

## ADJUSTABLE PRECISION SHUNT REGULATOR

### Description

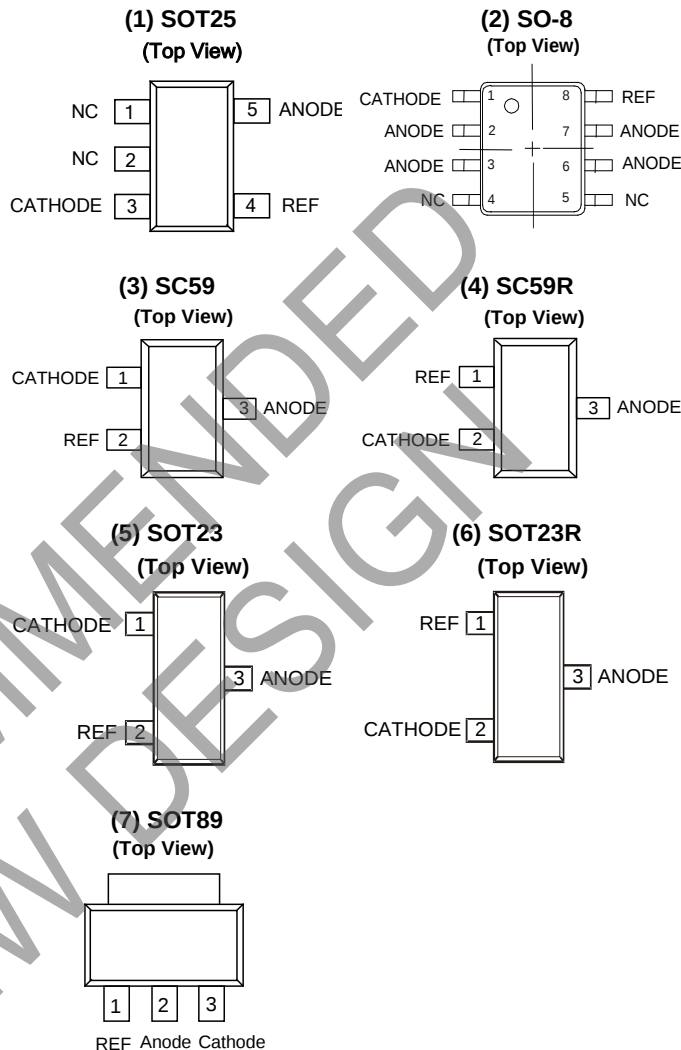
The AP431 and AP431A are 3-terminal adjustable precision shunt regulators with guaranteed temperature stability over the applicable extended commercial temperature range. The output voltage may be set at any level greater than 2.495V ( $V_{REF}$ ) up to 36V merely by selecting two external resistors that act as a voltage divider network. These devices have a typical output impedance of 0.2Ω. Active output circuitry provides very sharp turn-on characteristics, making these devices excellent improved replacements for Zener diodes in many applications.

The precise (+/-) 1% reference voltage tolerance of the AP431/AP431A make 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.

### Features

- Precision Reference Voltage
- AP431: 2.495V ± 1%
- AP431A: 2.495V ± 0.5%
- Sink Current Capability: 200mA
- Minimum Cathode Current for Regulation: 300μA
- Equivalent Full-Range Temp Coefficient: 30ppm/°C
- Fast Turn-On Response
- Low Dynamic Output Impedance: 0.2Ω
- Programmable Output Voltage to 36V
- Low Output Noise
- Lead Free Packages: SOT25, SC59, SC59R, SOT89 and SO-8
  - **Totally Lead-Free; RoHS Compliant (Notes 1 & 2)**
- SOT23, SOT23R, SOT25, SC59, SC59R, SO-8, SOT89: Available in "Green" Molding Compound (No Br, Sb). See "Ordering Information"
  - **Halogen and Antimony Free. "Green" Device (Note 3)**

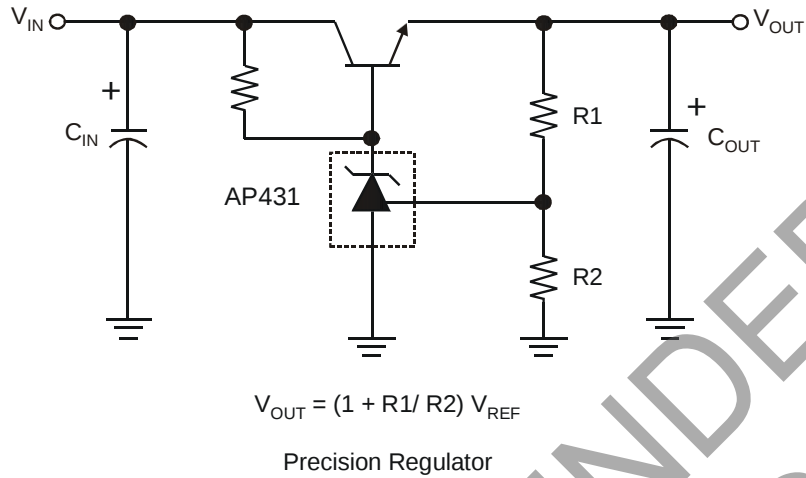
### Pin Assignments



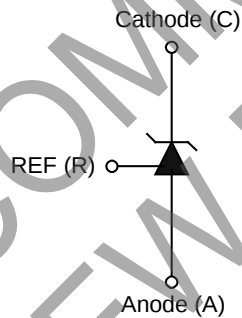
Notes:

1. No purposely added lead. Fully EU Directive 2002/95/EC (RoHS) & 2011/65/EU (RoHS 2) compliant.
2. See <http://www.diodes.com> for more information about Diodes Incorporated's definitions of Halogen- and Antimony-free, "Green" and Lead-free.
3. Halogen- and Antimony-free "Green" products are defined as those which contain <900ppm bromine, <900ppm chlorine (<1500ppm total Br + Cl) and <1000ppm antimony compounds.

