

# TL431A, B Series, NCV431A, B Series, SCV431A

## Programmable Precision References

The TL431A, B 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  $V_{ref}$  to 36 V with two external resistors. These devices exhibit a wide operating current range of 1.0 mA to 100 mA with a typical dynamic impedance of 0.22  $\Omega$ . 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 V reference makes it convenient to obtain a stable reference from 5.0 V logic supplies, and since the TL431A, B operates as a shunt regulator, it can be used as either a positive or negative voltage reference.

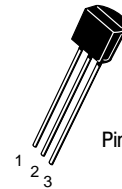
### Features

- Programmable Output Voltage to 36 V
- Voltage Reference Tolerance:  $\pm 0.4\%$ , Typ @ 25°C (TL431B)
- Low Dynamic Output Impedance, 0.22  $\Omega$  Typical
- Sink Current Capability of 1.0 mA to 100 mA
- Equivalent Full-Range Temperature Coefficient of 50 ppm/°C Typical
- Temperature Compensated for Operation over Full Rated Operating Temperature Range
- Low Output Noise Voltage
- NCV/SCV Prefixes for Automotive and Other Applications Requiring Unique Site and Control Change Requirements; AEC-Q100 Qualified and PPAP Capable
- These Devices are Pb-Free, Halogen Free/BFR Free and are RoHS Compliant



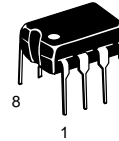
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TO-92 (TO-226)  
LP SUFFIX  
CASE 29

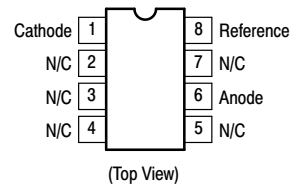
Pin 1. Reference  
2. Anode  
3. Cathode



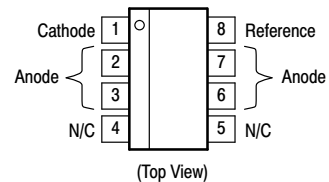
PDIP-8  
P SUFFIX  
CASE 626



Micro8™  
DM SUFFIX  
CASE 846A



SOIC-8  
D SUFFIX  
CASE 751



This is an internally modified SOIC-8 package. Pins 2, 3, 6 and 7 are electrically common to the die attach flag. This internal lead frame modification increases power dissipation capability when appropriately mounted on a printed circuit board. This modified package conforms to all external dimensions of the standard SOIC-8 package.

### ORDERING INFORMATION

See detailed ordering and shipping information on page 13 of this data sheet.

### DEVICE MARKING INFORMATION

See general marking information in the device marking section on page 14 of this data sheet.

# TL431A, B Series, NCV431A, B Series, SCV431A



Figure 1. Symbol

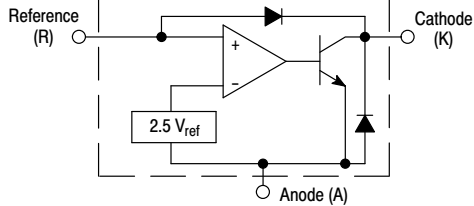


Figure 2. Representative Block Diagram

This device contains 12 active transistors.

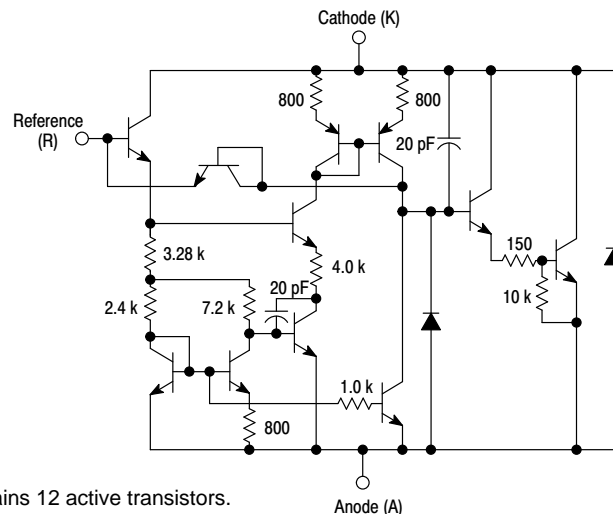


Figure 3. Representative Schematic Diagram

Component values are nominal

## 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	$T_A$		°C
TL431I, TL431AI, TL431BI		-40 to +85	
TL431C, TL431AC, TL431BC		0 to +70	
NCV431AI, NCV431B, TL431BV, SCV431AI		-40 to +125	
Storage Temperature Range	$T_{stg}$	-65 to +150	°C
Total Power Dissipation @ $T_A = 25^\circ\text{C}$	$P_D$		W
Derate above 25°C Ambient Temperature			
D, LP Suffix Plastic Package		0.70	
P Suffix Plastic Package		1.10	
DM Suffix Plastic Package		0.52	
Total Power Dissipation @ $T_C = 25^\circ\text{C}$	$P_D$		W
Derate above 25°C Case Temperature			
D, LP Suffix Plastic Package		1.5	
P Suffix Plastic Package		3.0	
ESD Rating (Note 1)			V
Human Body Model per JEDEC JESD22-A114F	HBM	>2000	
Machine Model per JEDEC JESD22-A115C	MM	>200	
Charged Device Model per JEDEC JESD22-C101E	CDM	>500	

Stresses exceeding those listed in the Maximum Ratings table may damage the device. If any of these limits are exceeded, device functionality should not be assumed, damage may occur and reliability may be affected.

1. This device contains latch-up protection and exceeds  $\pm 100$  mA per JEDEC standard JESD78.

## RECOMMENDED OPERATING CONDITIONS

Condition	Symbol	Min	Max	Unit
Cathode to Anode Voltage	$V_{KA}$	$V_{ref}$	36	V
Cathode Current	$I_K$	1.0	100	mA

Functional operation above the stresses listed in the Recommended Operating Ranges is not implied. Extended exposure to stresses beyond the Recommended Operating Ranges limits may affect device reliability.

# TL431A, B Series, NCV431A, B Series, SCV431A

## THERMAL CHARACTERISTICS

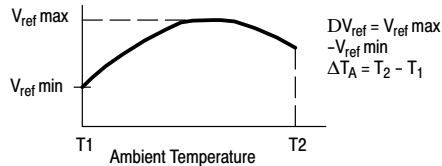
Characteristic	Symbol	D, LP Suffix Package	P Suffix Package	DM Suffix Package	Unit
Thermal Resistance, Junction-to-Ambient	$R_{\theta JA}$	178	114	240	$^{\circ}\text{C}/\text{W}$
Thermal Resistance, Junction-to-Case	$R_{\theta JC}$	83	41	–	$^{\circ}\text{C}/\text{W}$

## ELECTRICAL CHARACTERISTICS ( $T_A = 25^{\circ}\text{C}$ , unless otherwise noted.)

Characteristic	Symbol	TL431I			TL431C			Unit
		Min	Typ	Max	Min	Typ	Max	
Reference Input Voltage (Figure 1) $V_{KA} = V_{ref}$ , $I_K = 10\text{ mA}$ $T_A = 25^{\circ}\text{C}$ $T_A = T_{low}$ to $T_{high}$ (Note 1)	$V_{ref}$	2.44 2.41	2.495 –	2.55 2.58	2.44 2.423	2.495 –	2.55 2.567	V
Reference Input Voltage Deviation Over Temperature Range (Figure 1, Notes 1, 2) $V_{KA} = V_{ref}$ , $I_K = 10\text{ mA}$	$\Delta V_{ref}$	–	7.0	30	–	3.0	17	mV
Ratio of Change in Reference Input Voltage to Change in Cathode to Anode Voltage $I_K = 10\text{ mA}$ (Figure 2), $\Delta V_{KA} = 10\text{ V}$ to $V_{ref}$ $\Delta V_{KA} = 36\text{ V}$ to $10\text{ V}$	$\frac{\Delta V_{ref}}{\Delta V_{KA}}$	– –	–1.4 –1.0	–2.7 –2.0	– –	–1.4 –1.0	–2.7 –2.0	mV/V
Reference Input Current (Figure 2) $I_K = 10\text{ mA}$ , $R_1 = 10\text{ k}$ , $R_2 = \infty$ $T_A = 25^{\circ}\text{C}$ $T_A = T_{low}$ to $T_{high}$ (Note 1)	$I_{ref}$	– –	1.8 –	4.0 6.5	– –	1.8 –	4.0 5.2	$\mu\text{A}$
Reference Input Current Deviation Over Temperature Range (Figure 2, Note 1, 4) $I_K = 10\text{ mA}$ , $R_1 = 10\text{ k}$ , $R_2 = \infty$	$\Delta I_{ref}$	–	0.8	2.5	–	0.4	1.2	$\mu\text{A}$
Minimum Cathode Current For Regulation $V_{KA} = V_{ref}$ (Figure 1)	$I_{min}$	–	0.5	1.0	–	0.5	1.0	mA
Off-State Cathode Current (Figure 3) $V_{KA} = 36\text{ V}$ , $V_{ref} = 0\text{ V}$	$I_{off}$	–	20	1000	–	20	1000	nA
Dynamic Impedance (Figure 1, Note 3) $V_{KA} = V_{ref}$ , $\Delta I_K = 1.0\text{ mA}$ to $100\text{ mA}$ $f \leq 1.0\text{ kHz}$	$ Z_{KA} $	–	0.22	0.5	–	0.22	0.5	$\Omega$

