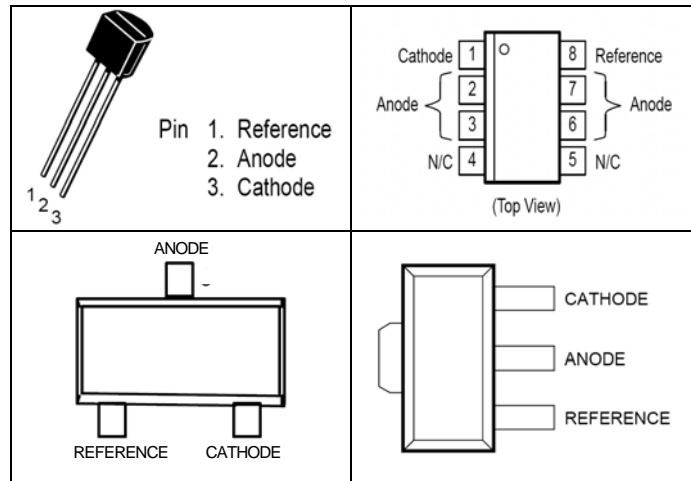# Programmable Precision Reference

## TL431

## FEATURES

- Programmable Output Voltage to 40V
- Low Dynamic Output Impedance $0.2\Omega$
- Sink Current Capability of 0.1 mA to 100 mA
- Equivalent Full-Range Temperature Coefficient of 50 ppm/$^o$C
- Temperature Compensated for Operation over Full Rated Operating Temperature Range
- Low Output Noise Voltage
- Fast Turn on Response
- TO-92, SOP- 8, SOT-23, SOT-89 packages

## PIN CONNECTIONS

Pin 1. Reference
    2. Anode
    3. Cathode

| Cathode | 1 | | 8 | Reference |
Anode { 2, 3 } ... 7 Anode
N/C | 4 ... 5 | N/C

(Top View)

ANODE
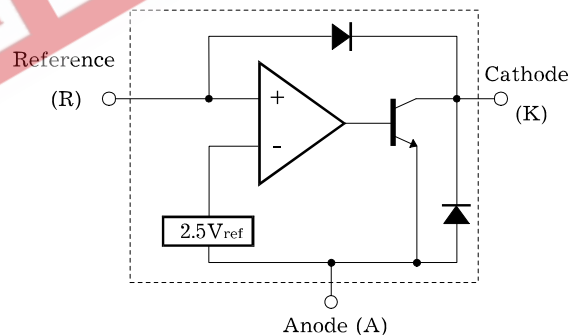REFERENCE    CATHODE

CATHODE
ANODE
REFERENCE

## DESCRIPTION

The TL431 is a three-terminal adjustable regulator series with a guaranteed thermal stability over applicable temperature ranges. The output voltage may be set to any value between Vref (approximately 2.5 volts) and 40 volts with two external resistors. These devices have a typical dynamic output impedance of $0.2\Omega$. Active output circuitry provides a very sharp turn-on characteristic, making these devices excellent replacement for zener diodes in many applications.
The TL431 is characterized for operation from -25$^o$C to +85$^o$C.

## SYMBOL

Cathode
(K)

Reference
(R)

Anode
(A)
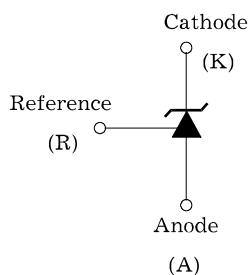
## FUNCTIONAL BLOCK DIAGRAM

Reference
(R)

Cathode
(K)

$2.5V_{ref}$

Anode (A)

## ABSOLUTE MAXIMUM RATINGS

(Operating temperature range applies unless otherwise specified)

| Characteristic | Symbol | Value | Unit |
|---|---|---|---|
| Cathode Voltage | $V_{KA}$ | 40 | V |
| Cathode Current Range (Continuous) | $I_K$ | -100 ~ 150 | mA |
| Reference Input Current Range | $I_{REF}$ | 0.05 ~ 10 | mA |
| Power Dissipation at 25$^o$C:<br>SOP, TO – 92 Package ($R_{\theta JA}$ = 178$^o$C/W)<br>SOT Package ($R_{\theta JA}$ = 625$^o$C/W) | $P_D$ | 0.7<br>0.2 | W<br>W |
| Junction Temperature Range | $T_J$ | -40 ~ 150 | $^o$C |
| Operating Temperature Range | $T_g$ | -40 ~ +85 | $^o$C |
| Storage Temperature Range | $T_{stg}$ | -65 ~ +150 | $^o$C |

## RECOMMENDED OPERATING CONDITIONS

| Characteristic | Symbol | Test Condition | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| Cathode Voltage | $V_{KA}$ | | $V_{REF}$ | | 40 | V |
| Cathode Current | $I_K$ | | 0.5 | | 100 | mA |

