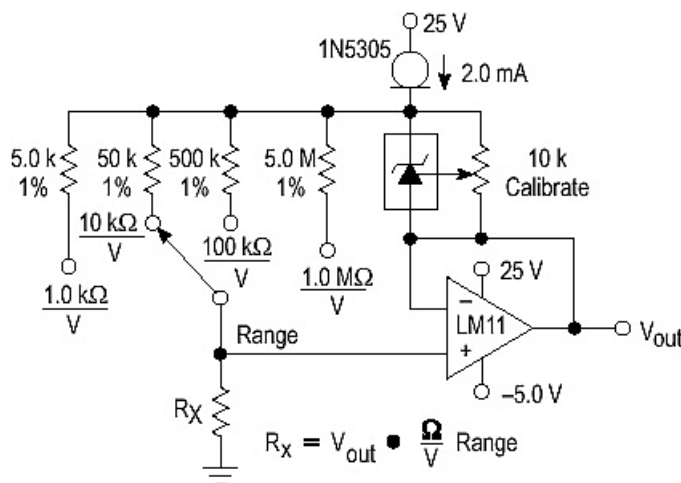
**Fig 14. Voltage monitor**



**Fig 15 . Single-supply comparator with temperature-compensated threshold**

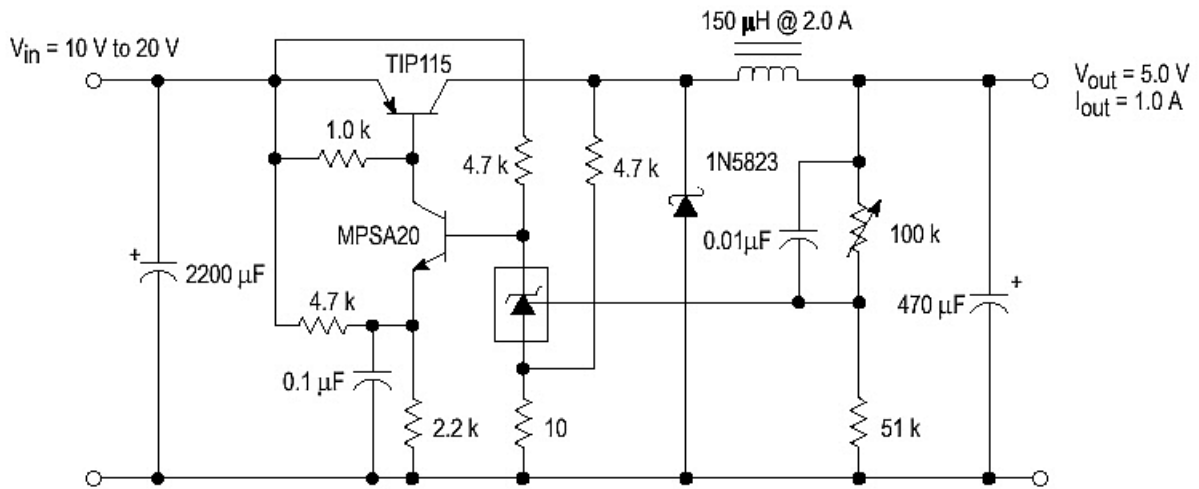


**Fig 16 .Simple 400mW phone amplifier**



**Fig 17. Liner ohmmeter**





Test	Conditions	Results
Line Regulation	$V_{in}=10V$ to $20V, I_o=1.0A$	53mV (1.1%)
Load Regulation	$V_{in}=15V, I_o=0A$ to $1.0A$	25mV (0.5%)
Output Ripple	$V_{in}=10V, I_o=1.0A$	50mV <sub>PP</sub> P.A.R.D
Output Ripple	$V_{in}=20V, I_o=1.0A$	100mV <sub>PP</sub> P.A.R.D
Efficiency	$V_{in}=15V, I_o=1.0A$	82%

