

## Adjustable Precision Shunt Regulator

### FEATURES

- Precision Reference Voltage.  
AIC431 :2.495V  $\pm 0.5\%$   
TL431A :2.495V  $\pm 1.0\%$   
TL431 :2.495V  $\pm 1.6\%$
- Sink Current Capability: 200mA.
- Minimum Cathode Current for Regulation: 250 $\mu$ A.
- Equivalent Full-Range Temperature Coefficient: 50 ppm/ $^{\circ}$ C.
- Fast Turn-On Response.
- Low Dynamic Output Impedance: 0.08 $\Omega$ .
- Adjustable Output Voltage.
- Low Output Noise.
- Space Saving Packages: SOT-89, SOT-23, TO-92 and SO-8.

### DESCRIPTION

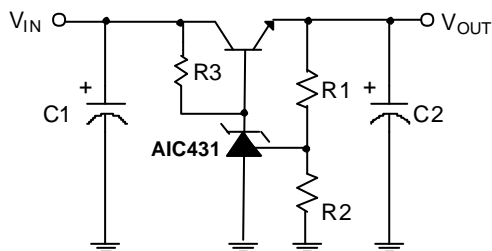
The AIC431, TL431A and TL431 are 3-terminal adjustable precision shunt regulators with guaranteed temperature stability over the applicable extended commercial temperature range. The output voltage may be set at any level greater than 2.495V ( $V_{REF}$ ) up to 30V merely by selecting two external resistors that act as a voltage divider network. These devices have a typical output impedance of 0.08 $\Omega$ . Active output circuitry provides a very sharp turn-on characteristics, making these devices excellent improved replacements for zener diodes in many applications.

### APPLICATIONS

- Linear Regulators.
- Adjustable Supplies.
- Switching Power Supplies.
- Battery Operated Computers.
- Instrumentation.
- Computer Disk Drivers.

The precise  $\pm 0.5\%$  reference voltage tolerance of the AIC431 makes it possible in many applications to avoid the use of a variable resistor, consequently saving cost and eliminating drift and reliability problems associated with it.

### TYPICAL APPLICATION CIRCUIT



$$V_{OUT} = (1 + R1/R2)V_{REF}$$

**Precision Regulator**

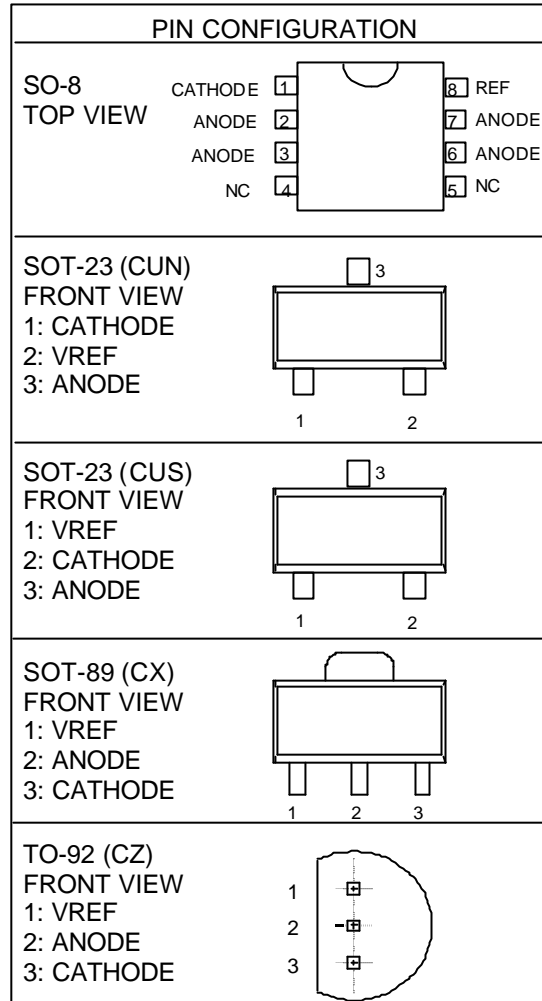
## ORDERING INFORMATION

AIC431 CXXX  
 TL431A CXXX  
 TL431 CXXX

PACKING TYPE  
 TR: TAPE & REEL  
 TB: TUBE (for SO-8)  
 BG: BAG

PACKAGE TYPE  
 S: SMALL OUTLINE  
 US: SOT-23  
 UN: SOT-23  
 X: SOT-89  
 Z: TO-92

Example: AIC431CSTR  
 → in SO-8 Package & Taping & Reel Packing Type (CS is not available in BAG packing type.)



