FEATUERS
- Trimmed 1% Bandgap Reference
- Nominal Temperature Range Extended to 105°C
- Temperature-Compensated: 30ppm/°C
- Internal Amplifier with 150mA Capability
- Low Output Noise
- Low Frequency Dynamic Output Impedance

DESCRIPTION
The TL431 is an adjustable shunt regulator designed to act as an open-loop error amplifier with a 2.5V temperature compensated reference. Its highly accurate 1% bandgap reference is perfect for applications requiring stability and accuracy over temperature and life.

Sharp turn-on characteristics and a low temperature coefficient make the TL431 an excellent replacement for many zener diode applications, programmable to any value greater than 2.5V and up to 36V by using two external resistors. As a combination error amplifier and reference, it can be used to manage control loops such as switching power supplies.

ORDERING INFORMATION

<table>
<thead>
<tr>
<th>Part</th>
<th>Package</th>
<th>Temperature Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>TL431LP</td>
<td>TO-92</td>
<td>0 to 105°C</td>
</tr>
<tr>
<td>TL431D</td>
<td>8-Pin Plastic SOIC</td>
<td>0 to 105°C</td>
</tr>
<tr>
<td>TL431S</td>
<td>SOT-89</td>
<td>0 to 105°C</td>
</tr>
</tbody>
</table>

PIN CONFIGURATION (Top View)
# TL431

## Absolute Maximum Ratings

<table>
<thead>
<tr>
<th>SYMBOL</th>
<th>PARAMETER</th>
<th>RATING</th>
<th>UNITS</th>
</tr>
</thead>
<tbody>
<tr>
<td>$V_{KA}$</td>
<td>Cathode-Anode Reverse Breakdown</td>
<td>37</td>
<td>V</td>
</tr>
<tr>
<td>$I_{AK}$</td>
<td>Anode-Cathode Forward Current</td>
<td>1</td>
<td>A</td>
</tr>
<tr>
<td>$I_{KA}$</td>
<td>Operating Cathode Current</td>
<td>250</td>
<td>mA</td>
</tr>
<tr>
<td>$I_{REF}$</td>
<td>Reference Input Current</td>
<td>10</td>
<td>mA</td>
</tr>
<tr>
<td>$P_{D}$</td>
<td>Continuous Power at 25°C</td>
<td>775</td>
<td>mW</td>
</tr>
<tr>
<td></td>
<td>TO-92</td>
<td>750</td>
<td>mW</td>
</tr>
<tr>
<td></td>
<td>8L SOIC</td>
<td>1000</td>
<td>mW</td>
</tr>
<tr>
<td>$T_{J}$</td>
<td>Junction Temperature</td>
<td>150</td>
<td>°C</td>
</tr>
<tr>
<td>$T_{STG}$</td>
<td>Storage Temperature</td>
<td>–65 to 150</td>
<td>°C</td>
</tr>
<tr>
<td>$T_{L}$</td>
<td>Lead Temperature, Soldering 10 Seconds</td>
<td>300</td>
<td>°C</td>
</tr>
</tbody>
</table>

Stresses greater than those listed under ABSOLUTE MAXIMUM RATINGS may cause permanent damage to the device. This is a stress rating only and functional operation of the device at these or any other conditions above those indicated in the operational sections of this specification is not implied. Exposure to absolute maximum rating conditions for extended periods may affect reliability.