## ELECTRICAL CHARACTERISTICS

($T_a = 25^oC$, $V_{KA} = V_{REF}$, $I_K = 10mA$ unless otherwise specified)

| Characteristic | Symbol | Test Condition | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| Reference Input Voltage | $V_{REF}$ | $V_{KA} = V_{REF}$, $I_K = 10mA$<br><br>TL431 (2%)<br>TL431-A (1%)<br>TL431-C (0.5%) | <br><br>2.440<br>2.470<br>2.482 | <br><br>2.495<br>2.495<br>2.495 | <br><br>2.550<br>2.520<br>2.508 | V |
| Deviation of Reference Input Voltage Over Full Temperature Range | $V_{REF(dev)}$ | $T_{min} \leq Ta \leq T_{max}$ | | 3 | 17 | MV |
| Ratio of Change in Reference Input Voltage to the Change in Cathode Voltage | $\dfrac{\Delta V_{REF}}{\Delta V_{KA}}$ | $\Delta V_{KA} = 10V\text{-}V_{REF}$<br>$\Delta V_{KA} = 36V\text{-} 10V$ | | -1.4<br>-1.0 | -2.7<br>-2.0 | mV/V |
| Reference Input Current | $I_{REF}$ | $R_1 = 10K\Omega$, $R_2 = \infty$ | | 1.8 | 4 | $\mu A$ |
| Deviation of Reference Input Current Over Full Temperature Range | $I_{REF(dev)}$ | $R_1 = 10K\Omega$, $R_2 = \infty$ | | 0.4 | 1.2 | $\mu A$ |
| Minimum Cathode Current for Regulation | $I_{K(min)}$ | | | 0.25 | 0.5 | mA |
| Off-State Cathode Current | $I_{K(off)}$ | $V_{KA} = 40\,V$, $V_{REF} = 0$ | | 0.26 | 0.9 | $\mu A$ |
| Dynamic Impedance | $Z_{KA}$ | $I_K = 10mA$ to $100\,mA$ , $f \leq 1.0KHz$ | | 0.22 | 0.5 | $\Omega$ |

## TEST CIRCUITS

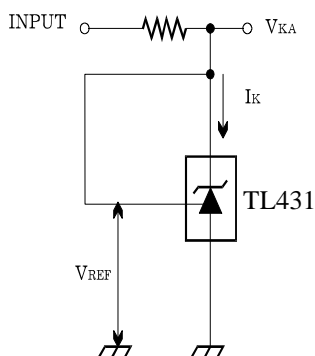**Figure 1. Test Circuit for $V_{KA} = V_{REF}$**



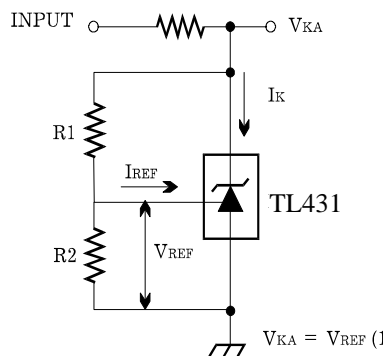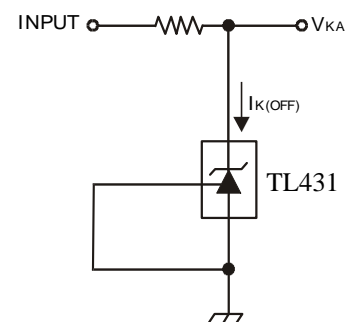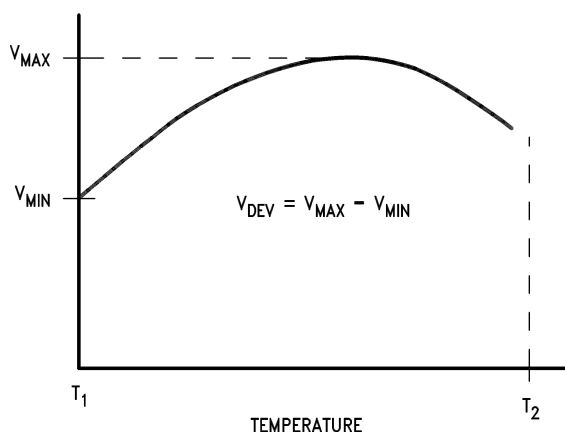**Figure 2. Test Circuit for $V_{KA} \geq V_{REF}$**



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

## Electrical Characteristics (Continued)



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

$$\propto V_{REF} \frac{ppm}{°C} = \frac{\pm \left[ \dfrac{V_{Max} - V_{Min}}{V_{REF} \text{ (at 25°C)}} \right] 10^6}{T_2 - T_1} = \frac{\pm \left[ \dfrac{V_{DEV}}{V_{REF} \text{ (at 25°C)}} \right] 10^6}{T_2 - T_1}$$

Where:

$T_2 - T_1$ = full temperature change (0-70°C).

$\propto V_{REF}$ can be positive or negative depending on whether the slope is positive or negative.

Example: $V_{DEV}$ = 8.0 mV, $V_{REF}$ = 2495 mV, $T_2 - T_1$ = 70°C, slope is positive.