## ABSOLUTE MAXIMUM RATINGS

|   |               |
|---|---------------|
| Cathode Voltage .....                             | 30V           |
| Continuous Cathode Current .....                  | -10mA ~ 250mA |
| Reference Input Current Range .....               | 10mA          |
| Operating Temperature Range, T <sub>A</sub> ..... | -40°C ~ 85°C  |
| Lead Temperature .....                            | 260°C         |
| Storage Temperature .....                         | -65°C ~ 150°C |
| Power Dissipation (Notes 1, 2)                    |               |
| SOT-89 Package .....                              | 0.80W         |
| TO-92 Package .....                               | 0.78W         |

**Note 1:** T<sub>J, max</sub> = 150°C.

**Note 2:** Ratings apply to ambient temperature at 25°C.

## TEST CIRCUITS

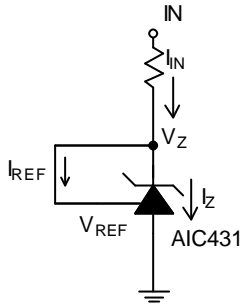
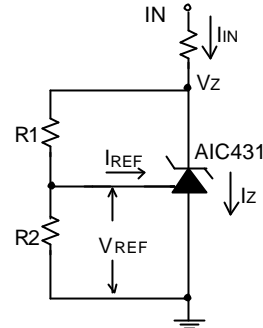


Fig. 1 Test Circuit for  $V_Z=V_{REF}$



Note:  $V_Z=V_{REF}(1+R1/R2)+I_{REF}R1$

Fig. 2 Test Circuit for  $V_Z>V_{REF}$

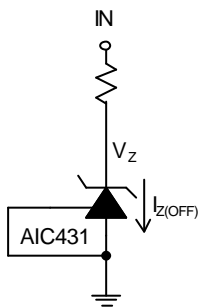


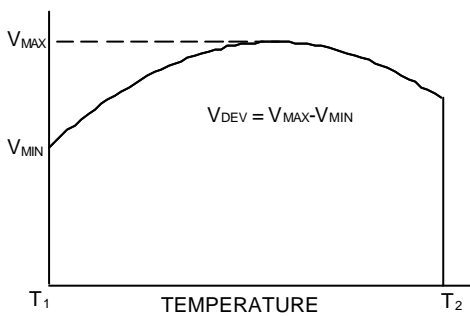
Fig. 3 Test Circuit for off-state Current

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

| PARAMETER   | TEST CONDITIONS   | SYMBOL  | MIN.  | TYP.  | MAX.  | UNIT |
|---|---|---|---|-------|-------|------|
| Reference Voltage   | $V_Z=V_{REF}$ ,<br>$I_{IN}=10\text{mA}$ (Fig. 1)  | AIC431  | 2.482   | 2.495 | 2.508 | V    |
|   |   | TL431A  | 2.470   | 2.495 | 2.520 |      |
|   |   | TL431   | 2.455   | 2.495 | 2.535 |      |
| Deviation of Reference Input Voltage Over Temperature (Note 3)            | $V_Z=V_{REF}$ , $I_{IN}=10\text{mA}$ ,<br>$T_A=0^\circ\text{C}\sim+70^\circ\text{C}$ (Fig. 1) | $V_{DEV}$   |   | 9.0   | 20    | mV   |
|   |   |   |   | 9.0   | 50    |      |
|   |   |   | $T_A=-40^\circ\text{C}\sim+85^\circ\text{C}$ (Fig. 1) |       |       |      |
| Ratio of the Change in Reference Voltage to the Change in Cathode voltage | $I_Z=10\text{mA}$<br>(Fig. 2)   | $\frac{\Delta V_Z=10\text{V}-V_{REF}}{\Delta V_Z}$    |   | -0.5  | -2.0  | mV/V |
|   |   | $\frac{\Delta V_Z=30\text{V}-10\text{V}}{\Delta V_Z}$ |   | -0.35 | -1.5  | mV/V |