Product parametric performance is indicated in the Electrical Characteristics for the listed test conditions, unless otherwise noted. Product performance may not be indicated by the Electrical Characteristics if operated under different conditions.

- $T_{low} = -40^{\circ}\text{C}$  for TL431AIP, TL431AILP, TL431IP, TL431ILP, TL431BID, TL431BIP, TL431BILP, TL431AIDM, TL431IDM, TL431BIDM;  
 $= 0^{\circ}\text{C}$  for TL431ACP, TL431ACL, TL431CP, TL431CLP, TL431CD, TL431ACD, TL431BCD, TL431BCP, TL431BCLP, TL431CDM, TL431ACDM, TL431BCDM  
 $T_{high} = +85^{\circ}\text{C}$  for TL431AIP, TL431AILP, TL431IP, TL431ILP, TL431BID, TL431BIP, TL431BILP, TL431IDM, TL431AIDM, TL431BIDM  
 $= +70^{\circ}\text{C}$  for TL431ACP, TL431ACL, TL431CP, TL431ACD, TL431BCD, TL431BCP, TL431BCLP, TL431CDM, TL431ACDM, TL431BCDM
- The deviation parameter  $\Delta V_{ref}$  is defined as the difference between the maximum and minimum values obtained over the full operating ambient temperature range that applies.



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

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

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

Example:  $\Delta V_{ref} = 8.0\text{ mV}$  and slope is positive,

$$V_{ref} @ 25^{\circ}\text{C} = 2.495\text{ V}, \Delta T_A = 70^{\circ}\text{C}$$

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

- 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,  $R_1$  and  $R_2$ ,

(refer to Figure 2) the total dynamic impedance of the circuit is defined as:  $|Z_{KA}'| \approx |Z_{KA}| \left( 1 + \frac{R_1}{R_2} \right)$

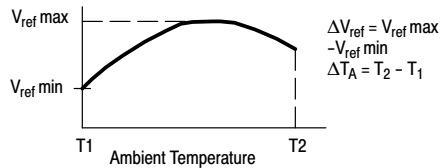
# TL431A, B Series, NCV431A, B Series, SCV431A

## ELECTRICAL CHARACTERISTICS (T<sub>A</sub> = 25°C, unless otherwise noted.)

Characteristic	Symbol	TL431AI / NCV431AI / SCV431AI			TL431AC			TL431BC / TL431BI / TL431BV / NCV431BV			Unit
		Min	Typ	Max	Min	Typ	Max	Min	Typ	Max	
Reference Input Voltage (Figure 1) V <sub>KA</sub> = V <sub>ref</sub> , I <sub>K</sub> = 10 mA T <sub>A</sub> = 25°C T <sub>A</sub> = T <sub>low</sub> to T <sub>high</sub>	V <sub>ref</sub>	2.47 2.44	2.495 –	2.52 2.55	2.47 2.453	2.495 –	2.52 2.537	2.485 2.475	2.495 2.495	2.505 2.515	V
Reference Input Voltage Deviation Over Temperature Range (Figure 1, Notes 5, 6) V <sub>KA</sub> = V <sub>ref</sub> , I <sub>K</sub> = 10 mA	ΔV <sub>ref</sub>	–	7.0	30	–	3.0	17	–	3.0	17	mV
Ratio of Change in Reference Input Voltage to Change in Cathode to Anode Voltage I <sub>K</sub> = 10 mA (Figure 2), ΔV <sub>KA</sub> = 10 V to V <sub>ref</sub> ΔV <sub>KA</sub> = 36 V to 10 V	$\frac{\Delta V_{ref}}{\Delta V_{KA}}$	–	–1.4 –1.0	–2.7 –2.0	–	–1.4 –1.0	–2.7 –2.0	–	–1.4 –1.0	–2.7 –2.0	mV/V
Reference Input Current (Figure 2) I <sub>K</sub> = 10 mA, R1 = 10 k, R2 = ∞ T <sub>A</sub> = 25°C T <sub>A</sub> = T <sub>low</sub> to T <sub>high</sub> (Note 5)	I <sub>ref</sub>	–	1.8 –	4.0 6.5	–	1.8 –	4.0 5.2	–	1.1 –	2.0 4.0	μA
Reference Input Current Deviation Over Temperature Range (Figure 2, Note 5) I <sub>K</sub> = 10 mA, R1 = 10 k, R2 = ∞	ΔI <sub>ref</sub>	–	0.8	2.5	–	0.4	1.2	–	0.8	2.5	μA
Minimum Cathode Current For Regulation V <sub>KA</sub> = V <sub>ref</sub> (Figure 1)	I <sub>min</sub>	–	0.5	1.0	–	0.5	1.0	–	0.5	1.0	mA
Off-State Cathode Current (Figure 3) V <sub>KA</sub> = 36 V, V <sub>ref</sub> = 0 V	I <sub>off</sub>	–	20	1000	–	20	1000	–	0.23	500	nA
Dynamic Impedance (Figure 1, Note 7) V <sub>KA</sub> = V <sub>ref</sub> , ΔI <sub>K</sub> = 1.0 mA to 100 mA f ≤ 1.0 kHz	Z <sub>KA</sub>	–	0.22	0.5	–	0.22	0.5	–	0.14	0.3	Ω

Product parametric performance is indicated in the Electrical Characteristics for the listed test conditions, unless otherwise noted. Product performance may not be indicated by the Electrical Characteristics if operated under different conditions.

- T<sub>low</sub> = –40°C for TL431AIP, TL431AILP, TL431IP, TL431ILP, TL431BID, TL431BIP, TL431BILP, TL431BV, TL431AIDM, TL431IDM, TL431BIDM, NCV431AIDMR2G, NCV431AIDR2G, NCV431BVDR2G, SCV431AIDMR2G  
= 0°C for TL431ACP, TL431ACLPL, TL431CP, TL431CLP, TL431CD, TL431ACD, TL431BCD, TL431BCP, TL431BCLP, TL431CDM, TL431ACDM, TL431BCDM, SCV431AIDMR2G  
T<sub>high</sub> = +85°C for TL431AIP, TL431AILP, TL431IP, TL431ILP, TL431BID, TL431BIP, TL431BILP, TL431IDM, TL431AIDM, TL431BIDM  
= +70°C for TL431ACP, TL431ACLPL, TL431CP, TL431ACD, TL431BCD, TL431BCP, TL431BCLP, TL431CDM, TL431ACDM, TL431BCDM  
= +125°C TL431BV, NCV431AIDMR2G, NCV431AIDR2G, NCV431BVDR2G, NCV431BVDR2G, SCV431AIDMR2G
- The deviation parameter ΔV<sub>ref</sub> is defined as the difference between the maximum and minimum values obtained over the full operating ambient temperature range that applies.



The average temperature coefficient of the reference input voltage, αV<sub>ref</sub> is defined as:

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

αV<sub>ref</sub> can be positive or negative depending on whether V<sub>ref</sub> Min or V<sub>ref</sub> Max occurs at the lower ambient temperature. (Refer to Figure 6.)