$$\propto V_{REF} = \frac{\left[ \dfrac{8.0 \text{ mV}}{2495 \text{ mV}} \right] 10^6}{70°C} = +46 \text{ ppm/°C}$$
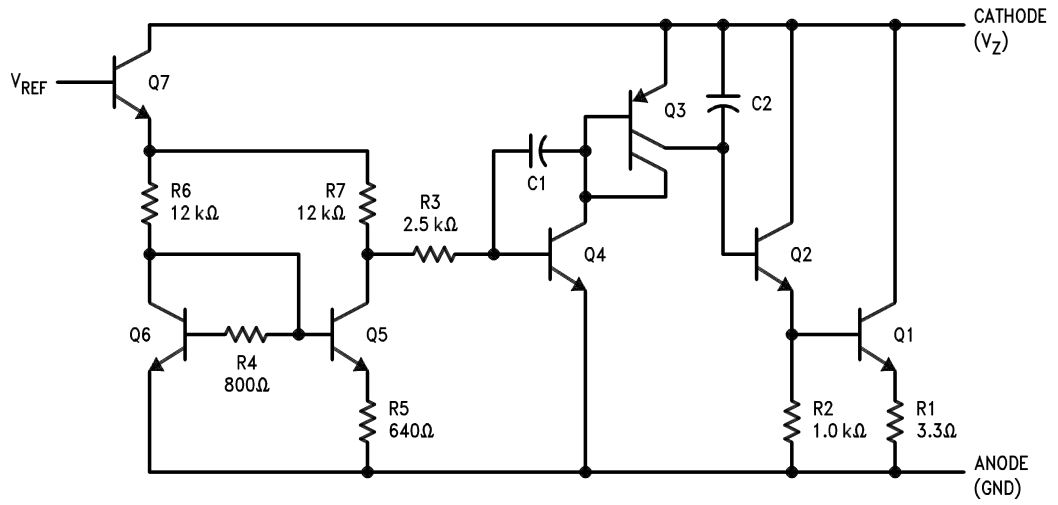
**Note 6:** The dynamic output impedance, $r_Z$, is defined as:
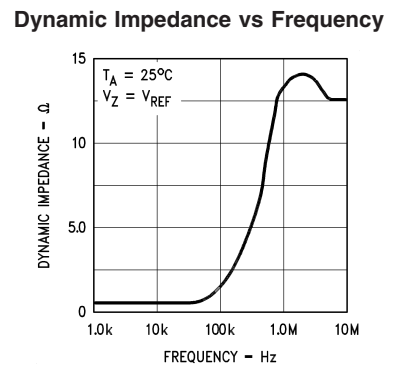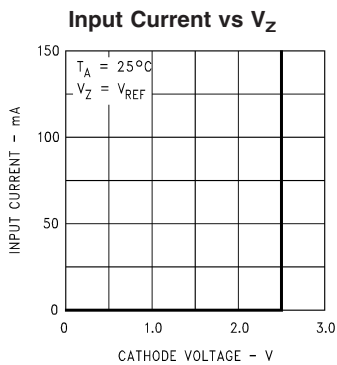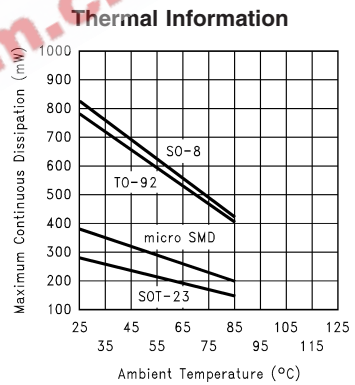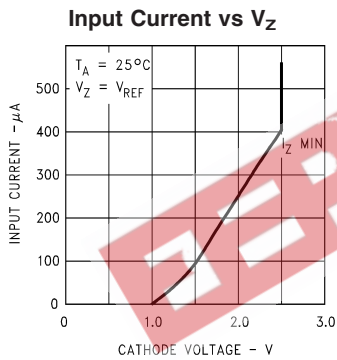
$$r_Z = \frac{\Delta V_Z}{\Delta I_Z}$$

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

$$r_Z = \frac{\Delta V_Z}{\Delta I_Z} \cong \left[ r_Z \left( 1 + \frac{R1}{R2} \right) \right]$$
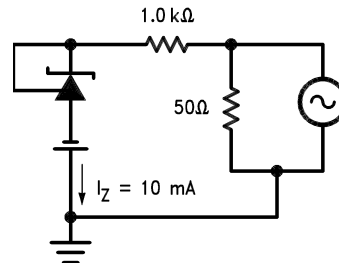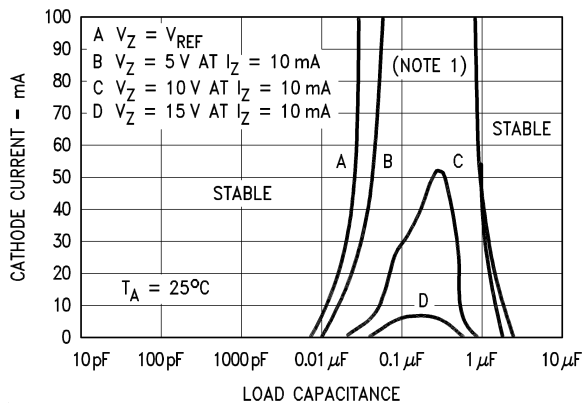
## Equivalent Circuit



## Typical Performance Characteristics

**Input Current vs V$_Z$**



**Thermal Information**



**Input Current vs V$_Z$**



**Dynamic Impedance vs Frequency**

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## Typical Performance Characteristics (Continued)