## ELECTRICAL CHARACTERISTICS (Continued)

| PARAMETER   | TEST CONDITIONS   | SYMBOL              | MIN. | TYP. | MAX. | UNIT |
|---|---|---------------------|------|------|------|------|
| Reference Input Current                               | R1 = 10KΩ, R2 = ∞,<br>I <sub>IN</sub> = 10mA (Fig. 2)                                   | I <sub>REF</sub>    |      | 0.8  | 3.5  | μA   |
| Deviation of Reference Input Current over Temperature | R1 = 10KΩ, R2 = ∞,<br>I <sub>IN</sub> = 10mA<br>T <sub>A</sub> = -40°C ~ +85°C (Fig. 2) | αI <sub>REF</sub>   |      | 0.3  | 1.2  | μA   |
| Minimum Cathode current for Regulation                | V <sub>Z</sub> = V <sub>REF</sub> (Fig. 1)  | I <sub>Z(MIN)</sub> |      | 0.25 | 0.5  | mA   |
| Off-State Current                                     | V <sub>Z</sub> = 20V, V <sub>REF</sub> = 0V (Fig. 3)                                    | I <sub>Z(OFF)</sub> |      | 0.1  | 1.0  | μA   |
| Dynamic Output Impedance<br><b>(Note 4)</b>           | V <sub>Z</sub> = V <sub>REF</sub><br>F < 1KHz (Fig. 1)                                  | R <sub>Z</sub>      |      | 0.08 | 0.3  | Ω    |



**Note 3.** Deviation of reference input voltage, V<sub>DEV</sub>, is defined as the maximum variation of the reference input voltage over the full temperature range.

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

$$\Delta V_{REF} \frac{\text{ppm}}{^{\circ}\text{C}} = \pm \frac{\left[ \frac{V_{MAX} - V_{MIN}}{V_{REF}(\text{at } 25^{\circ}\text{C})} \right] 10^6}{T_2 - T_1} = \pm \left[ \frac{V_{DEV}}{V_{REF}(\text{at } 25^{\circ}\text{C})} \right] 10^6$$

Where:

T<sub>2</sub>-T<sub>1</sub>=full temperature change.

αV<sub>REF</sub> can be positive or negative depending on whether the slope is positive or negative.

Example: V<sub>DEV</sub> = 9.0mV, V<sub>REF</sub> = 2495mV,

T<sub>2</sub>-T<sub>1</sub> = 70°C, slope is negative.

$$aV_{REF} = \frac{\left[ \frac{9.0\text{mV}}{2495\text{mV}} \right] 10^6}{70^{\circ}\text{C}} = -50\text{ppm}/^{\circ}\text{C}$$

**Note 4.** The dynamic output impedance, R<sub>Z</sub>, is defined as:

$$R_Z = \frac{\Delta V_Z}{\Delta I_Z}$$

When the device is programmed with two external resistors, R1 and R2, (see Fig. 2), the dynamic output impedance of the overall circuit, is defined as:

$$r_z = \frac{\Delta V}{\Delta I} \cong R_Z \left[ 1 + \frac{R_1}{R_2} \right]$$

## TYPICAL PERFORMANCE CHARACTERISTICS

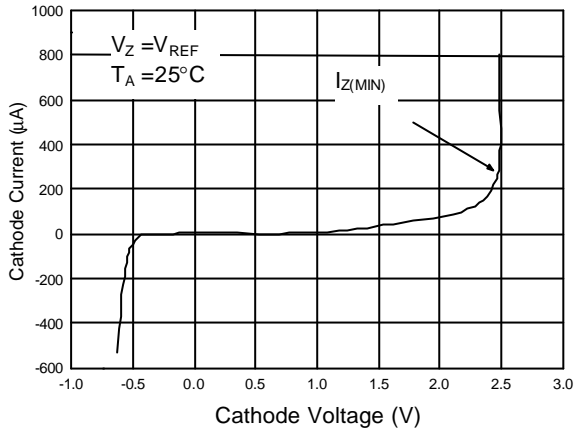


Fig. 4 Cathode Current vs. Cathode Voltage

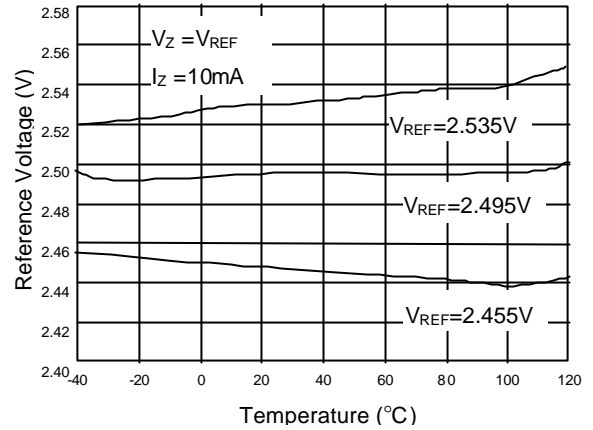


Fig. 5 Reference Voltage vs. Temperature

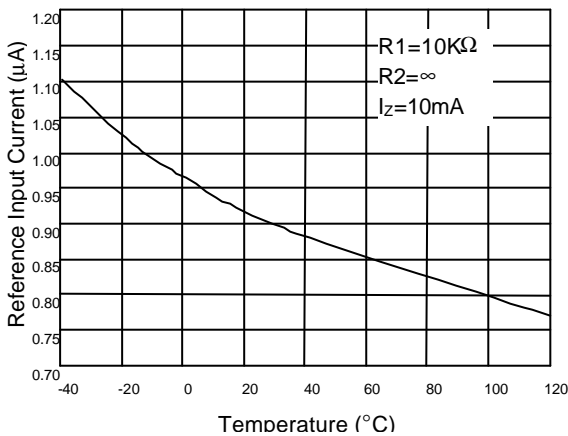


Fig. 6 Reference Input Current vs. Temperature

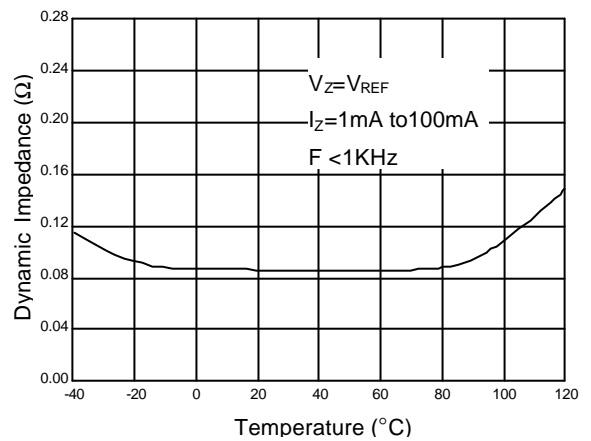


Fig. 7 Dynamic Impedance vs. Temperature

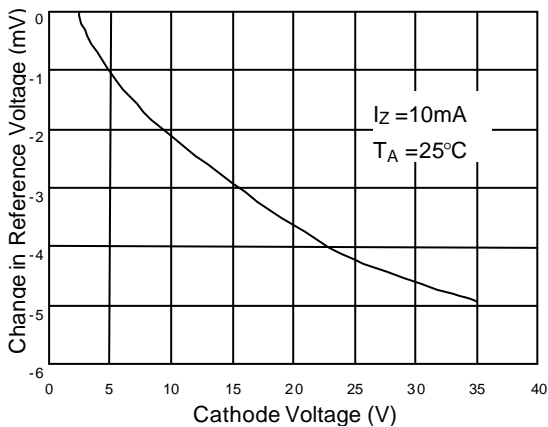


Fig. 8 Change in Reference Voltage vs. Cathode Voltage

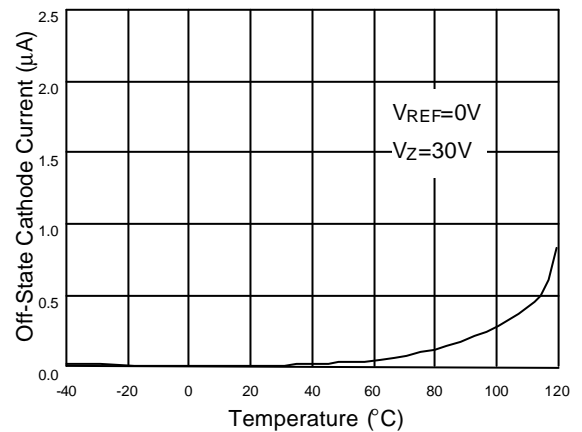