Example : ΔV<sub>ref</sub> = 8.0 mV and slope is positive,  
V<sub>ref</sub> @ 25°C = 2.495 V, ΔT<sub>A</sub> = 70°C

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

- The dynamic impedance Z<sub>KA</sub> 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:  $|Z_{KA}'| \approx |Z_{KA}| \left( 1 + \frac{R1}{R2} \right)$
- NCV431AIDMR2G, NCV431AIDR2G, NCV431BVDR2G, NCV431BVDR2G, SCV431AIDMR2G T<sub>low</sub> = –40°C, T<sub>high</sub> = +125°C. Guaranteed by design.  
NCV prefix is for automotive and other applications requiring unique site and control change requirements.

# TL431A, B Series, NCV431A, B Series, SCV431A



Figure 1. Test Circuit for  $V_{KA} = V_{ref}$

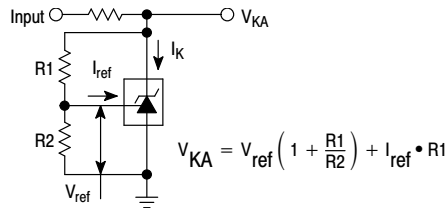


Figure 2. Test Circuit for  $V_{KA} > V_{ref}$



Figure 3. Test Circuit for  $I_{off}$

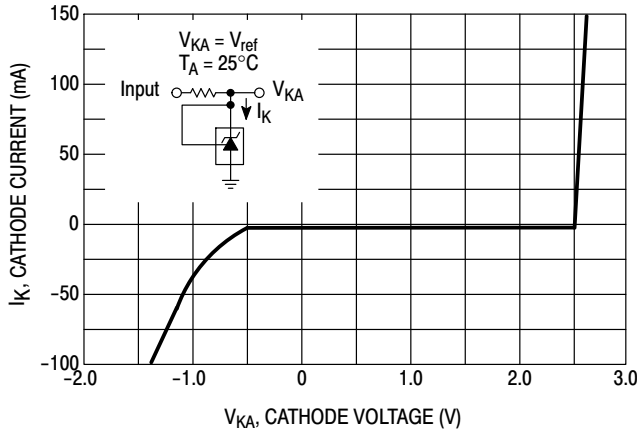


Figure 4. Cathode Current versus Cathode Voltage

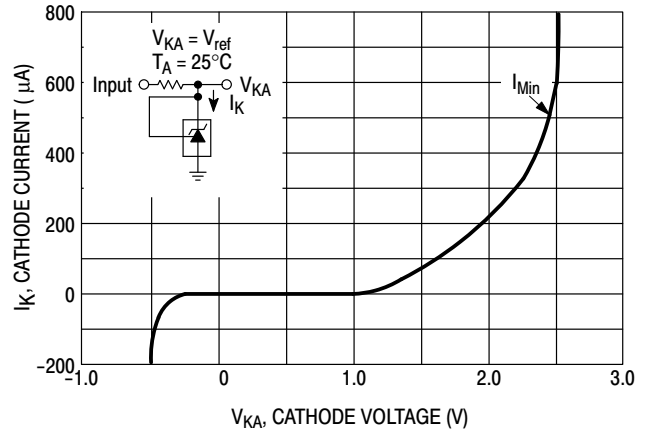


Figure 5. Cathode Current versus Cathode Voltage

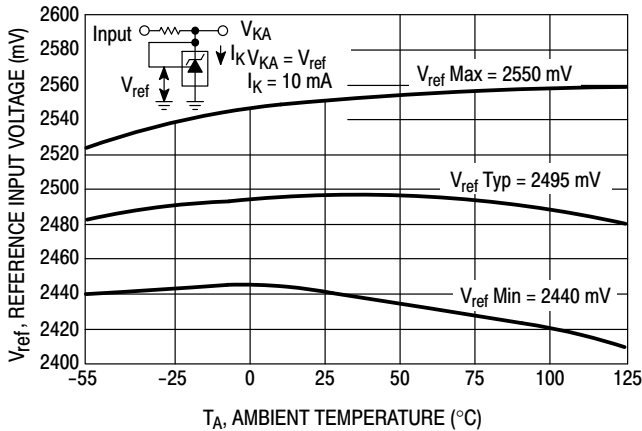


Figure 6. Reference Input Voltage versus Ambient Temperature

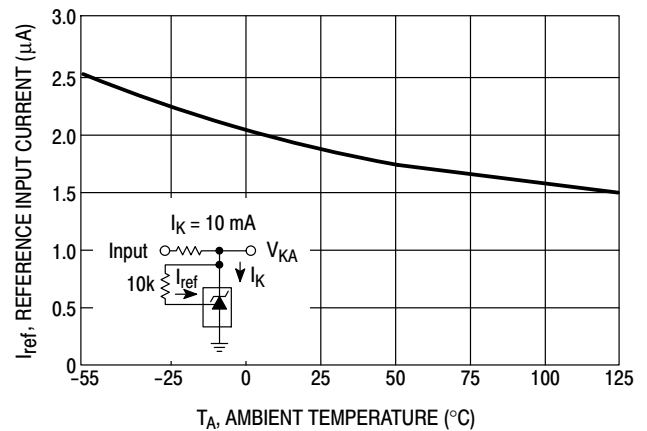
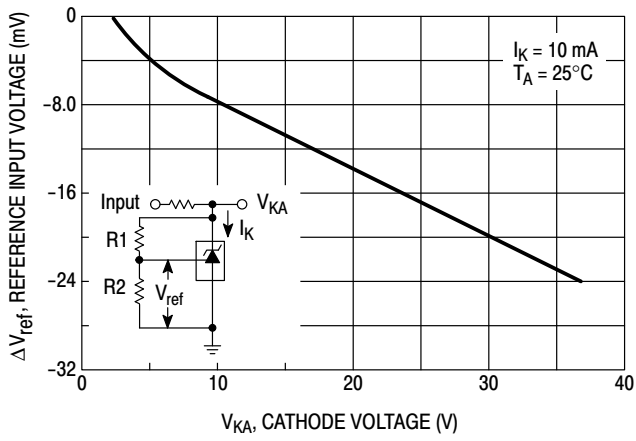


Figure 7. Reference Input Current versus Ambient Temperature

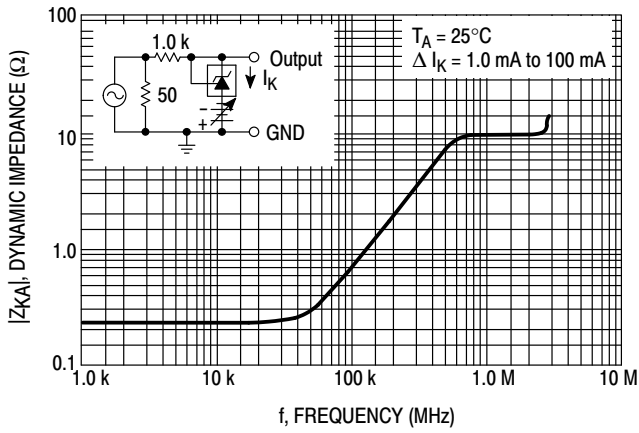
# TL431A, B Series, NCV431A, B Series, SCV431A



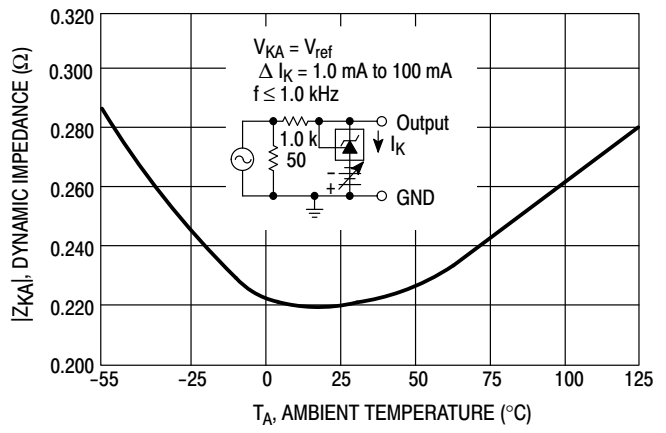
**Figure 8. Change in Reference Input Voltage versus Cathode Voltage**