**Stability Boundary Conditions**

A $V_Z = V_{REF}$
B $V_Z = 5\ V\ AT\ I_Z = 10\ mA$
C $V_Z = 10\ V\ AT\ I_Z = 10\ mA$
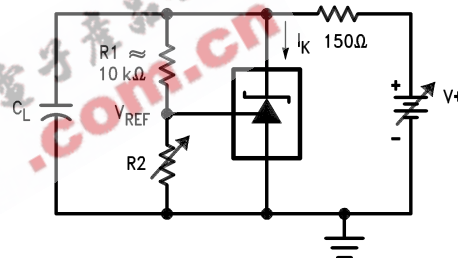D $V_Z = 15\ V\ AT\ I_Z = 10\ mA$

(NOTE 1)

STABLE

STABLE

$T_A = 25°C$

**Note:** The areas under the curves represent conditions that may cause the device to oscillate. For curves B, C, and D, R2 and V$^+$ were adjusted to establish the initial $V_Z$ and $I_Z$ conditions with $C_L = 0$. V$^+$ and $C_L$ were then adjusted to determine the ranges of stability.
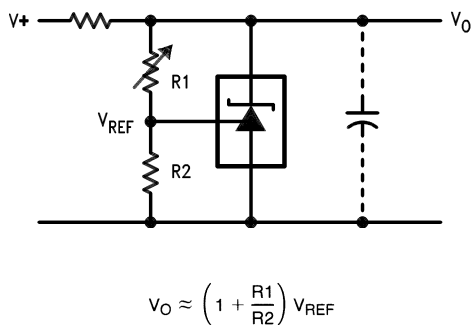
**Test Circuit for Curve A Above**
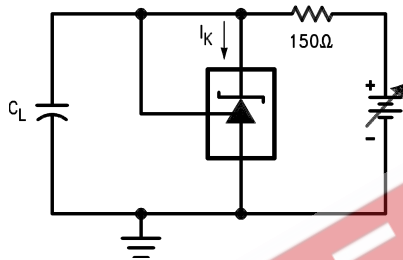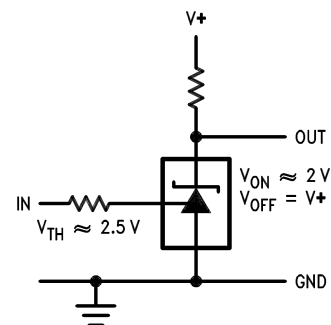
**Test Circuit for Curves B, C and D Above**

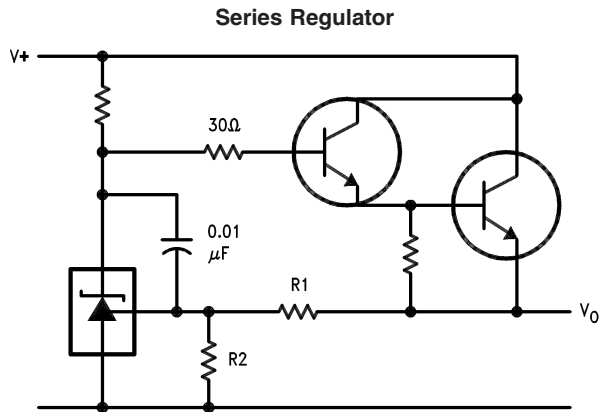## Typical Applications

**Shunt Regulator**

$$V_O \approx \left(1 + \frac{R1}{R2}\right) V_{REF}$$

**Single Supply Comparator with Temperature Compensated Threshold**

$V_{ON} \approx 2\ V$
$V_{OFF} = V^+$

$V_{TH} \approx 2.5\ V$

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# Typical Applications (Continued)

### Series Regulator
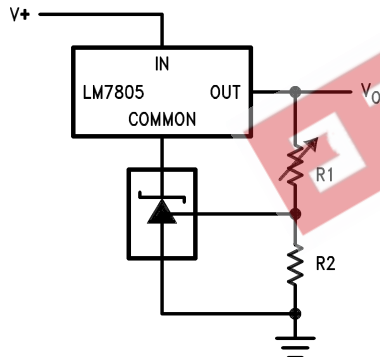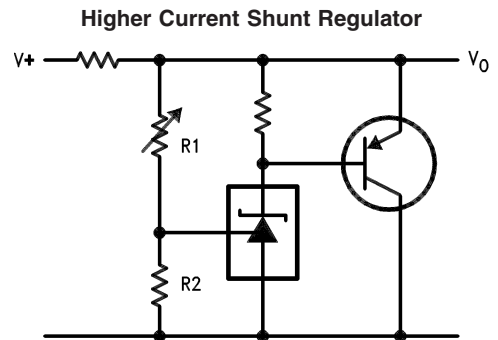


$$V_O \approx \left(1 + \frac{R1}{R2}\right) V_{REF}$$

### Output Control of a Three Terminal Fixed Regulator



$$V_O = \left(1 + \frac{R1}{R2}\right) V_{REF}$$
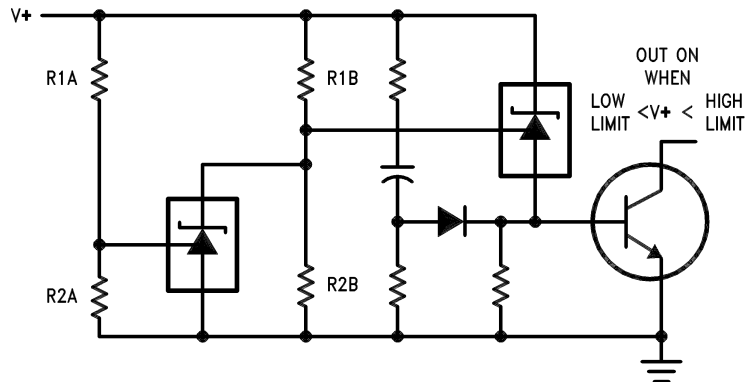
$$V_{O\ MIN} = V_{REF} + 5V$$