## Recommended Conditions

<table>
<thead>
<tr>
<th>SYMBOL</th>
<th>PARAMETER</th>
<th>RATING</th>
<th>UNIT</th>
</tr>
</thead>
<tbody>
<tr>
<td>$V_{KA}$</td>
<td>Cathode Voltage</td>
<td>V$_{REF}$ to 20</td>
<td>V</td>
</tr>
<tr>
<td>$I_{K}$</td>
<td>Cathode Current</td>
<td>10</td>
<td>mA</td>
</tr>
</tbody>
</table>

## Typical Thermal Resistance

<table>
<thead>
<tr>
<th>PACKAGE</th>
<th>$\theta_{JA}$</th>
<th>$\theta_{JC}$</th>
<th>TYPICAL DERATING</th>
</tr>
</thead>
<tbody>
<tr>
<td>TO-92</td>
<td>160°C/W</td>
<td>80°C/W</td>
<td>6.3mW/°C</td>
</tr>
<tr>
<td>SOIC</td>
<td>175°C/W</td>
<td>45°C/W</td>
<td>5.7mW/°C</td>
</tr>
<tr>
<td>SOT-89</td>
<td>110°C/W</td>
<td>8°C/W</td>
<td>9.1mW/°C</td>
</tr>
</tbody>
</table>

## Functional Block Diagram

![Functional Block Diagram](image-url)
ELECTRICAL CHARACTERISTICS

Electrical Characteristics are guaranteed over full junction temperature range (0 to 105°C). Ambient temperature must be derated based on power dissipation and package thermal characteristics. The conditions are: $V_{KA} = V_{REF}$ and $I_K = 10mA$ unless otherwise stated.

<table>
<thead>
<tr>
<th>SYMBOL</th>
<th>PARAMETER</th>
<th>MIN</th>
<th>TYP</th>
<th>MAX</th>
<th>UNIT</th>
<th>TEST CIRCUIT</th>
<th>TEST CONDITION</th>
</tr>
</thead>
<tbody>
<tr>
<td>$V_{REF}$</td>
<td>Reference Voltage</td>
<td>2.470</td>
<td>2.495</td>
<td>2.520</td>
<td>V</td>
<td>1</td>
<td>$T_A = 25°C$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2.449</td>
<td>2.541</td>
<td>V</td>
<td>1</td>
<td>Over Temp.</td>
<td></td>
</tr>
<tr>
<td>TC</td>
<td>$\Delta V_{REF}$ with Temp.*</td>
<td>0.07</td>
<td>0.20</td>
<td>mV/°C</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\Delta V_{REF}$</td>
<td>Ratio of Change in $V_{REF}$ to Cathode Voltage</td>
<td>-2.7</td>
<td>-1.0</td>
<td>mV/V</td>
<td>2</td>
<td>$V_{REF}$ to 10V</td>
<td></td>
</tr>
<tr>
<td></td>
<td>$\Delta I_{REF}$</td>
<td>-0.4</td>
<td>0.3</td>
<td>10V to 36V</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I_{REF}</td>
<td>Reference Input Current</td>
<td>0.7</td>
<td>4</td>
<td>µA</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\Delta I_{REF}$</td>
<td>$I_{REF}$ Temp Deviation</td>
<td>0.4</td>
<td>1.2</td>
<td>µA</td>
<td>2</td>
<td>Over Temp.</td>
<td></td>
</tr>
<tr>
<td>I_{(MIN)}</td>
<td>Min $I_K$ for Regulation</td>
<td>0.4</td>
<td>1</td>
<td>mA</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>I_{(OFF)}</td>
<td>Off State Leakage</td>
<td>0.04</td>
<td>250</td>
<td>nA</td>
<td>3</td>
<td>$V_{REF} = 0V, V_{KA} = 36V$</td>
<td></td>
</tr>
<tr>
<td>Z{KA}</td>
<td>Dynamic Output Impedance</td>
<td>0.15</td>
<td>0.5</td>
<td>Ω</td>
<td>1</td>
<td>$f \leq 1kHz, I_K = 1$ to 150mA</td>
<td></td>
</tr>
</tbody>
</table>

*CALCULATING AVERAGE TEMPERATURE COEFFICIENT (TC)*

- TC in mV/°C = $\frac{\Delta V_{REF} \text{ (mV)}}{\Delta T_A}$
- TC in %/°C = $\frac{\Delta V_{REF} \text{ at } 25°C}{\Delta T_A} \times 100$
- TC in ppm/°C = $\frac{\Delta V_{REF} \text{ at } 25°C}{\Delta T_A} \times 10^6$