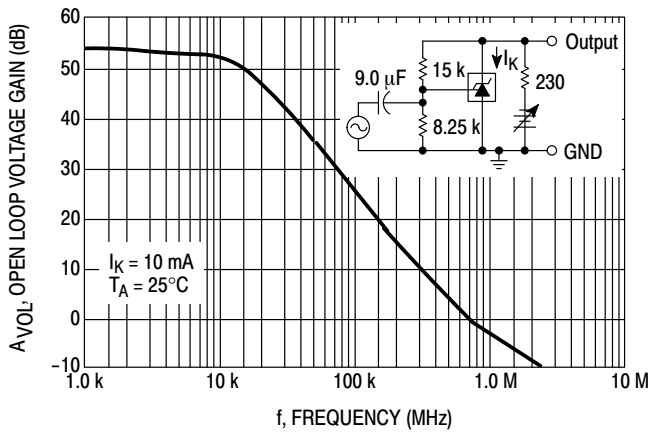
**Figure 9. Off-State Cathode Current versus Ambient Temperature**



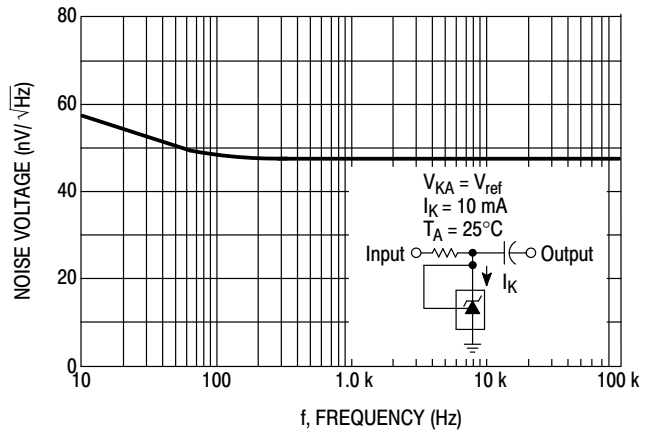
**Figure 10. Dynamic Impedance versus Frequency**



**Figure 11. Dynamic Impedance versus Ambient Temperature**



**Figure 12. Open-Loop Voltage Gain versus Frequency**



**Figure 13. Spectral Noise Density**

# TL431A, B Series, NCV431A, B Series, SCV431A

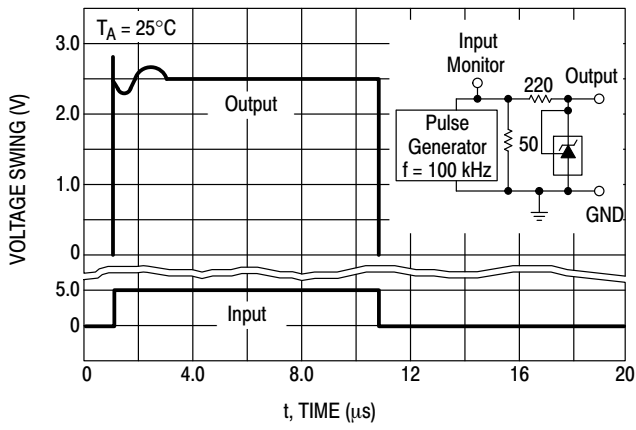


Figure 14. Pulse Response



Figure 15. Stability Boundary Conditions

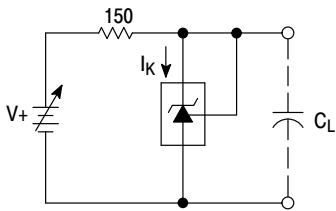


Figure 16. Test Circuit For Curve A of Stability Boundary Conditions

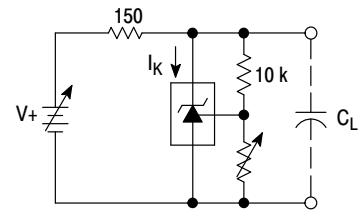


Figure 17. Test Circuit For Curves B, C, and D of Stability Boundary Conditions

## TYPICAL APPLICATIONS

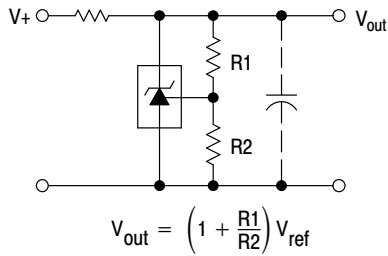


Figure 18. Shunt Regulator

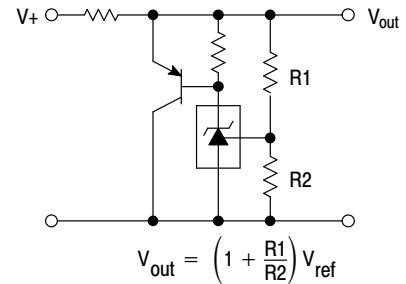


Figure 19. High Current Shunt Regulator

TL431A, B Series, NCV431A, B Series, SCV431A

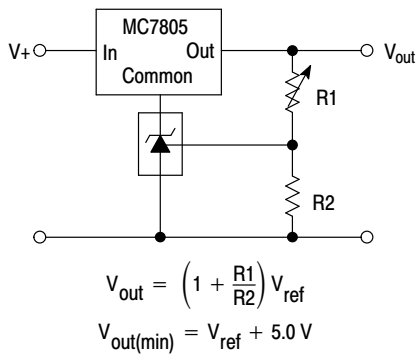


Figure 20. Output Control for a Three-Terminal Fixed Regulator

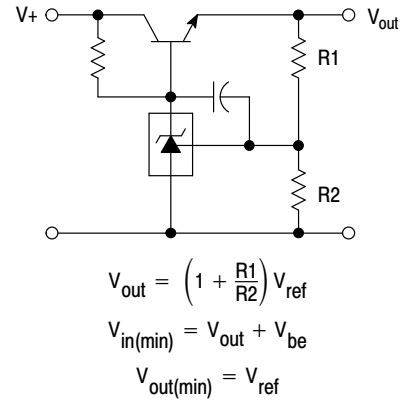


Figure 21. Series Pass Regulator



Figure 22. Constant Current Source

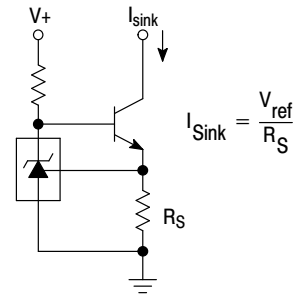


Figure 23. Constant Current Sink

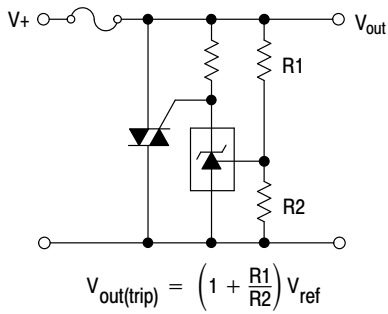


Figure 24. TRIAC Crowbar

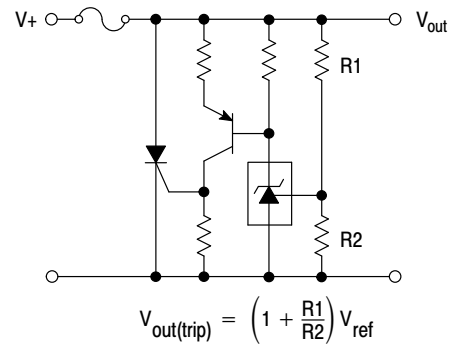


Figure 25. SRC Crowbar



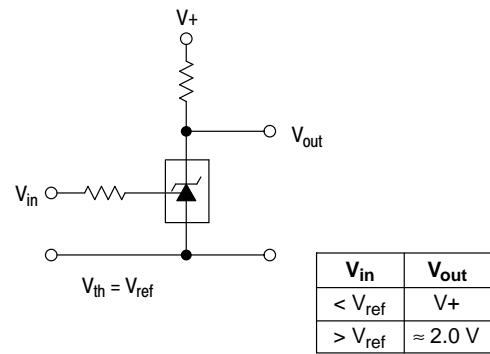
# TL431A, B Series, NCV431A, B Series, SCV431A