### Higher Current Shunt Regulator



$$V_O \approx \left(1 + \frac{R1}{R2}\right) V_{REF}$$

### Crow Bar
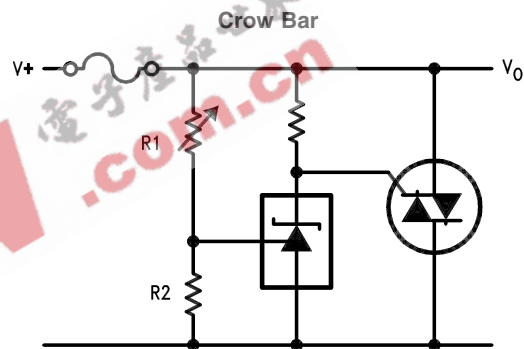


$$V_{LIMIT} \approx \left(1 + \frac{R1}{R2}\right) V_{REF}$$

## Typical Applications  (Continued)

**Over Voltage/Under Voltage
Protection Circuit**



$$\text{LOW LIMIT} \approx V_{REF} \left( 1 + \frac{R1B}{R2B} \right) + V_{BE}$$

$$\text{HIGH LIMIT} \approx V_{REF} \left( 1 + \frac{R1A}{R2A} \right)$$

**Voltage Monitor**
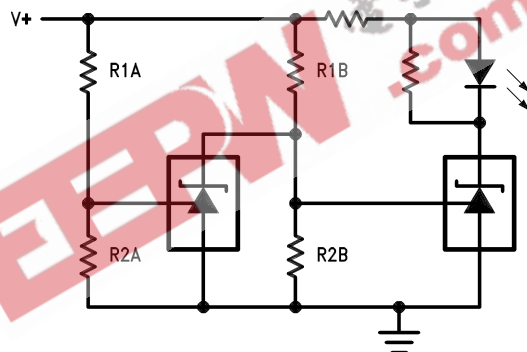


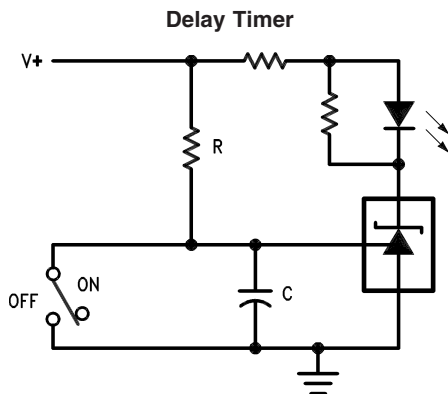$$\text{LOW LIMIT} \approx V_{REF} \left( 1 + \frac{R1B}{R2B} \right) \quad \begin{array}{l}\text{LED ON WHEN} \\ \text{LOW LIMIT} < V^+ < \text{HIGH LIMIT}\end{array}$$

$$\text{HIGH LIMIT} \approx V_{REF} \left( 1 + \frac{R1A}{R2A} \right)$$

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## Typical Applications  (Continued)

### Delay Timer



$$\text{DELAY} = \text{R} \bullet \text{C} \bullet \ell n \frac{\text{V}+}{(\text{V}^+) - \text{V}_{\text{REF}}}$$

### Current Limiter or Current Source



$$\text{I}_\text{O} = \frac{\text{V}_{\text{REF}}}{\text{R}_{\text{CL}}}$$
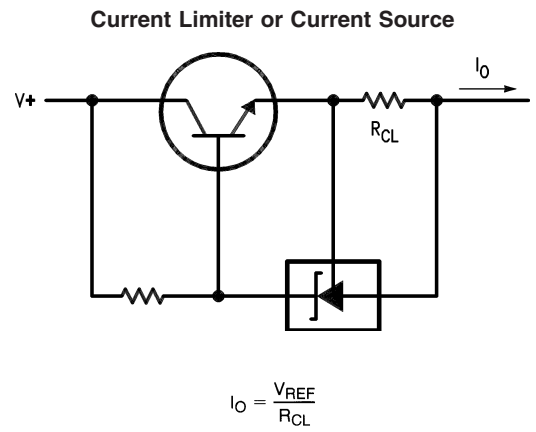
### Constant Current Sink



$$\text{I}_\text{O} = \frac{\text{V}_{\text{REF}}}{\text{R}_\text{S}}$$

**IKSemicon**
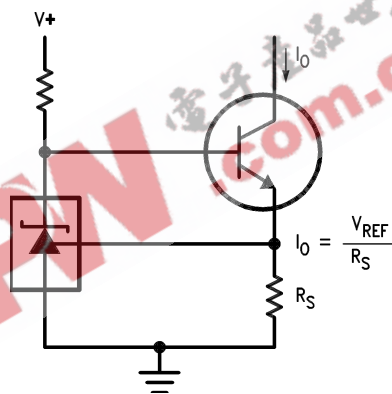
## Ordering Information

| Product Number | Reference Input Voltage | Package |
|---|---|---|
| TL431CLF<br>TL431CLS | 0.5% | TO-92 |
| TL431CD | | 8-SOP |
| TL431CS | | SOT-23 |
| TL431CP | | SOT-89 |
| TL431ALF<br>TL431ALS | 1% | TO-92 |
| TL431AD | | 8-SOP |
| TL431AS | | SOT-23 |
| TL431AP | | SOT-89 |
| TL431LF<br>TL431LS | 2% | TO-92 |
| TL431D | | 8-SOP |
| TL431S | | SOT-23 |
| TL431P | | SOT-89 |