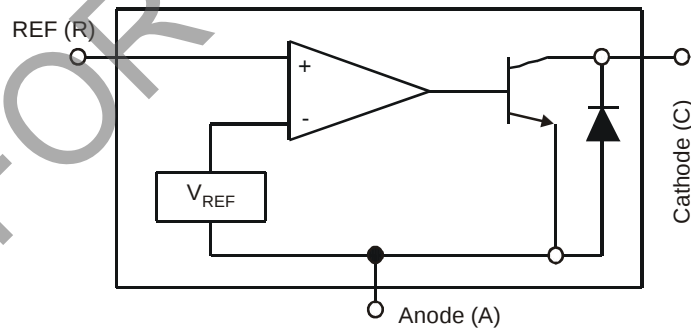
## Typical Applications Circuit



## Symbol



## Functional Block Diagram



### Absolute Maximum Ratings (@T<sub>A</sub> = +25°C, unless otherwise specified.)

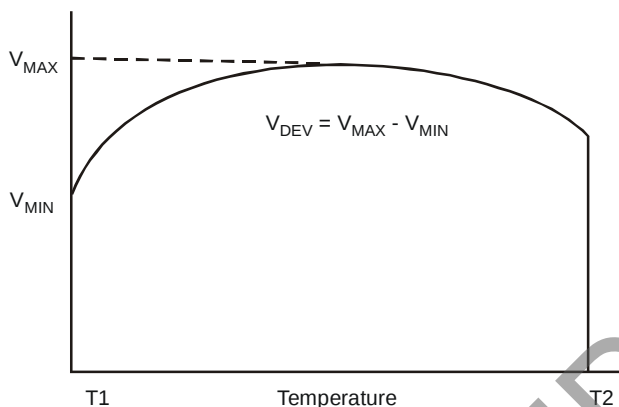
| Parameter                      |          | Rating      | Unit |
|--------------------------------|----------|-------------|------|
| Cathode Voltage                |          | +36         | V    |
| Continuous Cathode Current     |          | -10 to +250 | mA   |
| Reference Input Current        |          | 10          | mA   |
| Operating Temperature          |          | -20 to +85  | °C   |
| Storage Temperature            |          | -65 to +150 | °C   |
| Power Dissipation (Notes 4, 5) | SOT23(R) | 400         | mW   |
|                                | SOT25    | 550         | mW   |
|                                | SC59(R)  | 400         | mW   |
|                                | SO-8     | 600         | mW   |
|                                | SOT89    | 800         | mW   |

Notes: 4. T<sub>J</sub>, max = +150°C.  
5. Ratings apply to ambient temperature at +25°C.

### Electrical Characteristics (@T<sub>A</sub> = +25°C, V<sub>DD</sub> = 3V; unless otherwise specified.)

| Symbol                                 | Parameter                                                                 | Conditions                                                                                                                               | Min            | Typ        | Max            | Units        |
|----------------------------------------|---------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------|----------------|------------|----------------|--------------|
| V <sub>REF</sub>                       | Reference voltage                                                         | V <sub>KA</sub> = V <sub>REF</sub> , I <sub>KA</sub> = 10mA (Figure 1)<br>AP431 AP431A                                                   | 2.470<br>2.482 | 2.495      | 2.520<br>2.507 | V            |
| V <sub>DEV</sub>                       | Deviation of reference input voltage over temperature (Note 5)            | V <sub>KA</sub> = V <sub>REF</sub> , I <sub>KA</sub> = 10mA<br>T <sub>A</sub> = Full Range (Figure 1)                                    | —              | 8.0        | 20.0           | mV           |
| $\frac{\Delta V_{REF}}{\Delta V_{KA}}$ | Ratio of the change in reference voltage to the change in cathode voltage | I <sub>KA</sub> = 10mA (Figure 2)<br>V <sub>KA</sub> = V <sub>REF</sub> to 10V<br>V <sub>KA</sub> = 10V to 36V                           | —<br>—         | -1.4<br>-1 | -2.0<br>-2     | mV/V<br>mV/V |
| I <sub>REF</sub>                       | Reference input current                                                   | R1 = 10KΩ, R2 = ∞ I <sub>KA</sub> = 10mA (Figure 2)                                                                                      | —              | 1.4        | 3.5            | μA           |
| αI <sub>REF</sub>                      | Deviation of reference input current over temperature                     | R1 = 10KΩ, R2 = ∞ I <sub>KA</sub> = 10mA<br>T <sub>A</sub> = Full range (Figure 2)                                                       | —              | 0.4        | 1.2            | μA           |
| I <sub>KA(MIN)</sub>                   | Minimum cathode current for regulation                                    | V <sub>KA</sub> = V <sub>REF</sub> (Figure 1)                                                                                            | —              | 0.19       | 0.50           | mA           |
| I <sub>KA(OFF)</sub>                   | Off-state current                                                         | V <sub>KA</sub> = 36V, V <sub>REF</sub> = 0V (Figure 3)                                                                                  | —              | 0.1        | 1.0            | μA           |
| Z <sub>KA</sub>                        | Dynamic output impedance (Note 7)                                         | V <sub>KA</sub> = V <sub>REF</sub> V <sub>KA</sub> = V <sub>REF</sub><br>ΔI <sub>KA</sub> = 0.1mA to 15mA<br>Frequency ≤ 1KHz (Figure 1) | —              | 0.2        | 0.5            | Ω            |

## Electrical Characteristics (cont.) (@T<sub>A</sub> = +25°C, V<sub>DD</sub> = 3V; unless otherwise specified.)



Note: 6. Deviation of reference input voltage, V<sub>DEV</sub>, is defined as the maximum variation of the reference over the full temperature range. The average temperature coefficient of the reference input voltage αV<sub>REF</sub> is defined as:

$$|\alpha V_{REF}| = \frac{\left( \frac{V_{DEV}}{V_{REF}(25^\circ\text{C})} \right) \cdot 10^6}{T_2 - T_1} \quad \text{.....} \quad \left( \frac{\text{ppm}}{^\circ\text{C}} \right)$$

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.

Note: 7. The dynamic output impedance, R<sub>Z</sub>, is defined as:

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

When the device is programmed with two external resistors R<sub>1</sub> and R<sub>2</sub> (see Figure 2.), the dynamic output impedance of the overall circuit, is defined as:

$$|Z'_{KA}| = \frac{\Delta V}{\Delta I} \approx |Z_{KA}| \left( 1 + \frac{R_1}{R_2} \right)$$

## Test Conditions

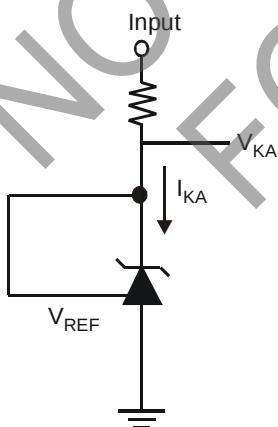
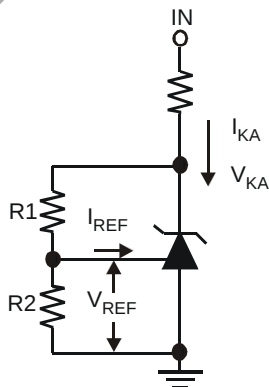


Figure. 1 Test Circuit for V<sub>KA</sub> = V<sub>REF</sub>



Note: V<sub>KA</sub> = V<sub>REF</sub> (1 + R<sub>1</sub>/R<sub>2</sub>) + I<sub>REF</sub> x R<sub>1</sub>