**TEST CIRCUITS**

- **TEST CIRCUIT 1**
- **TEST CIRCUIT 2**
- **TEST CIRCUIT 3**
**TYPICAL PERFORMANCE CURVES**

**LOW CURRENT OPERATING CHARACTERISTICS**

- \( V_{KA} = V_{REF} \) (TEMPERATURE RANGE: –55 to 125°C)
- \( I_{K} \) - CATHODE CURRENT (µA) vs. \( V_{KA} \) - CATHODE VOLTAGE (V)

**OFF STATE LEAKAGE**

- \( V_{KA} = 36V \)
- \( V_{REF} = 0V \)
- \( I_{z_{off}} \) - OFF STATE CATHODE CURRENT (nA) vs. \( T_{A} \) - AMBIENT TEMPERATURE (˚C)

**HIGH CURRENT OPERATING CHARACTERISTICS**

- \( V_{KA} = V_{REF} \) (TEMPERATURE RANGE: –55 to 125°C)
- \( I_{K} \) - CATHODE CURRENT (mA) vs. \( V_{KA} \) - CATHODE VOLTAGE (V)

**TEMPERATURE COEFFICIENT AS A FUNCTION OF TRIM VALUE**

- \( V_{KA} = V_{REF} \)
- \( I_{K} = 10mA \)
- \( V_{REF} = 2.503V \) AT 25°C

**REFERENCE INPUT CURRENT**

- \( R1 = 10kΩ \)
- \( R2 = \infty \)
- \( I_{K} = 10mA \)
- \( I_{REF} \) - REFERENCE INPUT CURRENT (µA) vs. \( T_{A} \) - AMBIENT TEMPERATURE (˚C)

**REFERENCE VOLTAGE LINE REGULATION**

- \( V_{KA} \) - CATHODE VOLTAGE (V) vs. \( V_{REF} \) - CHANGE IN REFERENCE VOLTAGE (mV)

**REFERENCE VOLTAGE LINE REGULATION**

- \( V_{KA} = V_{REF} \) (TEMPERATURE RANGE: –55 to 125°C)
- \( I_{K} = 10mA \)
- \( V_{REF} \) - CHANGE IN REFERENCE VOLTAGE (mV) vs. \( T_{A} \) - AMBIENT TEMPERATURE (˚C)
TYPICAL PERFORMANCE CURVES (continued)

**Noise Voltage**

- **V<sub>KA</sub> = V<sub>REF</sub>**
- **I<sub>K</sub> = 10mA**
- **T<sub>A</sub> = 25°C**

**Low Frequency Dynamic Output Impedance**

- **V<sub>KA</sub> = V<sub>REF</sub>**
- **I<sub>KA</sub> = 1 TO 100mA**
- **f ≤ 1kHz**

**Dynamic Output Impedance**

- **T<sub>A</sub> = 25°C**
- **I<sub>K</sub> = 1 TO 100mA**

**Small Signal Gain vs Frequency**

- **T<sub>A</sub> = 25°C**
- **I<sub>K</sub> = 10mA**
TYPICAL PERFORMANCE CURVES (continued)

PULSE RESPONSE

INPUT AND OUTPUT VOLTAGES (V)

STABILITY BOUNDARY CONDITIONS

A: $V_{KA} = V_{REF}$
B: $V_{KA} = 5V$ AT $I_K = 10mA$
C: $V_{KA} = 10V$ AT $I_K = 10mA$
D: $V_{KA} = 15V$ AT $I_K = 10mA$

$T_A = 25^\circ C$

INPUT MONITOR

$\beta = 100kHz$

INPUT

OUTPUT

GND

50Ω

220Ω

150Ω

10k

$C_L$ - LOAD CAPACITANCE (pF)