Fig 18.High efficiency step-down switching converter



## ELECTRICAL CHARACTERISTICS CURVES

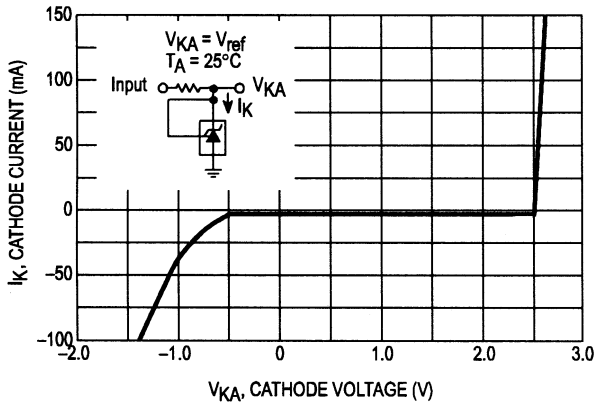


Fig 19. Cathode current versus cathode voltage

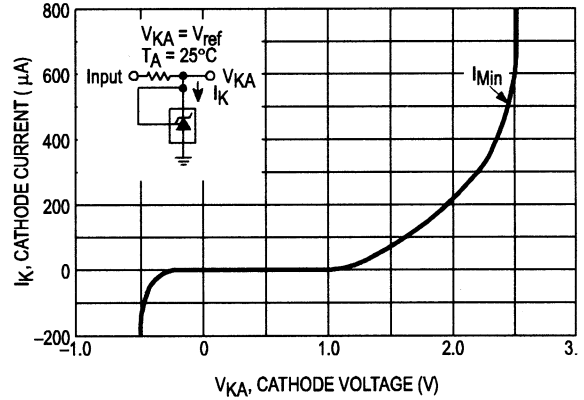


Fig 20. Cathode current versus cathode voltage

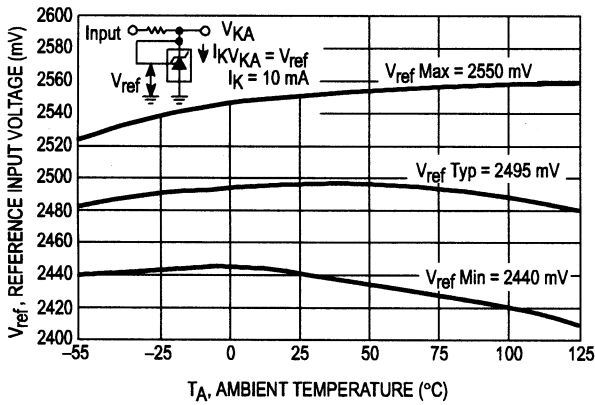


Fig 21. Reference input voltage versus ambient temperature

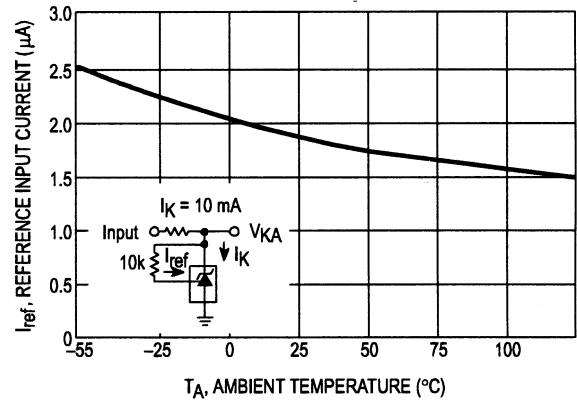


Fig 22. Reference input current versus ambient temperature

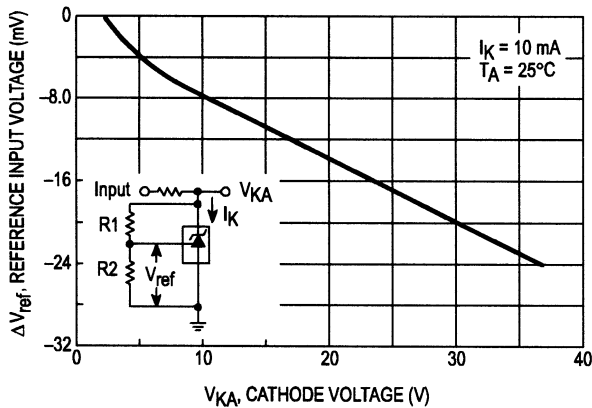


Fig 23. Change in reference input voltage versus Cathode voltage