Figure. 2 Test Circuit for V<sub>KA</sub> > V<sub>REF</sub>

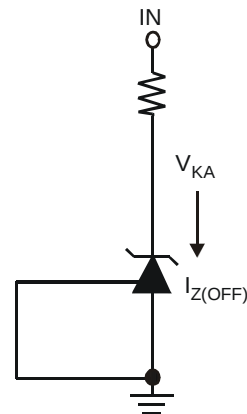
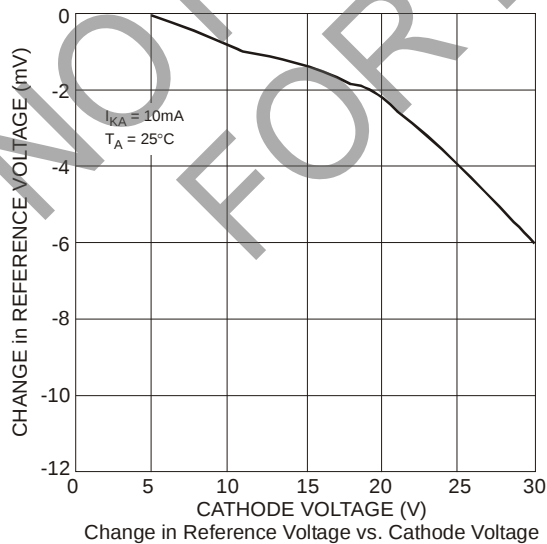
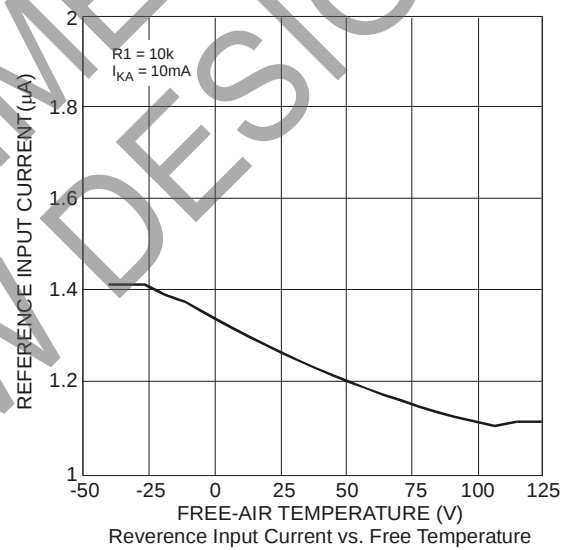
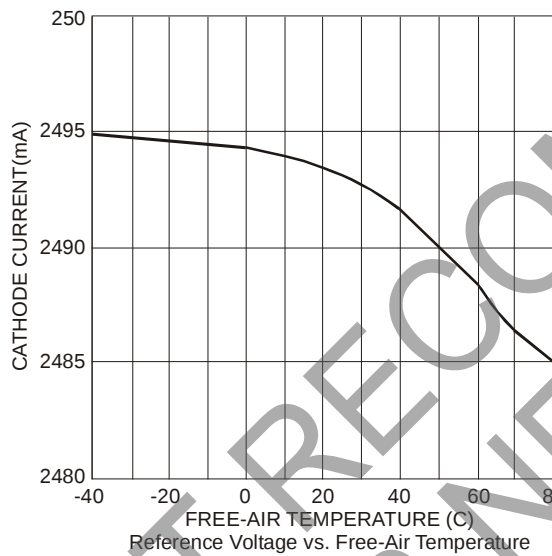
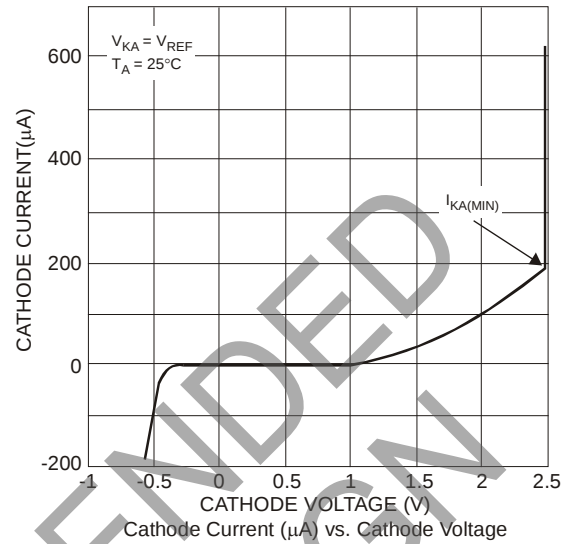
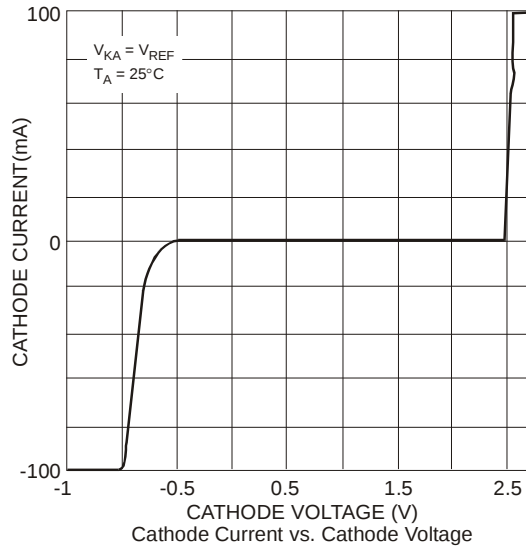
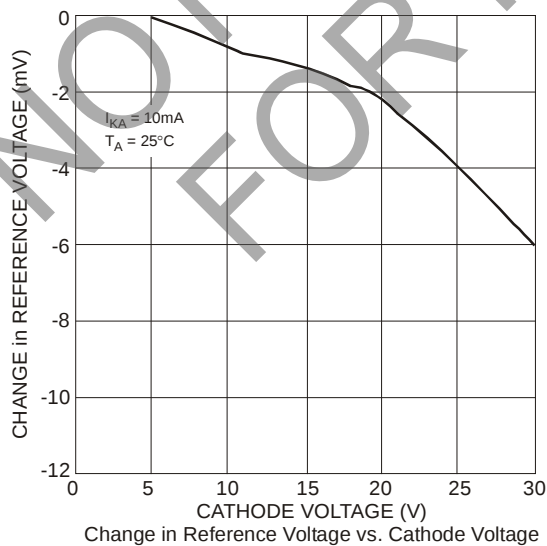
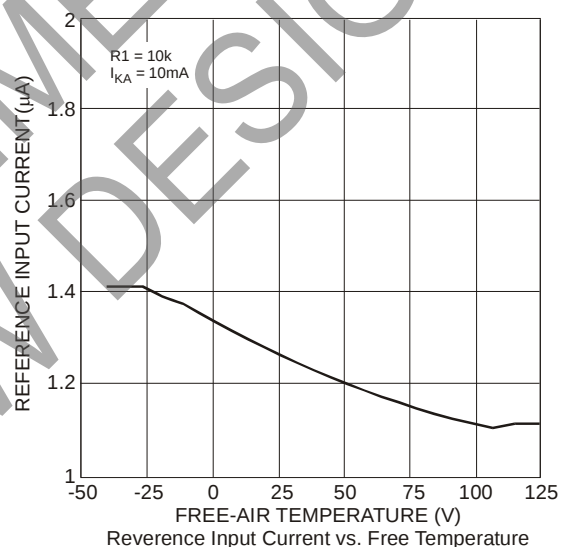
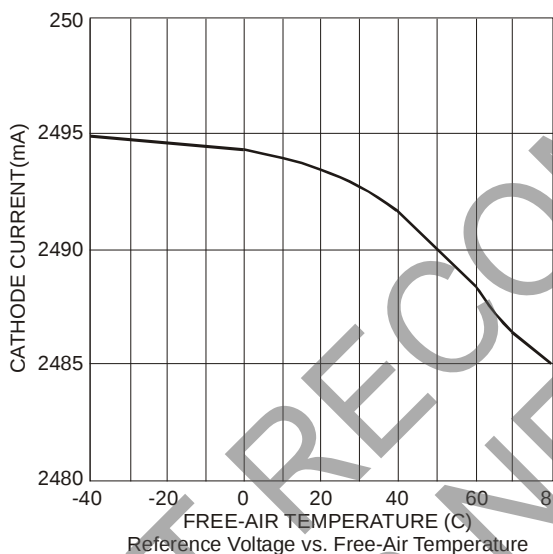
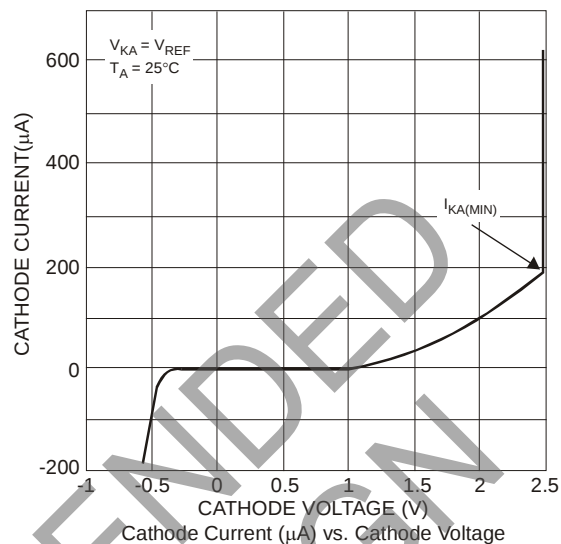
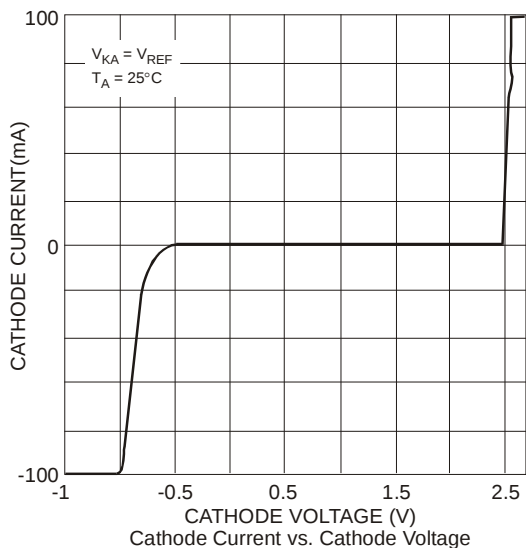