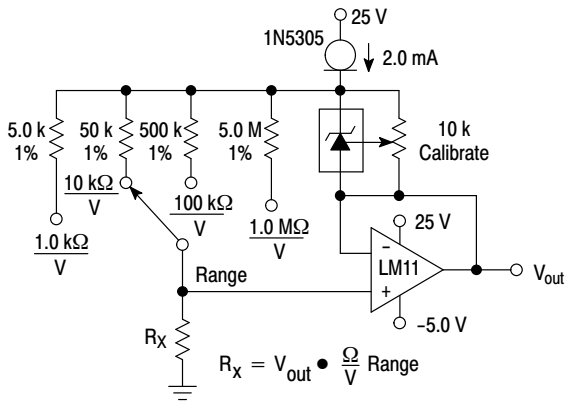
$$\text{Lower Limit} = \left(1 + \frac{R1}{R2}\right) V_{ref}$$

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

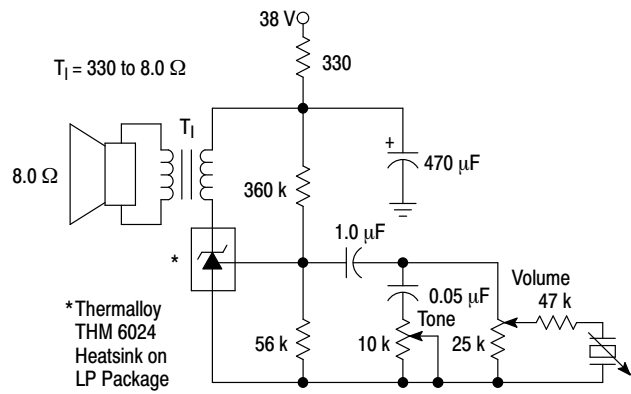
**Figure 26. Voltage Monitor**



**Figure 27. Single-Supply Comparator with Temperature-Compensated Threshold**

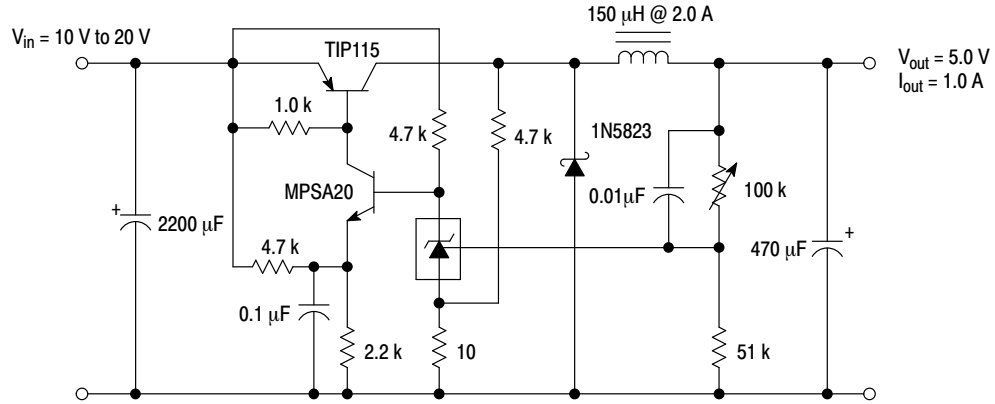


**Figure 28. Linear Ohmmeter**



**Figure 29. Simple 400 mW Phono Amplifier**

## TL431A, B Series, NCV431A, B Series, SCV431A



**Figure 30. High Efficiency Step-Down Switching Converter**

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

APPLICATIONS INFORMATION

The TL431 is a programmable precision reference which is used in a variety of ways. It serves as a reference voltage in circuits where a non-standard reference voltage is needed. Other uses include feedback control for driving an optocoupler in power supplies, voltage monitor, constant current source, constant current sink and series pass regulator. In each of these applications, it is critical to maintain stability of the device at various operating currents and load capacitances. In some cases the circuit designer can estimate the stabilization capacitance from the stability boundary conditions curve provided in Figure 15. However, these typical curves only provide stability information at specific cathode voltages and at a specific load condition. Additional information is needed to determine the capacitance needed to optimize phase margin or allow for process variation.

A simplified model of the TL431 is shown in Figure 31. When tested for stability boundaries, the load resistance is 150 Ω. The model reference input consists of an input transistor and a dc emitter resistance connected to the device anode. A dependent current source, G<sub>m</sub>, develops a current whose amplitude is determined by the difference between the 1.78 V internal reference voltage source and the input transistor emitter voltage. A portion of G<sub>m</sub> flows through compensation capacitance, C<sub>P2</sub>. The voltage across C<sub>P2</sub> drives the output dependent current source, G<sub>o</sub>, which is connected across the device cathode and anode.

Model component values are:

$$V_{ref} = 1.78 \text{ V}$$

$$G_m = 0.3 + 2.7 \exp(-I_C/26 \text{ mA})$$

where I<sub>C</sub> is the device cathode current and G<sub>m</sub> is in mhos

$$G_o = 1.25 (V_{cp2}) \mu\text{mhos.}$$

Resistor and capacitor typical values are shown on the model. Process tolerances are ±20% for resistors, ±10% for capacitors, and ±40% for transconductances.

An examination of the device model reveals the location of circuit poles and zeroes:

$$P1 = \frac{1}{2\pi R_{GM} C_{P1}} = \frac{1}{2\pi * 1.0 \text{ M} * 20 \text{ pF}} = 7.96 \text{ kHz}$$

$$P2 = \frac{1}{2\pi R_{P2} C_{P2}} = \frac{1}{2\pi * 10 \text{ M} * 0.265 \text{ pF}} = 60 \text{ kHz}$$

$$Z1 = \frac{1}{2\pi R_{Z1} C_{P1}} = \frac{1}{2\pi * 15.9 \text{ k} * 20 \text{ pF}} = 500 \text{ kHz}$$

In addition, there is an external circuit pole defined by the load:

$$P_L = \frac{1}{2\pi R_L C_L}$$

Also, the transfer dc voltage gain of the TL431 is:

$$G = G_M R_{GM} G_o R_L$$

Example 1:

I<sub>C</sub> = 10 mA, R<sub>L</sub> = 230 Ω, C<sub>L</sub> = 0. Define the transfer gain.

The DC gain is:

$$G = G_M R_{GM} G_o R_L = (2.138)(1.0 \text{ M})(1.25 \mu)(230) = 615 = 56 \text{ dB}$$

$$\text{Loop gain} = G \frac{8.25 \text{ k}}{8.25 \text{ k} + 15 \text{ k}} = 218 = 47 \text{ dB}$$

The resulting transfer function Bode plot is shown in Figure 32. The asymptotic plot may be expressed as the following equation:

$$A_v = 615 \frac{\left(1 + \frac{jf}{500 \text{ kHz}}\right)}{\left(1 + \frac{jf}{8.0 \text{ kHz}}\right)\left(1 + \frac{jf}{60 \text{ kHz}}\right)}$$

The Bode plot shows a unity gain crossover frequency of approximately 600 kHz. The phase margin, calculated from the equation, would be 55.9 degrees. This model matches the Open-Loop Bode Plot of Figure 12. The total loop would have a unity gain frequency of about 300 kHz with a phase margin of about 44 degrees.