# Package Dimensions



**D SUFFIX SOIC**
**(MS - 012AA)**
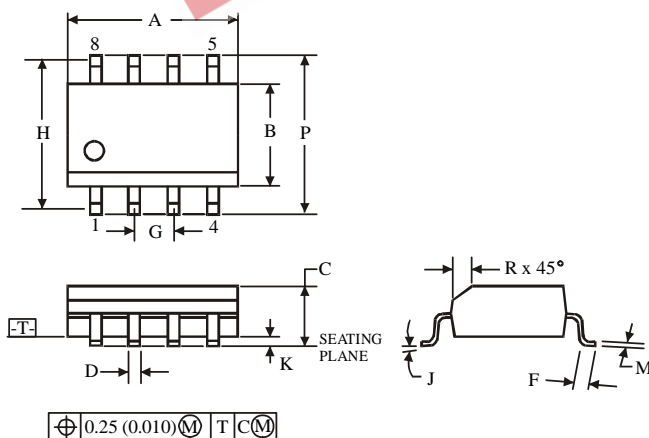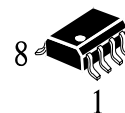
| Symbol | Dimension, mm | |
|---|---|---|
| | MIN | MAX |
| A | 4.80 | 5.00 |
| B | 3.80 | 4.00 |
| C | 1.35 | 1.75 |
| D | 0.33 | 0.51 |
| F | 0.40 | 1.27 |
| G | 1.27 | |
| H | 5.72 | |
| J | 0° | 8° |
| K | 0.10 | 0.25 |
| M | 0.19 | 0.25 |
| P | 5.80 | 6.20 |
| R | 0.25 | 0.50 |

**NOTES:**

1. Dimensions A and B do not include mold flash or protrusion.

2. Maximum mold flash or protrusion 0.15 mm (0.006) per side for A; for B - 0.25 mm (0.010) per side.

# TO-92



0.205 (5,21)
0.175 (4,44) DIA

0.165 (4,19)
0.125 (3,17)

0.210 (5,34)
0.170 (4,32)

0.157 (4,00) MAX

Seating Plane

0.050 (1,27)

0.500 (12,70) MIN

0.104 (2,65)

0.022 (0,56)
0.016 (0,41)

0.016 (0,41)
0.014 (0,35)

FORMED LEAD OPTION

STRAIGHT LEAD OPTION

0.135 (3,43) MIN

0.105 (2,67)
0.095 (2,41)

0.055 (1,40)
0.045 (1,14)

1  2  3

0.105 (2,67)
0.080 (2,03)

0.105 (2,67)
0.080 (2,03)