Fig. 9 Off-State Cathode Current vs. Temperature

## TYPICAL PERFORMANCE CHARACTERISTICS (Continued)

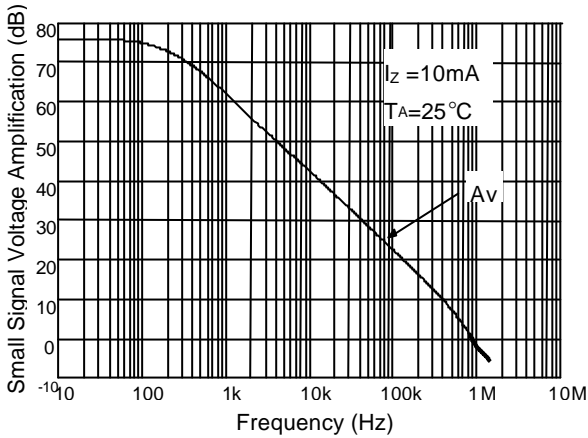


Fig. 10 Small Signal Voltage Amplification vs. Frequency

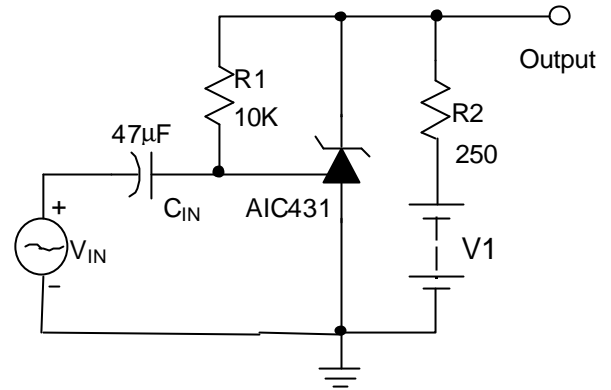


Fig. 11 Test Circuit For Frequency Response

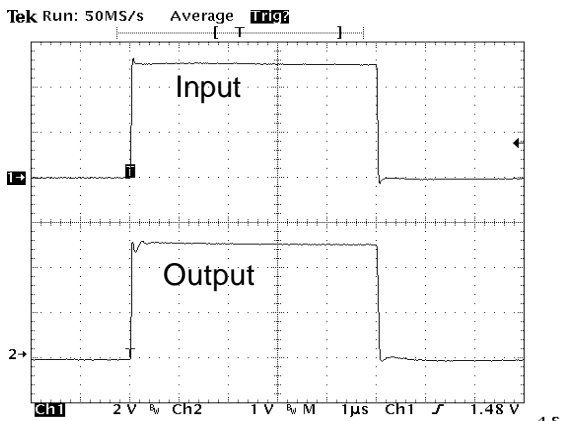


Fig. 12 Pulse Response

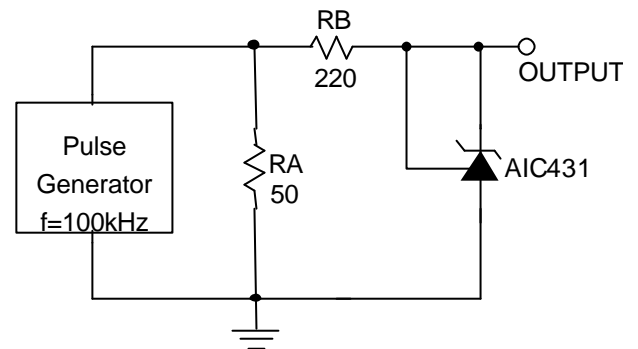


Fig. 13 Test Circuit For Pulse Response

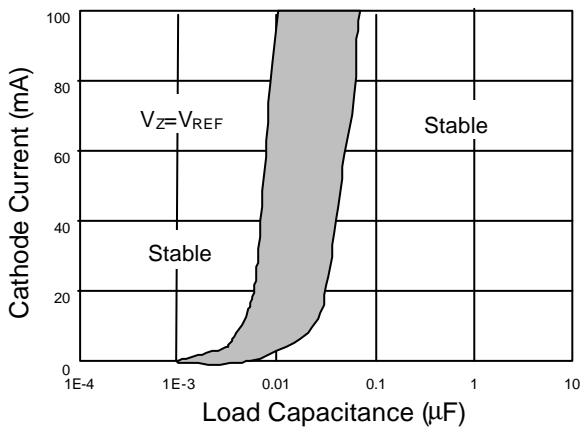


Fig. 14 Stability Boundary Conditions

The areas between the curves represent condition that may cause the device oscillate