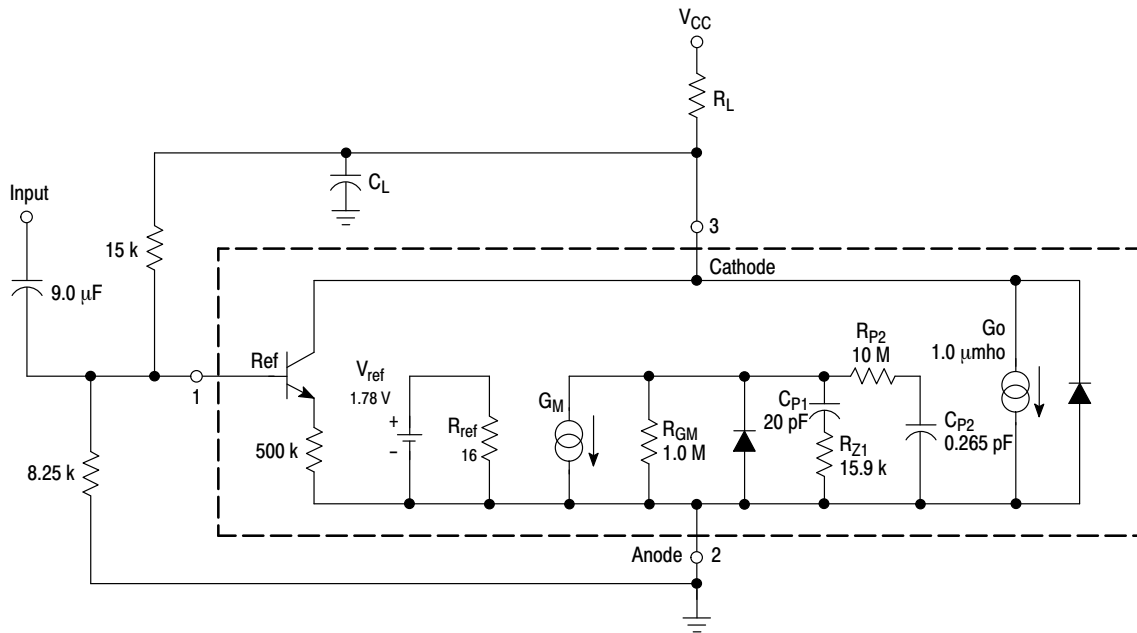


Figure 31. Simplified TL431 Device Model



Figure 32. Example 1 Circuit Open Loop Gain Plot

Example 2.

$I_C = 7.5 \text{ mA}$ ,  $R_L = 2.2 \text{ k}\Omega$ ,  $C_L = 0.01 \text{ }\mu\text{F}$ . Cathode tied to reference input pin. An examination of the data sheet stability boundary curve (Figure 15) shows that this value of load capacitance and cathode current is on the boundary. Define the transfer gain.

The DC gain is:

$$G = G_M R_{GM} G_o R_L =$$

$$(2.323)(1.0 \text{ M})(1.25 \text{ }\mu)(2200) = 6389 = 76 \text{ dB}$$

The resulting open loop Bode plot is shown in Figure 33. The asymptotic plot may be expressed as the following equation:

$$A_v = 615 \frac{\left(1 + \frac{jf}{500 \text{ kHz}}\right)}{\left(1 + \frac{jf}{8.0 \text{ kHz}}\right)\left(1 + \frac{jf}{60 \text{ kHz}}\right)\left(1 + \frac{jf}{7.2 \text{ kHz}}\right)}$$

Note that the transfer function now has an extra pole formed by the load capacitance and load resistance.

Note that the crossover frequency in this case is about 250 kHz, having a phase margin of about  $-46$  degrees. Therefore, instability of this circuit is likely.

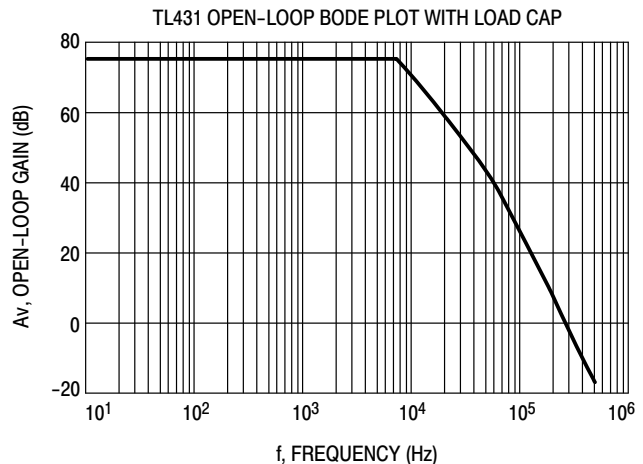


Figure 33. Example 2 Circuit Open Loop Gain Plot

With three poles, this system is unstable. The only hope for stabilizing this circuit is to add a zero. However, that can only be done by adding a series resistance to the output capacitance, which will reduce its effectiveness as a noise filter. Therefore, practically, in reference voltage applications, the best solution appears to be to use a smaller value of capacitance in low noise applications or a very large value to provide noise filtering and a dominant pole rolloff of the system.

# TL431A, B Series, NCV431A, B Series, SCV431A

## ORDERING INFORMATION

Device	Marking Code	Operating Temperature Range	Package Code	Shipping Information†	Tolerance		
TL431ACDG	AC	0°C to 70°C	SOIC-8 (Pb-Free)	98 Units / Rail	1.0%		
TL431BCDG	BC				2500 / Tape & Reel	0.4%	
TL431CDG	C					2.2%	
TL431ACDR2G	AC			4000 / Tape & Reel		1.0%	
TL431BCDR2G	BC				0.4%		
TL431CDR2G	C				2.2%		
TL431ACDMR2G	TAC		Micro8 (Pb-Free)	4000 / Tape & Reel	1.0%		
TL431BCDMR2G	TBC				0.4%		
TL431CDMR2G	T-C				2.2%		
TL431ACPG	ACP		PDIP-8 (Pb-Free)	50 Units / Rail	1.0%		
TL431BCPG	BCP				0.4%		
TL431CPG	CP				2.2%		
TL431ACLPG	ACLPG		TO-92 (Pb-Free)	2000 Units / Bag	1.0%		
TL431BCLPG	BCLPG				0.4%		
TL431CLPG	CLPG				2.2%		
TL431ACLPRAG	ACLPRAG			2000 / Tape & Reel	1.0%		
TL431BCLPRAG	BCLPRAG				0.4%		
TL431CLPRAG	CLPRAG				2.2%		
TL431ACLPRAG	ACLPRAG			2000 / Tape & Reel	1.0%		
TL431BCLPRAG	BCLPRAG				0.4%		
TL431CLPRAG	CLPRAG				2.2%		
TL431ACLPRAG	ACLPRAG			2000 / Tape & Ammo Box	1.0%		
TL431BCLPRAG	BCLPRAG				0.4%		
TL431CLPRAG	CLPRAG				2.2%		
TL431ACLPRPG	ACLPRPG	TO-92 (Pb-Free)	2000 / Fan-Fold	1.0%			
TL431BCLPRPG	BCLPRPG			0.4%			
TL431CLPRPG	CLPRPG			2.2%			
TL431AIDG	AI		-40°C to 85°C	SOIC-8 (Pb-Free)	98 Units / Rail	1.0%	
TL431BIDG	BI					2500s / Tape & Reel	0.4%
TL431IDG	I						2.2%
TL431AIDR2G	AI				4000 / Tape & Reel		1.0%
TL431BIDR2G	BI					0.4%	
TL431IDR2G	I					2.2%	
TL431AIDMR2G	TAI			Micro8 (Pb-Free)	4000 / Tape & Reel	1.0%	
TL431BIDMR2G	TBI					0.4%	
TL431IDMR2G	T-I					2.2%	
TL431AIPG	AIP	PDIP-8 (Pb-Free)		50 Units / Rail	1.0%		
TL431BIPG	BIP				0.4%		
TL431IPG	IP				2.2%		
TL431AILPG	AILPG	TO-92 (Pb-Free)		2000 Units / Bag	1.0%		
TL431BILPG	BILPG				0.4%		
TL431ILPG	ILPG				2.2%		
TL431AILPRAG	AILPRAG			2000 / Tape & Reel	1.0%		
TL431BILPRAG	BILPRAG				0.4%		
SC431ILPRAG	ILPRAG				2.2%		
TL431ILPRAG	ILPRAG			2000 / Tape & Reel	1.0%		
TL431AILPRMG	AILP				2000 / Tape & Ammo Box	0.4%	
TL431AILPRPG						1.0%	
TL431ILPRPG	ILP			2.2%			

†For information on tape and reel specifications, including part orientation and tape sizes, please refer to our Tape and Reel Packaging Specifications Brochure, BRD8011/D.

\*NCV/SCV Prefixes for Automotive and Other Applications Requiring Unique Site and Control Change Requirements; AEC-Q100 Qualified and PPAP Capable.