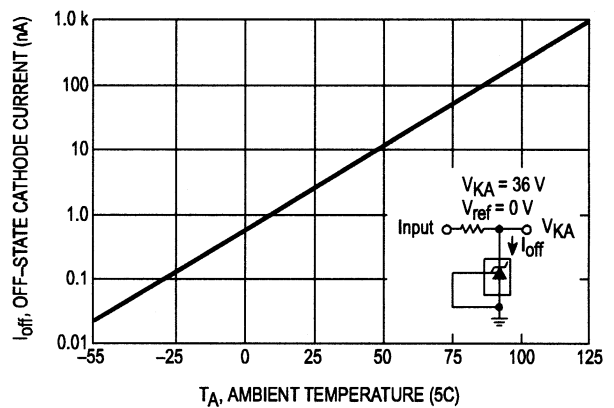


Fig 24. Off state cathode current versus ambient temperature

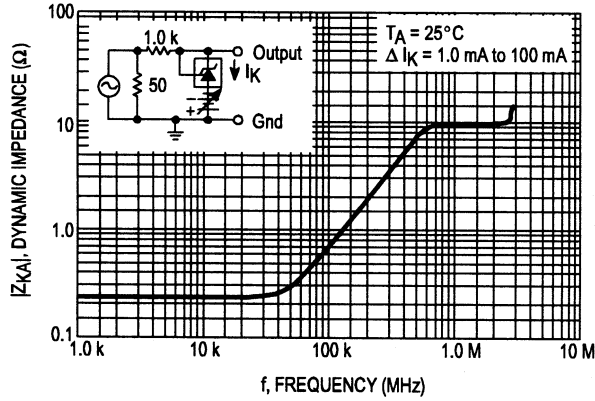


Fig 25. Dynamic impedance versus frequency

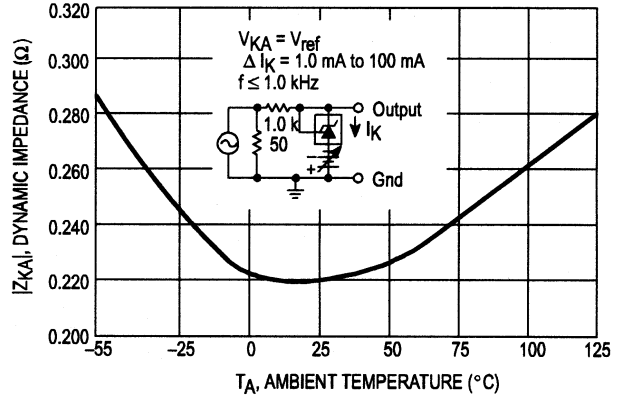


Fig 26. Dynamic impedance versus ambient temperature

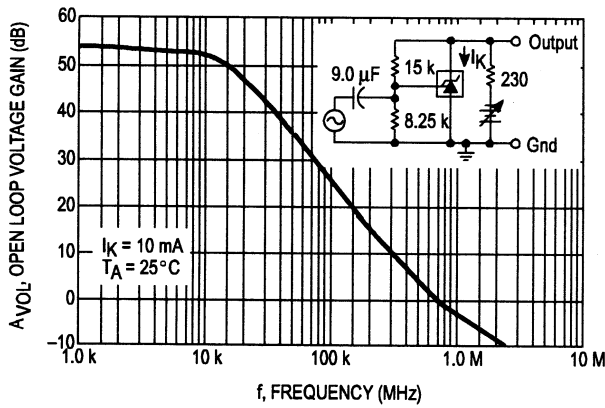


Fig 27. Open loop voltage gain versus frequency

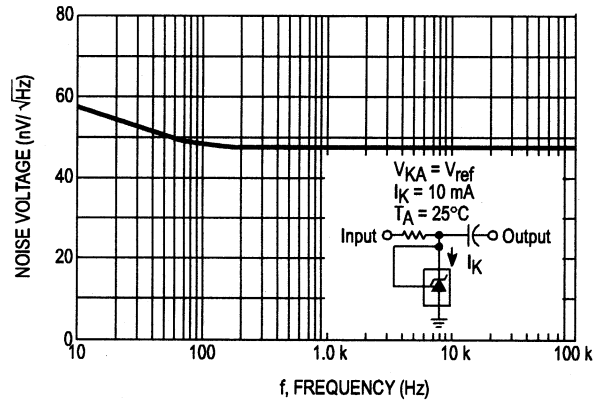


Fig 28. Spectral noise density

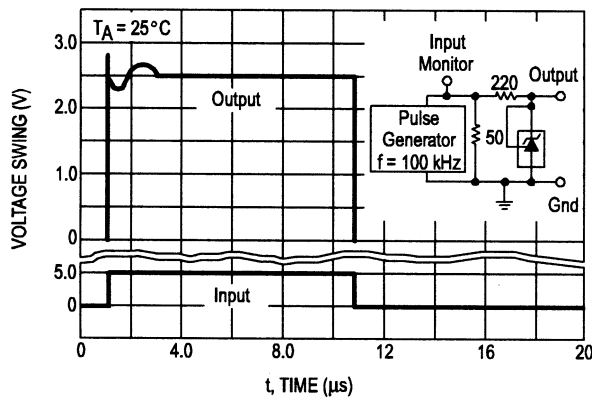


Fig 29. Pulse response

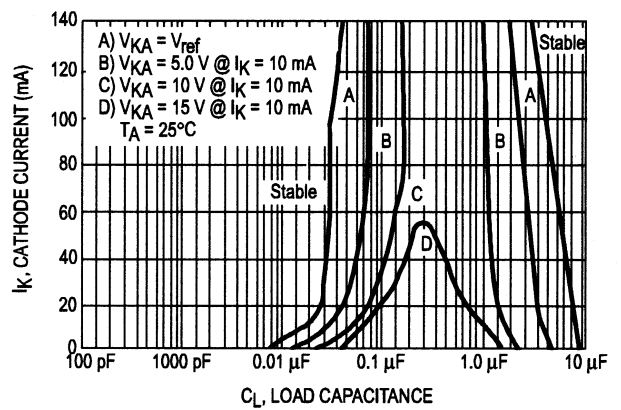


Fig 30. Stability boundary conditions



## ORDER INFORMATION

DEVICE	TEMPERATURE RANGE	PACKAGE
TL431BCT 0.5%	-20~+85°C	TO-92
TL431ACT 1%	-20~+85°C	TO-92
TL431CT 2%	-20~+85°C	TO-92
TL431BCP 0.5%	-20~+85°C	DIP-8
TL431ACP 1%	-20~+85°C	DIP-8
TL431CP 2%	-20~+85°C	DIP-8
TL431BCD 0.5%	-20~+85°C	SOP-8
TL431ACD 1%	-20~+85°C	SOP-8
TL431CD 2%	-20~+85°C	SOP-8
TL431BCLT1 0.5%	-20~+85°C	SOT-23
TL431ACL1 1%	-20~+85°C	SOT-23
TL431CL1 2%	-20~+85°C	SOT-23
TL431BCH 0.5%	-20~+85°C	SOT-89
TL431ACH 1%	-20~+85°C	SOT-89
TL431CH 2%	-20~+85°C	SOT-89



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