Figure. 3 Test Circuit for Off-State Current

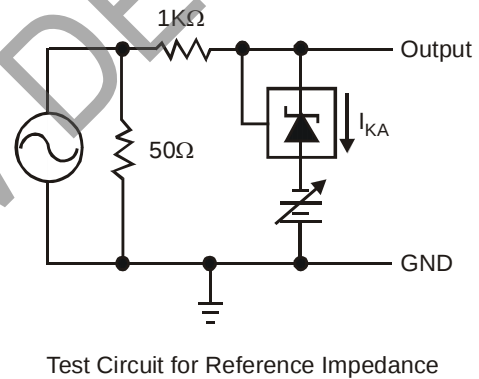
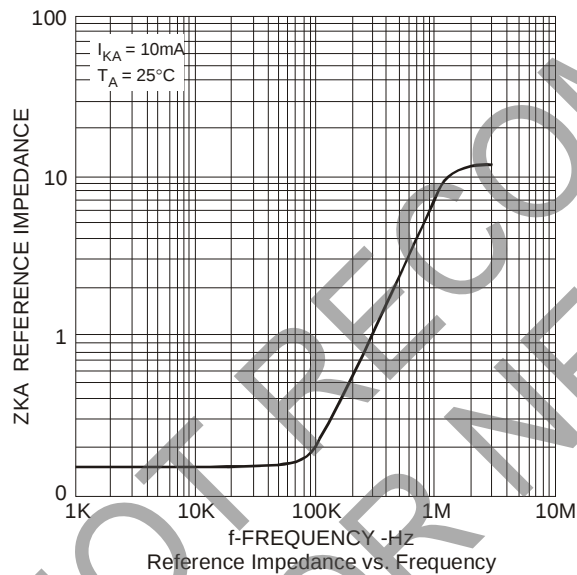
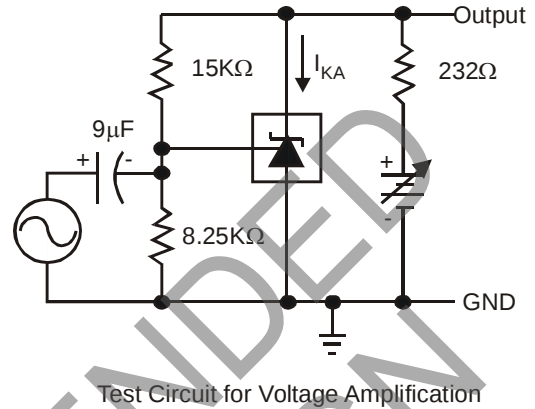
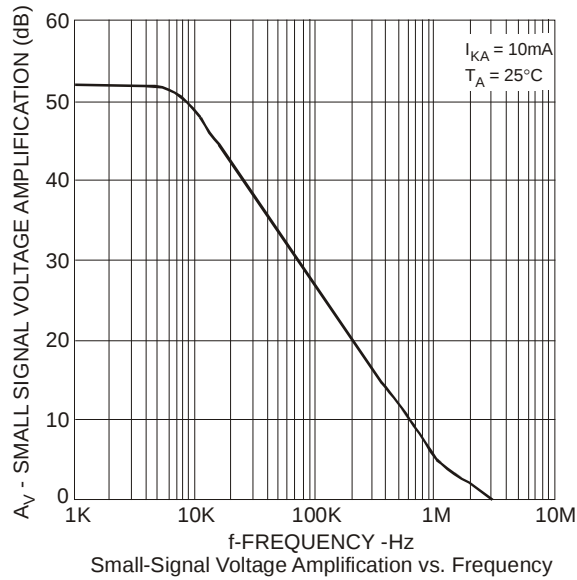
## Typical Performance Characteristics