# TL431A, B Series, NCV431A, B Series, SCV431A

## ORDERING INFORMATION

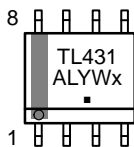
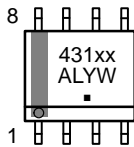
Device	Marking Code	Operating Temperature Range	Package Code	Shipping Information†	Tolerance
TL431BVDBG	BV	-40°C to 125°C	SOIC-8 (Pb-Free)	98 Units / Rail	0.4%
TL431BVDR2G				2500 / Tape & Reel	
TL431BVDMR2G	TBV		Micro8 (Pb-Free)	4000 / Tape & Reel	
TL431BVLPG	BVLP		TO-92 (Pb-Free)	2000 Units / Bag	
TL431BVLPRAG			2000 / Tape & Reel		
TL431BVPG	BVP		PDIP-8 (Pb-Free)	50 Units / Rail	
NCV431AIDMR2G*	RAN		Micro8 (Pb-Free)	4000 / Tape & Reel	1%
SCV431AIDMR2G*	RAP		SOIC-8 (Pb-Free)	2500 / Tape & Reel	
NCV431AIDR2G*	AV		SOIC-8 (Pb-Free)	2500 / Tape & Reel	
NCV431BVDMR2G*	NVB		Micro8 (Pb-Free)	4000 / Tape & Reel	0.4%
NCV431BVDR2G*	BV		SOIC-8 (Pb-Free)	2500 / Tape & Reel	

†For information on tape and reel specifications, including part orientation and tape sizes, please refer to our Tape and Reel Packaging Specifications Brochure, BRD8011/D.

\*NCV/SCV Prefixes for Automotive and Other Applications Requiring Unique Site and Control Change Requirements; AEC-Q100 Qualified and PPAP Capable.

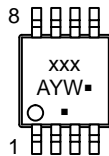
## MARKING DIAGRAMS

**SOIC-8  
D SUFFIX  
CASE 751**

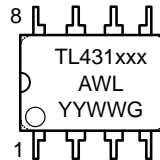


(Exception for the TL431CD and TL431ID only)

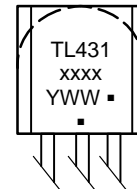
**Micro8  
CASE 846A**



**PDIP-8  
CASE 626**



**TO-92 (TO-226)  
CASE 29**

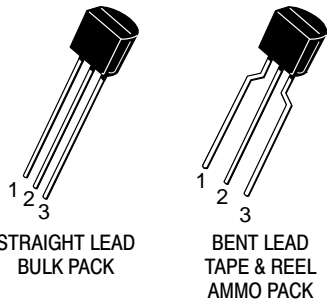


xxxx = See Specific Marking Code  
 A = Assembly Location  
 Y, YY = Year  
 WW, W = Work Week  
 ■ or G = Pb-Free Package

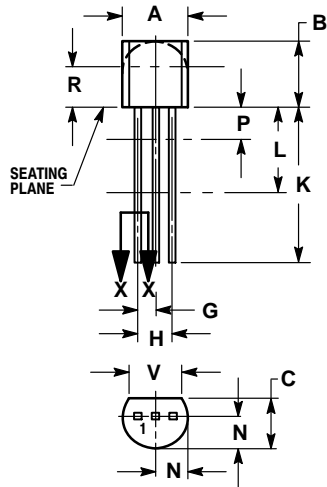
(Note: Microdot may be in either location)

# TL431A, B Series, NCV431A, B Series, SCV431A

## PACKAGE DIMENSIONS



TO-92 (TO-226)  
CASE 29-11  
ISSUE AM

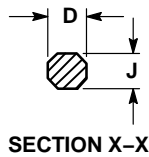


STRAIGHT LEAD  
BULK PACK

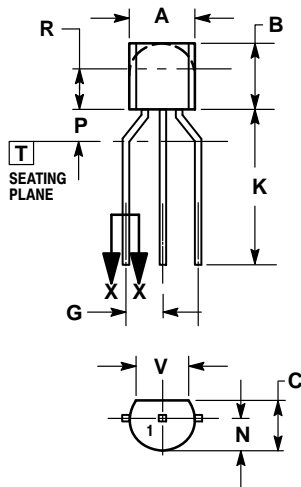
NOTES:

1. DIMENSIONING AND TOLERANCING PER ANSI Y14.5M, 1982.
2. CONTROLLING DIMENSION: INCH.
3. CONTOUR OF PACKAGE BEYOND DIMENSION R IS UNCONTROLLED.
4. LEAD DIMENSION IS UNCONTROLLED IN P AND BEYOND DIMENSION K MINIMUM.

DIM	INCHES		MILLIMETERS	
	MIN	MAX	MIN	MAX
A	0.175	0.205	4.45	5.20
B	0.170	0.210	4.32	5.33
C	0.125	0.165	3.18	4.19
D	0.016	0.021	0.407	0.533
G	0.045	0.055	1.15	1.39
H	0.095	0.105	2.42	2.66
J	0.015	0.020	0.39	0.50
K	0.500	---	12.70	---
L	0.250	---	6.35	---
N	0.080	0.105	2.04	2.66
P	---	0.100	---	2.54
R	0.115	---	2.93	---
V	0.135	---	3.43	---



SECTION X-X

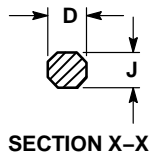


BENT LEAD  
TAPE & REEL  
AMMO PACK

NOTES:

1. DIMENSIONING AND TOLERANCING PER ASME Y14.5M, 1994.
2. CONTROLLING DIMENSION: MILLIMETERS.
3. CONTOUR OF PACKAGE BEYOND DIMENSION R IS UNCONTROLLED.
4. LEAD DIMENSION IS UNCONTROLLED IN P AND BEYOND DIMENSION K MINIMUM.

DIM	MILLIMETERS	
	MIN	MAX
A	4.45	5.20
B	4.32	5.33
C	3.18	4.19
D	0.40	0.54
G	2.40	2.80
J	0.39	0.50
K	12.70	---
N	2.04	2.66
P	1.50	4.00
R	2.93	---
V	3.43	---

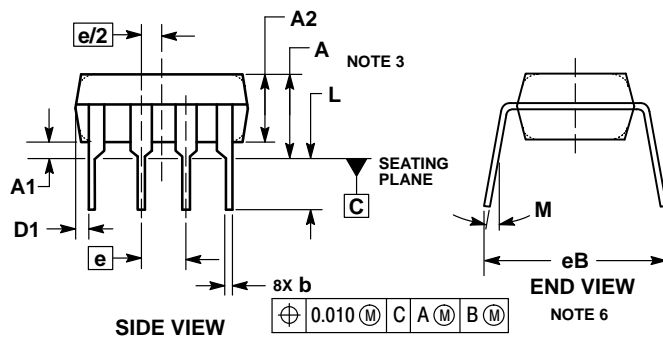
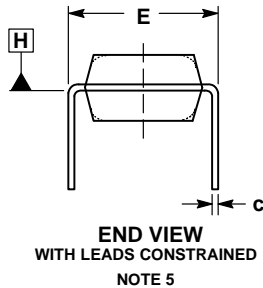
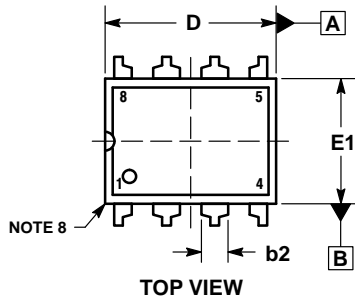


SECTION X-X

# TL431A, B Series, NCV431A, B Series, SCV431A

## PACKAGE DIMENSIONS

PDIP-8  
CASE 626-05  
ISSUE N



**NOTES:**

1. DIMENSIONING AND TOLERANCING PER ASME Y14.5M, 1994.
2. CONTROLLING DIMENSION: INCHES.
3. DIMENSIONS A, A1 AND L ARE MEASURED WITH THE PACKAGE SEATED IN JEDEC SEATING PLANE GAUGE GS-3.
4. DIMENSIONS D, D1 AND E1 DO NOT INCLUDE MOLD FLASH OR PROTRUSIONS. MOLD FLASH OR PROTRUSIONS ARE NOT TO EXCEED 0.10 INCH.
5. DIMENSION E IS MEASURED AT A POINT 0.015 BELOW DATUM PLANE H WITH THE LEADS CONSTRAINED PERPENDICULAR TO DATUM C.
6. DIMENSION E3 IS MEASURED AT THE LEAD TIPS WITH THE LEADS UNCONSTRAINED.
7. DATUM PLANE H IS COINCIDENT WITH THE BOTTOM OF THE LEADS, WHERE THE LEADS EXIT THE BODY.
8. PACKAGE CONTOUR IS OPTIONAL (ROUNDED OR SQUARE CORNERS).