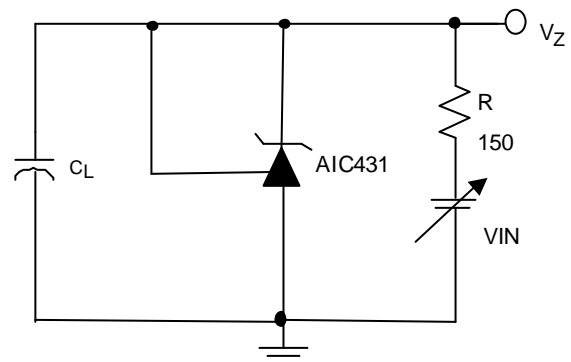


Fig. 15 Test Circuit for Stability Boundary

## TYPICAL PERFORMANCE CHARACTERISTICS (Continued)

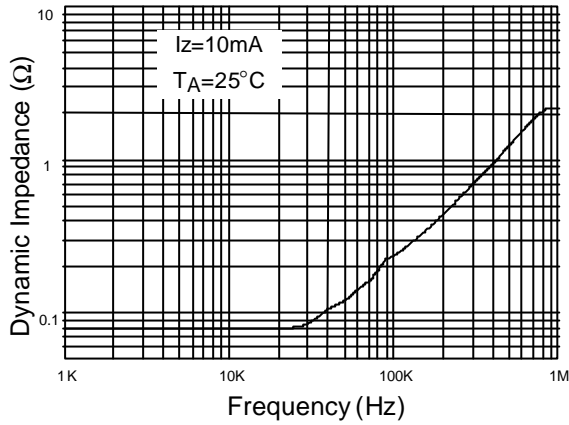


Fig. 16 Dynamic impedance vs. Frequency

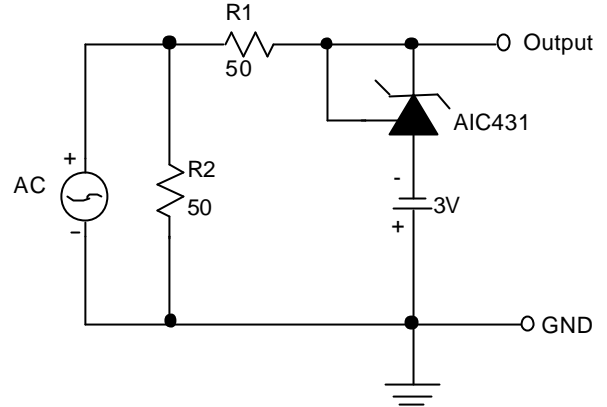
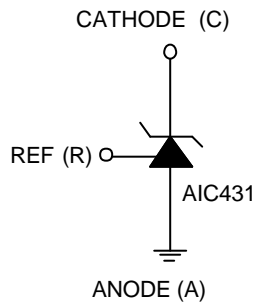
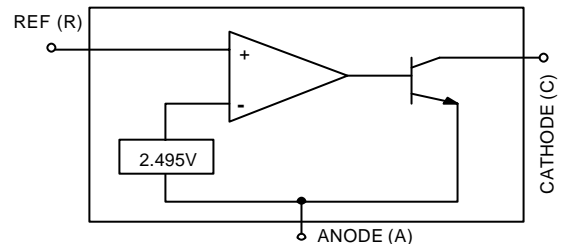


Fig. 17 Test Circuit for Dynamic Impedance

## SYMBOL



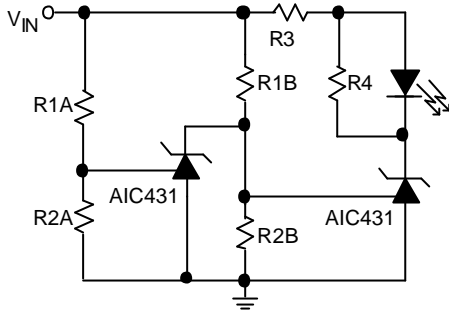
## BLOCK DIAGRAM



## PIN DESCRIPTIONS

- CATHODE Pin - Sinks current with a range from 250 $\mu\text{A}$  to 200mA for normal applications.
- VREF Pin - Providing  $V_{\text{REF}}=2.495\text{V}$  (typ.) for adjustable output voltage.
- ANODE Pin - Anode pin sources current for normal application. The current value is the same as Cathode pin.

## APPLICATION EXAMPLES



LED Turn on when  $Low\ Limit < V_{IN} < High\ Limit$

$$Low\ Limit \cong V_{REF} (1 + R1B/R2B) \quad Delay = R \times C \times \ln \left( \frac{V_{IN}}{V_{IN} - V_{REF}} \right)$$

$$High\ Limit \cong V_{REF} (1 + R1A/R2A)$$

Fig. 18 Voltage Monitor

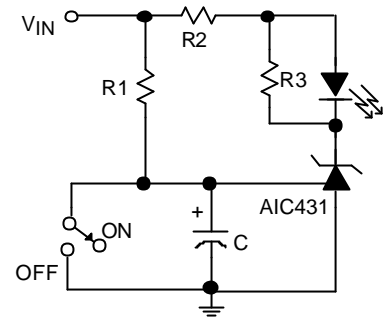
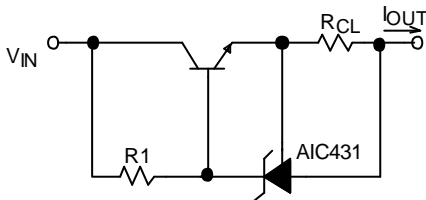
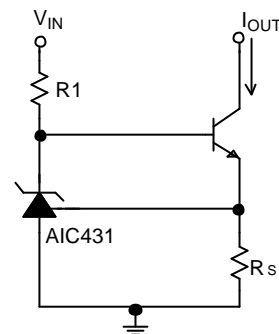