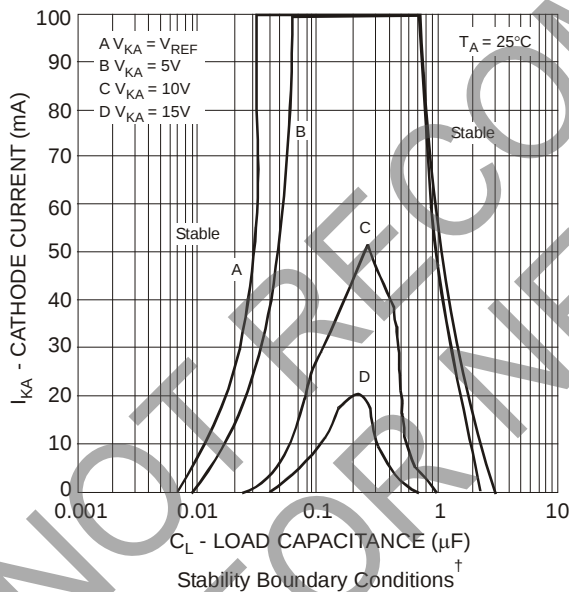
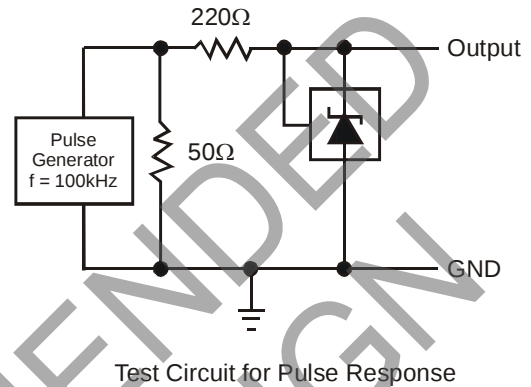
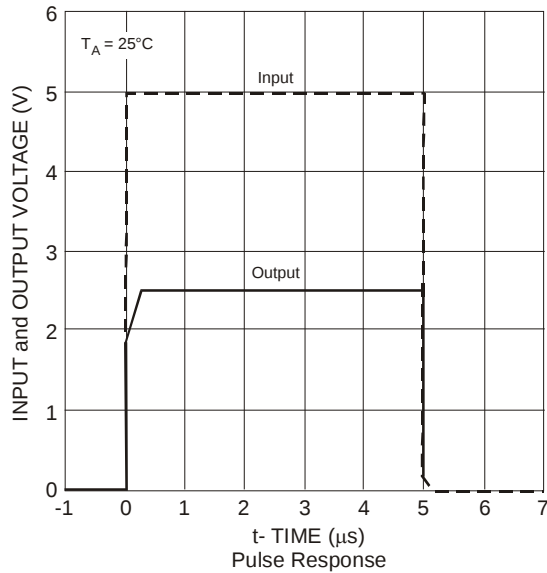
**Typical Performance Characteristics (cont.)**



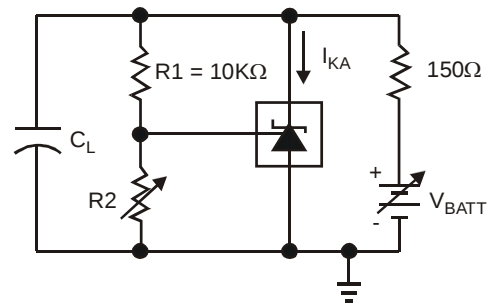
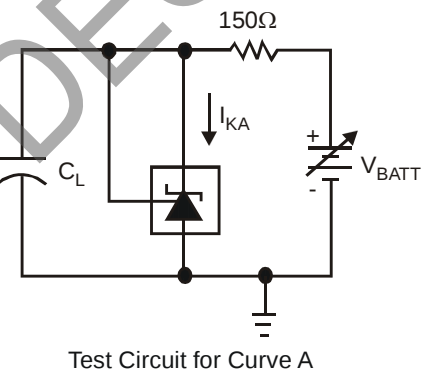
## Typical Performance Characteristics (cont.)



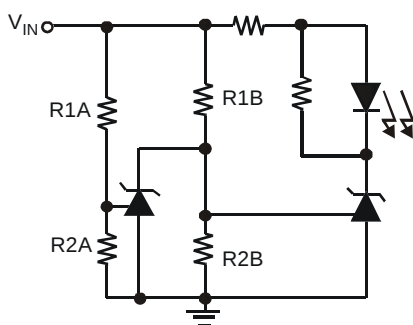
## Typical Performance Characteristics (cont.)



† The areas under the curves represent conditions that may cause the device to oscillate. For curves B, C, and D,  $R_2$  and  $V_+$  were adjusted to establish the initial  $V_{KA}$  and  $I_{KA}$  conditions with  $C_L = 0$ .  $V_{BATT}$  and  $C_L$  were then adjusted to determine the ranges of stability.

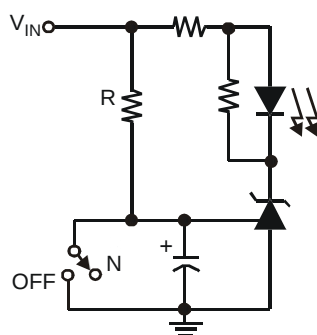


## Application Examples



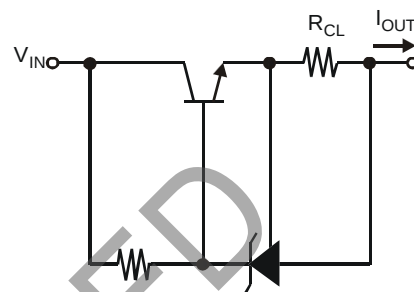
LED on when Low Limit  $< V_{IN} <$  High Limit  
 Low Limit  $\approx V_{REF} (1 + R1B/R2B)$   
 High Limit  $\approx V_{REF} (1 + R1A/R2A)$

Fig. 4 Voltage Monitor



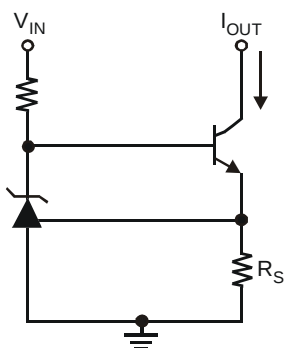
$$\text{Delay} = RC \times \ln\left(\frac{V_{IN}}{V_{IN} - V_{REF}}\right)$$