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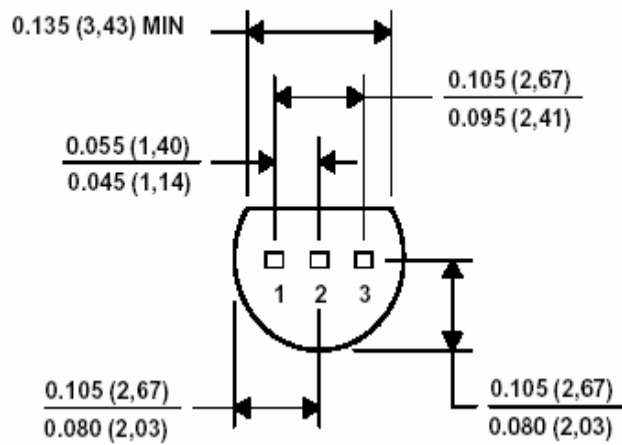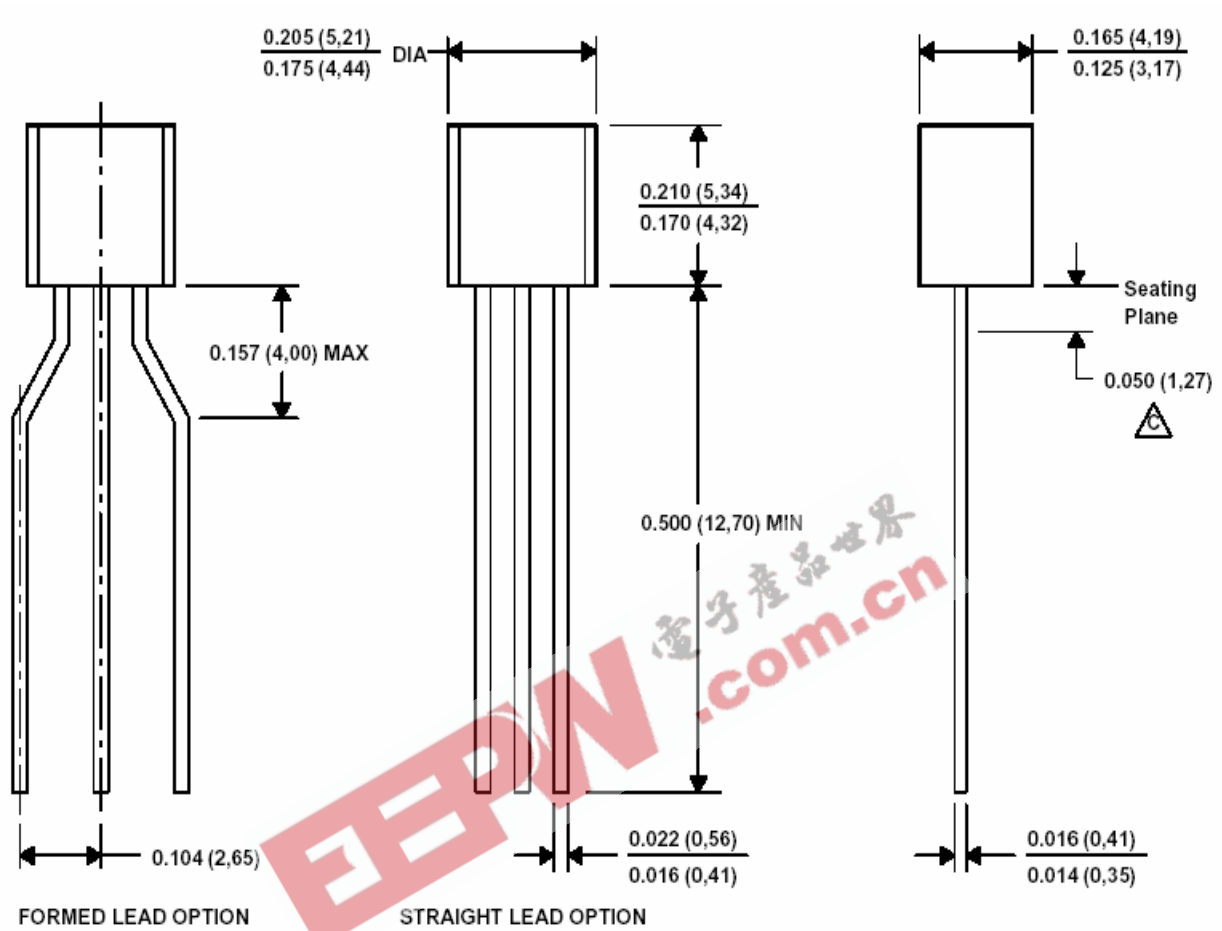
## SOT-23-3L PACKAGE OUTLINE DIMENSIONS
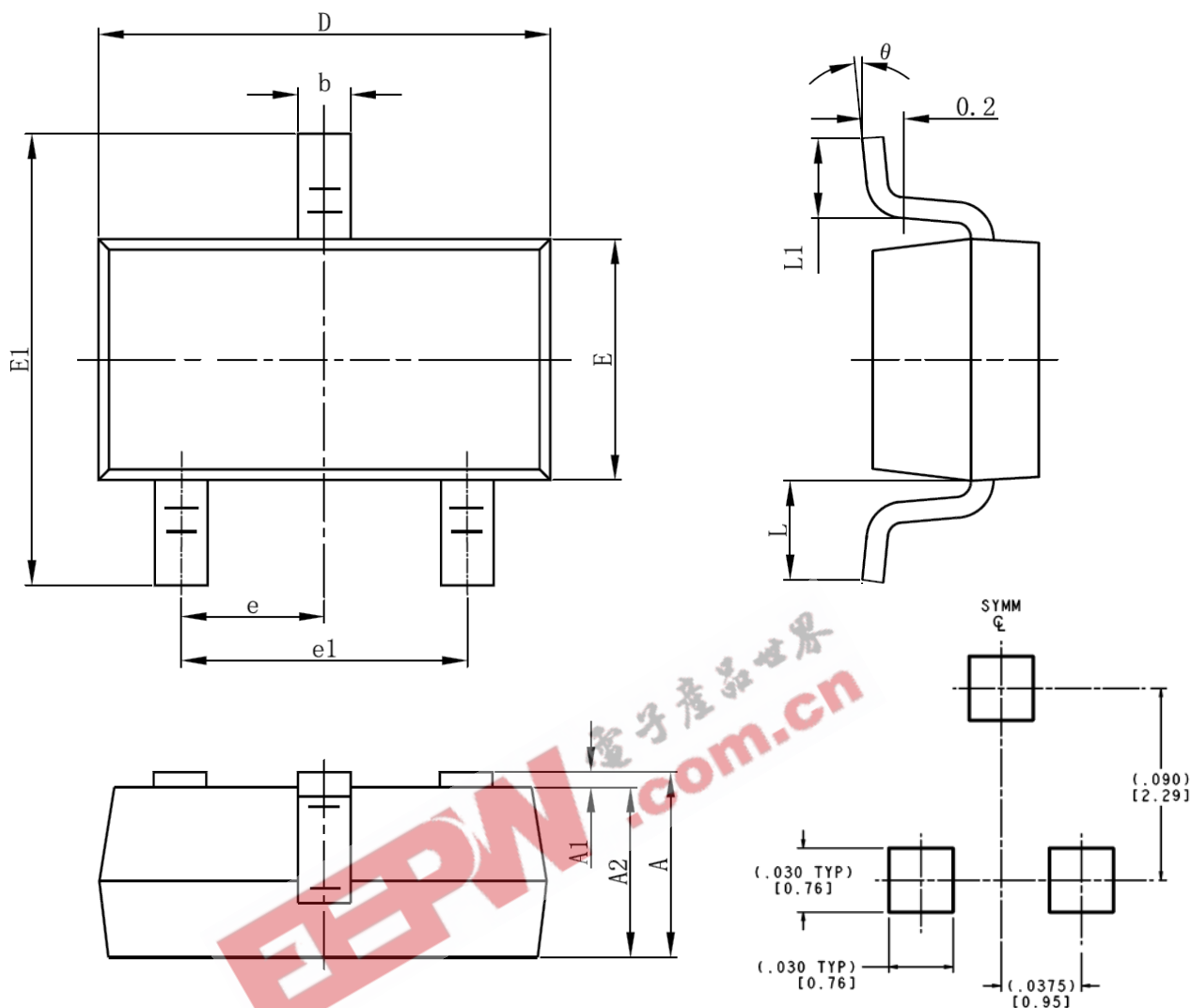