Fig. 19 Delay Timer



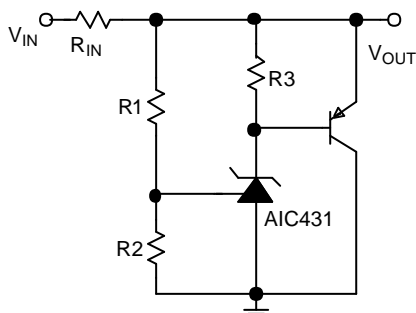
$$I_{OUT} = V_{REF} / R_{CL}$$

Fig. 20 Current Limiter or Current Source



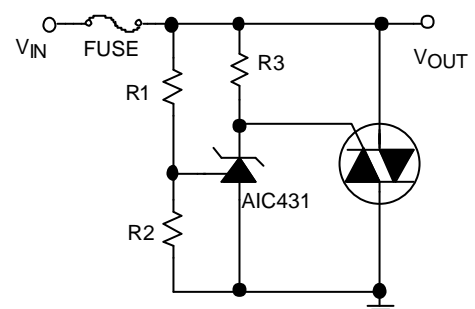
$$I_{OUT} = V_{REF} / R_s$$

Fig. 21 Constant-Current Sink



$$V_{OUT} \cong (1 + R1/R2) \times V_{REF}$$

Fig. 22. Higher-Current Shunt Regulator

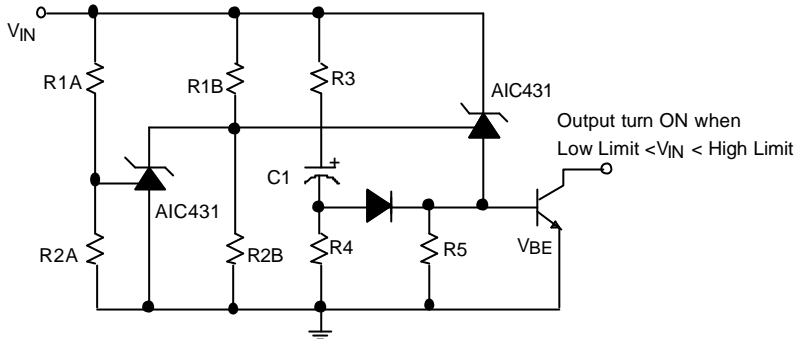


$$V_{LIMIT} \cong (1 + R1/R2) \times V_{REF}$$

Fig. 23 Crow Bar



## APPLICATION EXAMPLES (Continued)



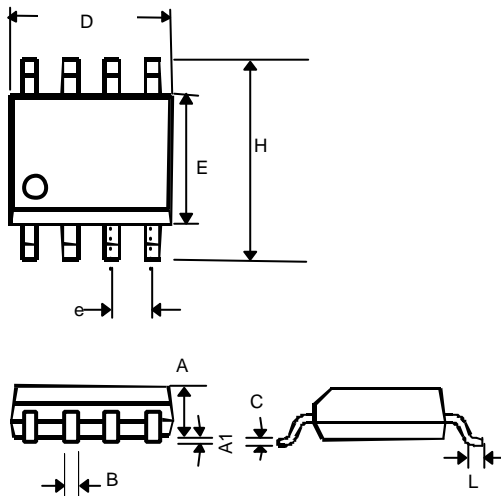
$$\text{Low Limit} \cong V_{REF} (1 + R1B / R2B) + V_{BE}$$