Fig 5. Delay Timer



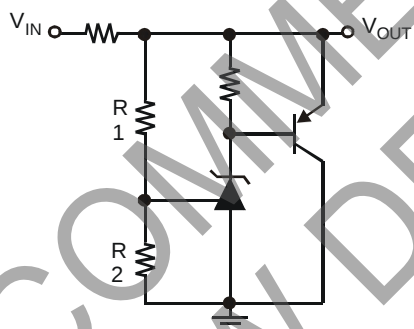
$$I_{OUT} = V_{REF} / R_{CL}$$

Fig 6. Current Limiter or Current Source



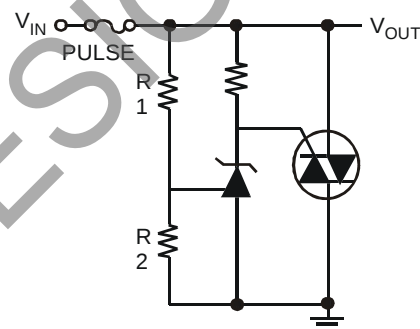
$$I_{OUT} = V_{REF} / R_S$$

Fig. 7 Constant-Current Sink



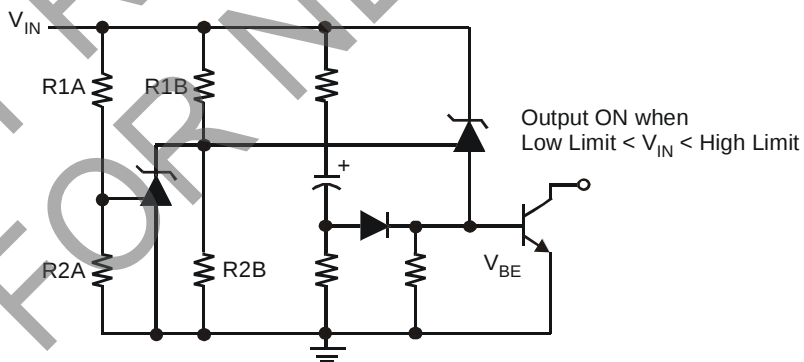
$$V_{OUT} = (1 + R1/R2) \times V_{REF}$$

Fig. 8 Higher-Current Shunt Regulator



$$\text{Limit} \approx (1 + R1/R2) \times V_{REF}$$

Fig. 9 Crow Bar



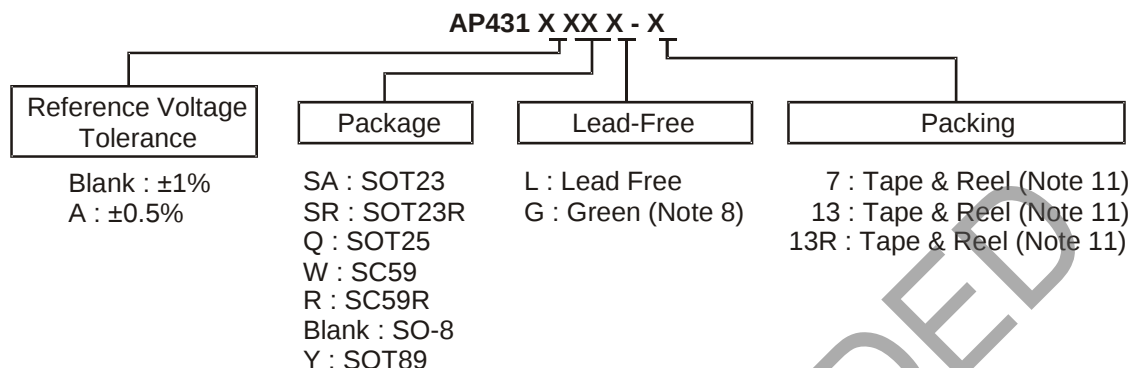
$$\text{Low Limit} \approx V_{REF} (1 + R1B/R2B) + V_{BE}$$

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

Fig. 10 Over-Voltage/ Under-Voltage Protection Circuit

Note: 12. Online application note, "Design Consideration with AP431 when used as a Comparator"  
 URL: [http://www.diodes.com/\\_files/products\\_appnote\\_pdfs/AN78.pdf](http://www.diodes.com/_files/products_appnote_pdfs/AN78.pdf)

## Ordering Information



| Part Number<br>(Note 10) | Package Code | Packaging | 7"/13 Tape and Reel |                                 | Ammo Box |                    |
|--------------------------|--------------|-----------|---------------------|---------------------------------|----------|--------------------|
|                          |              |           | Quantity            | Part Number Suffix<br>(Note 11) | Quantity | Part Number Suffix |
| AP431(A)SAG-7            | SA           | SOT23     | 3000/Tape & Reel    | -7                              | NA       | NA                 |
| AP431(A)SRG-7            | SR           | SOT23R    | 3000/Tape & Reel    | -7                              | NA       | NA                 |
| AP431(A)QL-7             | Q            | SOT25     | 3000/Tape & Reel    | -7                              | NA       | NA                 |
| AP431(A)QG-7             | Q            | SOT25     | 3000/Tape & Reel    | -7                              | NA       | NA                 |
| AP431AWL-7               | W            | SC59      | 3000/Tape & Reel    | -7                              | NA       | NA                 |
| AP431(A)WG-7             | W            | SC59      | 3000/Tape & Reel    | -7                              | NA       | NA                 |
| AP431(A)RL-7             | R            | SC59R     | 3000/Tape & Reel    | -7                              | NA       | NA                 |
| AP431(A)RG-7             | R            | SC59R     | 3000/Tape & Reel    | -7                              | NA       | NA                 |
| AP431(A)G-13             |              | SO-8      | 2500/Tape & Reel    | -13                             | NA       | NA                 |
| AP431(A)YL-13            | Y            | SOT89     | 2500/Tape & Reel    | -13                             | NA       | NA                 |
| AP431(A)YG-13            | Y            | SOT89     | 2500/Tape & Reel    | -13                             | NA       | NA                 |
| AP431(A)YG-13R           | Y            | SOT89     | 4000/Tape & Reel    | -13R                            | NA       | NA                 |

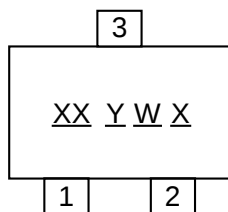
Notes:

8. SO-8, SOT23 and SOT23R are available in "Green" products only.
9. Suffix "A" denotes AP431A device.
10. Details of tape and reel options can be seen in document AP2007, which can be found on our website at <http://www.diodes.com/datasheets/ap02007.pdf>

## Marking Information

### (1) SC59 and SC59R

( Top View )



XX : Identification code

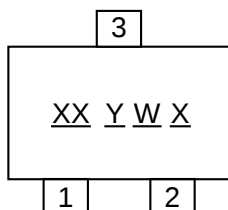
Y : Year 0~9

W : Week : A~Z : 1~26 week;  
a~z : 27~52 week; z represents  
52 and 53 week

X : A~Z : Green  
a~z : Lead Free

### (2) SOT23 and SOT23R

( Top View )



XX : Identification code

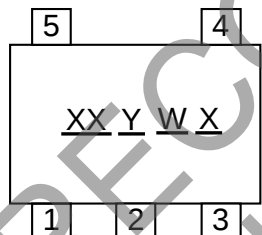
Y : Year 0~9

W : Week : A~Z : 1~26 week;  
a~z : 27~52 week; z represents  
52 and 53 week

X : A~Z : Green

### (3) SOT25

( Top View )