LAND PATTERN RECOMMENDATION

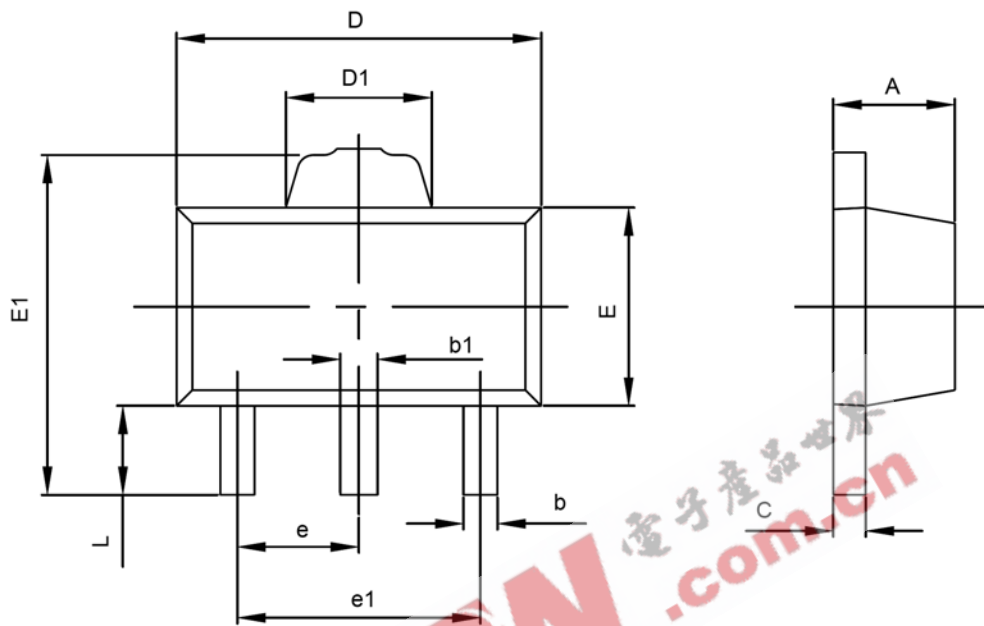| Symbol | Dimensions In Millimeters | | Dimensions In Inches | |
|--------|---------|---------|---------|---------|
| | Min | Max | Min | Max |
| A | 1.050 | 1.250 | 0.041 | 0.049 |
| A1 | 0.000 | 0.100 | 0.000 | 0.004 |
| A2 | 1.050 | 1.150 | 0.041 | 0.045 |
| b | 0.300 | 0.400 | 0.012 | 0.016 |
| c | 0.100 | 0.200 | 0.004 | 0.008 |
| D | 2.820 | 3.020 | 0.111 | 0.119 |
| E | 1.500 | 1.700 | 0.059 | 0.067 |
| E1 | 2.650 | 2.950 | 0.104 | 0.116 |
| e | 0.950TYP | | 0.037TYP | |
| e1 | 1.800 | 2.000 | 0.071 | 0.079 |
| L | 0.700REF | | 0.028REF | |
| L1 | 0.300 | 0.600 | 0.012 | 0.024 |
| θ | 0° | 8° | 0° | 8° |

**IKSemicon**

## SOT-89-3L  PACKAGE OUTLINE DIMENSIONS



| Symbol | Dimensions In Millimeters | | Dimensions In Inches | |
|---|---|---|---|---|
| | Min | Max | Min | Max |
| A | 1.400 | 1.600 | 0.055 | 0.063 |
| b | 0.320 | 0.520 | 0.013 | 0.020 |
| b1 | 0.360 | 0.560 | 0.014 | 0.022 |
| c | 0.350 | 0.440 | 0.014 | 0.017 |
| D | 4.400 | 4.600 | 0.173 | 0.181 |
| D1 | 1.400 | 1.800 | 0.055 | 0.071 |
| E | 2.300 | 2.600 | 0.091 | 0.102 |
| E1 | 3.940 | 4.250 | 0.155 | 0.167 |
| e | 1.500TYP | | 0.060TYP | |
| e1 | 2.900 | 3.100 | 0.114 | 0.122 |
| L | 0.900 | 1.100 | 0.035 | 0.043 |