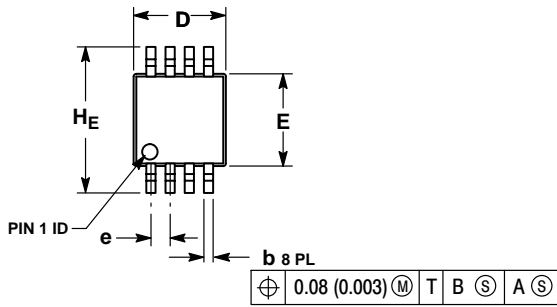
DIM	INCHES		MILLIMETERS	
	MIN	MAX	MIN	MAX
A	---	0.210	---	5.33
A1	0.015	---	0.38	---
A2	0.115	0.195	2.92	4.95
b	0.014	0.022	0.35	0.56
b2	0.060 TYP		1.52 TYP	
C	0.008	0.014	0.20	0.36
D	0.355	0.400	9.02	10.16
D1	0.005	---	0.13	---
E	0.300	0.325	7.62	8.26
E1	0.240	0.280	6.10	7.11
e	0.100 BSC		2.54 BSC	
eB	---	0.430	---	10.92
L	0.115	0.150	2.92	3.81
M	---	10°	---	10°



# TL431A, B Series, NCV431A, B Series, SCV431A

## PACKAGE DIMENSIONS

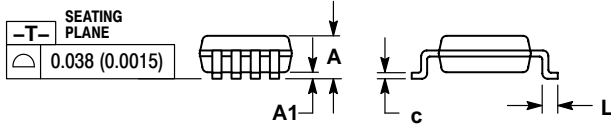
Micro8™  
CASE 846A-02  
ISSUE J



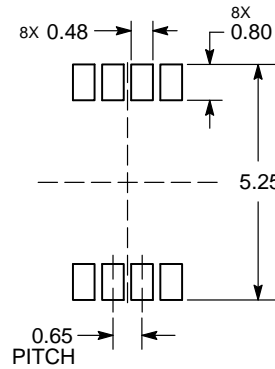
NOTES:

1. DIMENSIONING AND TOLERANCING PER ANSI Y14.5M, 1982.
2. CONTROLLING DIMENSION: MILLIMETER.
3. DIMENSION A DOES NOT INCLUDE MOLD FLASH, PROTRUSIONS OR GATE BURRS. MOLD FLASH, PROTRUSIONS OR GATE BURRS SHALL NOT EXCEED 0.15 (0.006) PER SIDE.
4. DIMENSION B DOES NOT INCLUDE INTERLEAD FLASH OR PROTRUSION. INTERLEAD FLASH OR PROTRUSION SHALL NOT EXCEED 0.25 (0.010) PER SIDE.
5. 846A-01 OBSOLETE, NEW STANDARD 846A-02.

DIM	MILLIMETERS			INCHES		
	MIN	NOM	MAX	MIN	NOM	MAX
A	---	---	1.10	---	---	0.043
A1	0.05	0.08	0.15	0.002	0.003	0.006
b	0.25	0.33	0.40	0.010	0.013	0.016
c	0.13	0.18	0.23	0.005	0.007	0.009
D	2.90	3.00	3.10	0.114	0.118	0.122
E	2.90	3.00	3.10	0.114	0.118	0.122
e	0.65 BSC			0.026 BSC		
L	0.40	0.55	0.70	0.016	0.021	0.028
HE	4.75	4.90	5.05	0.187	0.193	0.199



### RECOMMENDED SOLDERING FOOTPRINT\*



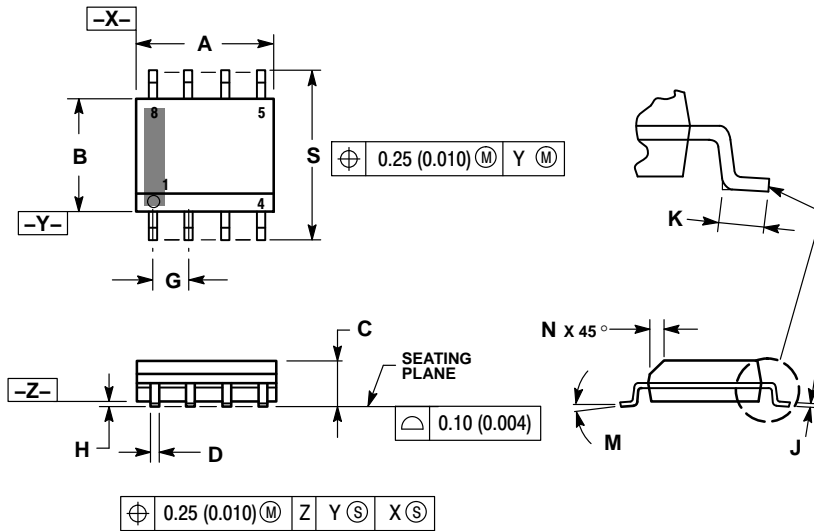
DIMENSION: MILLIMETERS

\*For additional information on our Pb-Free strategy and soldering details, please download the ON Semiconductor Soldering and Mounting Techniques Reference Manual, SOLDERRM/D.

# TL431A, B Series, NCV431A, B Series, SCV431A

## PACKAGE DIMENSIONS

### SOIC-8 D SUFFIX CASE 751-07 ISSUE AK

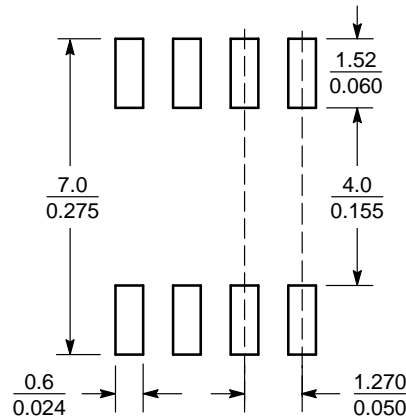


#### NOTES:

1. DIMENSIONING AND TOLERANCING PER ANSI Y14.5M, 1982.
2. CONTROLLING DIMENSION: MILLIMETER.
3. DIMENSION A AND B DO NOT INCLUDE MOLD PROTRUSION.
4. MAXIMUM MOLD PROTRUSION 0.15 (0.006) PER SIDE.
5. DIMENSION D DOES NOT INCLUDE DAMBAR PROTRUSION. ALLOWABLE DAMBAR PROTRUSION SHALL BE 0.127 (0.005) TOTAL IN EXCESS OF THE D DIMENSION AT MAXIMUM MATERIAL CONDITION.
6. 751-01 THRU 751-06 ARE OBSOLETE. NEW STANDARD IS 751-07.

DIM	MILLIMETERS		INCHES	
	MIN	MAX	MIN	MAX
A	4.80	5.00	0.189	0.197
B	3.80	4.00	0.150	0.157
C	1.35	1.75	0.053	0.069
D	0.33	0.51	0.013	0.020
G	1.27 BSC		0.050 BSC	
H	0.10	0.25	0.004	0.010
J	0.19	0.25	0.007	0.010
K	0.40	1.27	0.016	0.050
M	0°	8°	0°	8°
N	0.25	0.50	0.010	0.020
S	5.80	6.20	0.228	0.244

### SOLDERING FOOTPRINT\*



SCALE 6:1 (mm/inches)

\*For additional information on our Pb-Free strategy and soldering details, please download the ON Semiconductor Soldering and Mounting Techniques Reference Manual, SOLDERRM/D.

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