XX : Identification code

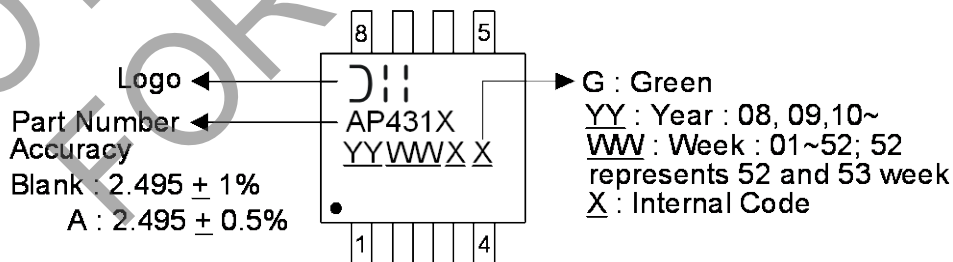
Y : Year 0~9

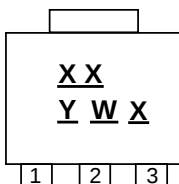
W : Week : A~Z : 1~26 week;  
a~z : 27~52 week; z represents  
52 and 53 week

X : A~Z : Green  
a~z : Lead Free

### (4) SO-8

( Top View )



**Marking Information (cont.)**
**(5) SOT89**
**( Top View )**

XX : Identification code

Y : Year : 0~9

W : Week : A~Z : 1~26 week;  
 a~z : 27~52 week;  
 z represents 52 and 53 week

X : Internal code

A~Z: Green

a~z : Lead Free

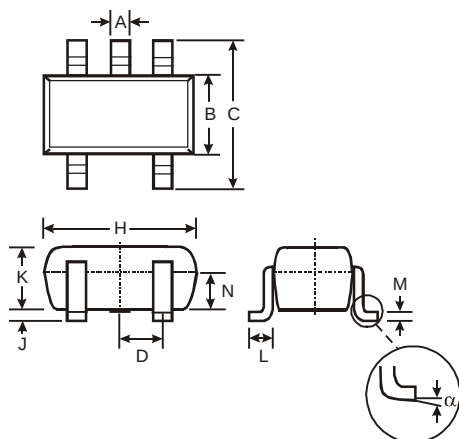
**Identification Code Table**

| Device   | Package (Note 11) | Identification Code | Date Code |
|----------|-------------------|---------------------|-----------|
| AP431SA  | SOT23             | D1                  | YM        |
| AP431ASA | SOT23             | D2                  | YM        |
| AP431SR  | SOT23R            | D5                  | YM        |
| AP431ASR | SOT23R            | D6                  | YM        |
| AP431Q   | SOT25             | A2                  | YM        |
| AP431AQ  | SOT25             | A3                  | YM        |
| AP431W   | SC59              | A6                  | YM        |
| AP431AW  | SC59              | A7                  | YM        |
| AP431R   | SC59              | A8                  | YM        |
| AP431AR  | SC59              | A9                  | YM        |
| AP431Y   | SOT89             | A4                  | YM        |
| AP431AY  | SOT89             | A5                  | YM        |

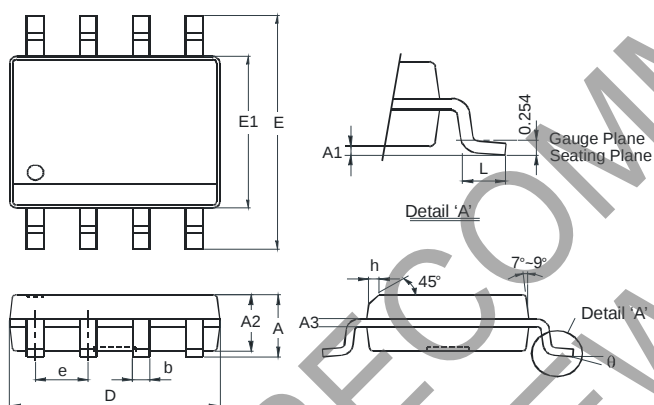
 Note: 11. For Packaging Details, go to our website at <http://www.diodes.com/datasheets/ap02007.pdf>.

**Package Outline Dimensions** (All dimensions in mm.)

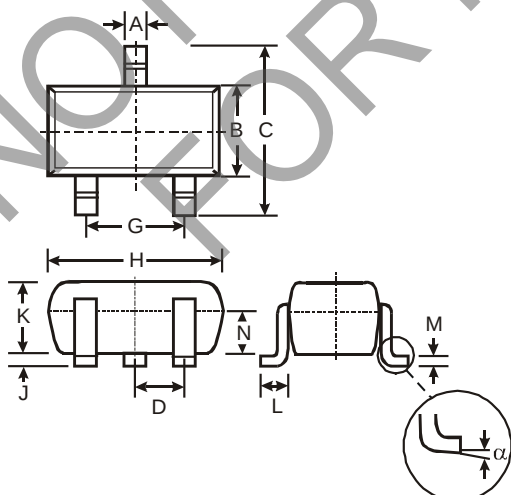
 Please see AP02002 at <http://www.diodes.com/datasheets/ap02002.pdf> for latest version.

**(1) SOT25**


| SOT25                |       |      |      |
|----------------------|-------|------|------|
| Dim                  | Min   | Max  | Typ  |
| A                    | 0.35  | 0.50 | 0.38 |
| B                    | 1.50  | 1.70 | 1.60 |
| C                    | 2.70  | 3.00 | 2.80 |
| D                    | —     | —    | 0.95 |
| H                    | 2.90  | 3.10 | 3.00 |
| J                    | 0.013 | 0.10 | 0.05 |
| K                    | 1.00  | 1.30 | 1.10 |
| L                    | 0.35  | 0.55 | 0.40 |
| M                    | 0.10  | 0.20 | 0.15 |
| N                    | 0.70  | 0.80 | 0.75 |
| $\alpha$             | 0°    | 8°   |      |
| All Dimensions in mm |       |      |      |

**(2) SO-8**


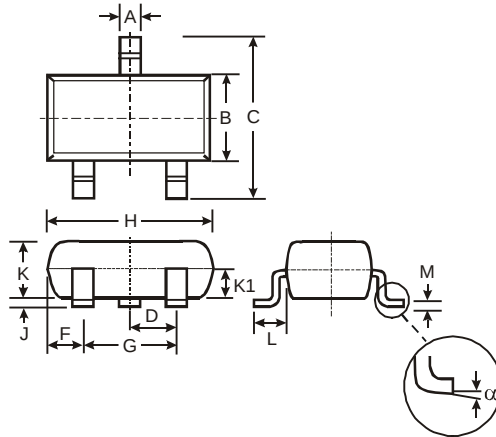
| SO-8                 |          |      |
|----------------------|----------|------|
| Dim                  | Min      | Max  |
| A                    | —        | 1.75 |
| A1                   | 0.10     | 0.20 |
| A2                   | 1.30     | 1.50 |
| A3                   | 0.15     | 0.25 |
| b                    | 0.3      | 0.5  |
| D                    | 4.85     | 4.95 |
| E                    | 5.90     | 6.10 |
| E1                   | 3.85     | 3.95 |
| e                    | 1.27 Typ |      |
| h                    | —        | 0.35 |
| L                    | 0.62     | 0.82 |
| $\theta$             | 0°       | 8°   |
| All Dimensions in mm |          |      |