$$\text{High Limit} \cong V_{REF} (1 + R1A / R2A)$$

Fig 24. Over-Voltage/Under-Voltage Protection Circuit

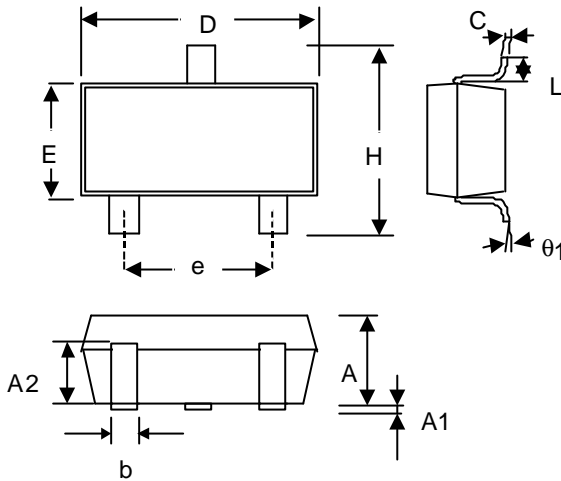
## PHYSICAL DIMENSIONS

- 8 LEAD PLASTIC SO (unit: mm)



| SYMBOL | MIN       | MAX  |
|--------|-----------|------|
| A      | 1.35      | 1.75 |
| A1     | 0.10      | 0.25 |
| B      | 0.33      | 0.51 |
| C      | 0.19      | 0.25 |
| D      | 4.80      | 5.00 |
| E      | 3.80      | 4.00 |
| e      | 1.27(TYP) |      |
| H      | 5.80      | 6.20 |
| L      | 0.40      | 1.27 |

● SOT-23 (unit: mm)



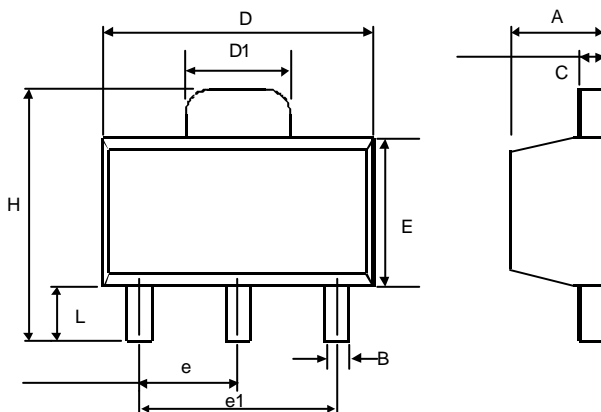
| SYMBOL | MIN        | MAX  |
|--------|------------|------|
| A      | 1.00       | 1.30 |
| A1     | —          | 0.10 |
| A2     | 0.70       | 0.90 |
| b      | 0.35       | 0.50 |
| C      | 0.10       | 0.25 |
| D      | 2.70       | 3.10 |
| E      | 1.40       | 1.80 |
| e      | 1.90 (TYP) |      |
| H      | 2.60       | 3.00 |
| L      | 0.37       | —    |
| 1      | 1°         | 9°   |

● SOT-23 MARKING

| Part No.  | Marking |
|-----------|---------|
| AIC431CUN | AC1N    |
| TL431CUN  | AC2N    |
| TL431ACUN | AC3N    |

| Part No.  | Marking |
|-----------|---------|
| AIC431CUS | AC1S    |
| TL431CUS  | AC2S    |
| TL431ACUS | AC3S    |

● SOT-89 (unit: mm)

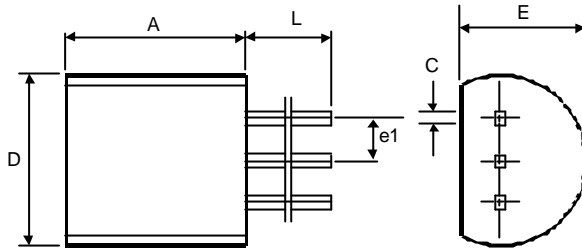


| SYMBOL | MIN         | MAX  |
|--------|-------------|------|
| A      | 1.40        | 1.60 |
| B      | 0.36        | 0.48 |
| C      | 0.35        | 0.44 |
| D      | 4.40        | 4.60 |
| D1     | 1.62        | 1.83 |
| E      | 2.29        | 2.60 |
| e      | 1.50 (TYP.) |      |
| e1     | 3.00 (TYP.) |      |
| H      | 3.94        | 4.25 |
| L      | 0.89        | 1.20 |

● SOT-89 MARKING

| Part No. | Marking |
|----------|---------|
| AIC431CX | AC01B   |
| TL431CX  | AC02B   |
| TL431ACX | AC03B   |

● TO-92 (unit: mm)



| SYMBOL | MIN         | MAX  |
|--------|-------------|------|
| A      | 4.32        | 5.33 |
| C      | 0.38 (TYP.) |      |
| D      | 4.40        | 5.20 |
| E      | 3.17        | 4.20 |
| e1     | 1.27 (TYP.) |      |
| L      | 12.7        | -    |