**(3) SC59 and SC59R**


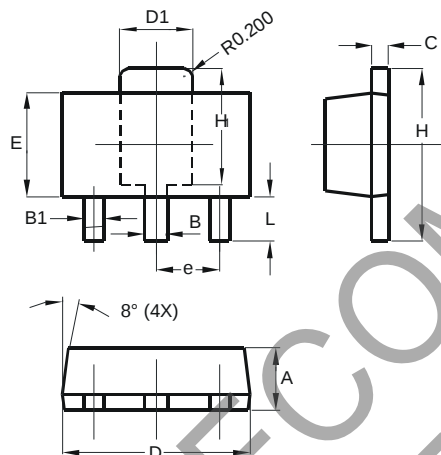
| SC59                 |       |      |      |
|----------------------|-------|------|------|
| Dim                  | Min   | Max  | Typ  |
| A                    | 0.35  | 0.50 | 0.38 |
| B                    | 1.50  | 1.70 | 1.60 |
| C                    | 2.70  | 3.00 | 2.80 |
| D                    | —     | —    | 0.95 |
| G                    | —     | —    | 1.90 |
| H                    | 2.90  | 3.10 | 3.00 |
| J                    | 0.013 | 0.10 | 0.05 |
| K                    | 1.00  | 1.30 | 1.10 |
| L                    | 0.35  | 0.55 | 0.40 |
| M                    | 0.10  | 0.20 | 0.15 |
| N                    | 0.70  | 0.80 | 0.75 |
| $\alpha$             | 0°    | 8°   | —    |
| All Dimensions in mm |       |      |      |

**Package Outline Dimensions (cont.) (All dimensions in mm.)**

 Please see AP02002 at <http://www.diodes.com/datasheets/ap02002.pdf> for latest version.

**(4) SOT23 and SOT23R**


| SOT23                |       |      |       |
|----------------------|-------|------|-------|
| Dim                  | Min   | Max  | Typ   |
| A                    | 0.37  | 0.51 | 0.40  |
| B                    | 1.20  | 1.40 | 1.30  |
| C                    | 2.30  | 2.50 | 2.40  |
| D                    | 0.89  | 1.03 | 0.915 |
| F                    | 0.45  | 0.60 | 0.535 |
| G                    | 1.78  | 2.05 | 1.83  |
| H                    | 2.80  | 3.00 | 2.90  |
| J                    | 0.013 | 0.10 | 0.05  |
| K                    | 0.903 | 1.10 | 1.00  |
| K1                   | -     | -    | 0.400 |
| L                    | 0.45  | 0.61 | 0.55  |
| M                    | 0.085 | 0.18 | 0.11  |
| $\alpha$             | 0°    | 8°   | -     |
| All Dimensions in mm |       |      |       |

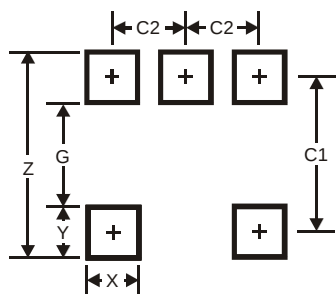
**(5) SOT89**


| SOT89                |          |      |
|----------------------|----------|------|
| Dim                  | Min      | Max  |
| A                    | 1.40     | 1.60 |
| B                    | 0.44     | 0.62 |
| B1                   | 0.35     | 0.54 |
| C                    | 0.35     | 0.44 |
| D                    | 4.40     | 4.60 |
| D1                   | 1.62     | 1.83 |
| E                    | 2.29     | 2.60 |
| e                    | 1.50 Typ |      |
| H                    | 3.94     | 4.25 |
| H1                   | 2.63     | 2.93 |
| L                    | 0.89     | 1.20 |
| All Dimensions in mm |          |      |

## Suggested Pad Layout

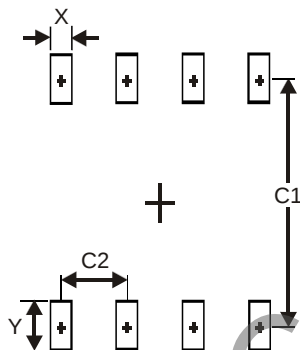
Please see AP02001 at <http://www.diodes.com/datasheets/ap02001.pdf> for the latest version.

### (1) SOT25



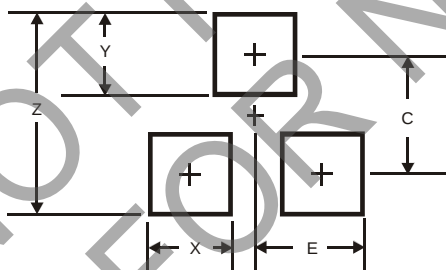
| Dimensions | Value (in mm) |
|------------|---------------|
| Z          | 3.20          |
| G          | 1.60          |
| X          | 0.55          |
| Y          | 0.80          |
| C1         | 2.40          |
| C2         | 0.95          |

### (2) SO-8



| Dimensions | Value (in mm) |
|------------|---------------|
| X          | 0.60          |
| Y          | 1.55          |
| C1         | 5.4           |
| C2         | 1.27          |

### (3) SC59 and SC59R

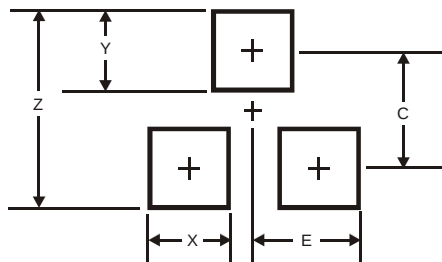


| Dimensions | Value (in mm) |
|------------|---------------|
| Z          | 3.4           |
| X          | 0.8           |
| Y          | 1.0           |
| C          | 2.4           |
| E          | 1.35          |

## Suggested Pad Layout (cont.)

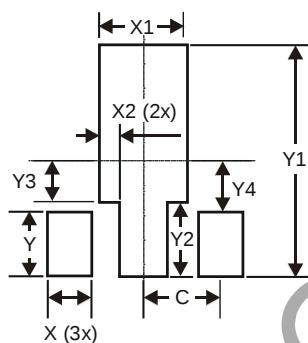
Please see AP02001 at <http://www.diodes.com/datasheets/ap02001.pdf> for the latest version.

### (4) SOT23 and SOT23R



| Dimensions | Value (in mm) |
|------------|---------------|
| Z          | 2.9           |
| X          | 0.8           |
| Y          | 0.9           |
| C          | 2.0           |
| E          | 1.35          |

### (5) SOT89



| Dimensions | Value (in mm) |
|------------|---------------|
| X          | 0.900         |
| X1         | 1.733         |
| X2         | 0.416         |
| Y          | 1.300         |
| Y1         | 4.600         |
| Y2         | 1.475         |
| Y3         | 0.950         |
| Y4         | 1.125         |
| C          | 1.500         |

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